ENERGY POLICY AND NDCs IN LATIN AMERICA AND THE CARIBBEAN:

EVALUATION OF THE CURRENT ENERGY DEVELOPMENT POLICIES OF THE REGION, AS A CONTRIBUTION TO THE COMPLIANCE WITH THE COMMITMENTS IN THE MATTER OF CLIMATE CHANGE

Basis for a necessary debate

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The opinions expressed by the authors in this document do not necessarily reflect in their entirety the point of view of the Member States of OLADE.

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III. Abbreviations and acronyms

BAU	*Business as usual*
Boe	Barrel of oil equivalent
CC	Climate Change
CO_2e	Carbon dioxide equivalent
COP21	21st International Conference on Climate Change in Paris
ECLAC	UN Economic Commission for Latin America and the Caribbean
EE	Energy Efficiency
EUEI-PDF	*EU Energy Initiative Partnership Dialogue Facility*
GDP	Gross Domestic Product
GHG	Green House Gases
GIZ	German International Cooperation Agency
GWh	Gigawatt-hour
inhab.	Inhabitants
IPCC	Intergovernmental Panel on Climate Change
kboe	Thousands of barrels of oil equivalent
kg	Kilograms
kW	Kilowatt
LAC	Latin America and the Caribbean
Mboe	Millions of barrels of oil equivalent
Mt	Millions of metric tones
MUS$	Millions of United States dollars
MW	Megawatt
MWh	Megawatt-hour
NCRE	Nonconventional Renewable Energies
NDCs	Nationally Determined Contributions of GHG
OLADE	Latin American Energy Organization
RE	Renewable energy sources
SAME	Energy Matrix Simulation and Analysis Model
SE4ALL	*Sustainable Energy for All*
SieLAC	Latin American and Caribbean Energy Information System
t	Metric Tones
TWh	Terawatt-hour
UNFCCC	United Nation Framework Convention on Climate Change
US$	United States dollar

IV. FOREWORD

The vast majority of the countries that have signed up to the Paris Agreement are facing the challenges of achieving the commitments they have made to mitigate climate change at the global level as a result of this Pact.
Latin America and the Caribbean are not indifferent to the vulnerability of many of our countries, especially those at lower levels of development; neither to the effects of climate change and the profound impact that climate events have on domestic economies. This gives particular importance to the topic addressed in this document.
Although the region has the highest percentage of renewable energy sources in the primary energy matrix at the global level and the contributions of greenhouse gases, both current and accumulated throughout history, are substantially lower than in other regions of the planet; the scope of these commitments, and fundamentally the goals defined in the National Determined Contributions (NDCs), involve a profound and necessary transition of the energy sector in Latin America and the Caribbean. This transition is also based on a historic commitment that Latin America and the Caribbean has demonstrated throughout the international environmental negotiations.

It is well known that this necessary transition to achieve the goals we have assumed implies a deepening of the incorporation of two lines of action, on the one hand, the greater penetration of non-conventional renewable energy sources to move to less carbon-dependent economies and, on the other, the necessary improvements in the energy efficiency of most of our economic activities and, at the same time, acting on the consumption patterns of our increasingly concentrated population in urban centres.

But we must also bear in mind that the actions for compliance in our region are very conditioned by the nature of our main economic activities, which have a strong extractive content, and by the historical backwardness of our population in the satisfaction of their basic needs. That is why we celebrate, for example, that in less than 20 years more than 20 million Latin Americans and Caribbean people had access to electricity, but this, although it is an important social achievement, also implies an awakening of a large part of our population to consumption patterns associated with middle-income economies.

Many of these factors influence the scenarios and future behavior of the countries of the region. And the questions to be answered are: Is Latin America and the Caribbean in a position to fulfill the commitments it has undertaken, considering the most likely evolution of energy demand and supply?; What would be the most likely evolution and the different possible scenarios?: Is the existing public policy framework enough to meet these commitments?

In order to shed some light on the potential answers to these complex questions, we can say that LAC has gradually achieved important progress in the transition process of its energy sector. Many countries in the region have a very high participation of renewable sources in their matrix. The generation of electricity and the incorporation of non-conventional renewable energies has been achieved mainly through market mechanisms, that is, incorporating efficient cost generation for interconnected systems, which has made it possible to provide efficiency and great dynamism of solar and wind energy in many of the countries in the region. If the resource allocation of the region is considered, this constitutes a suitable path for the future scaling of the installed capacity at the regional level of these generation technologies. However, is this progress and pace enough?

We must not forget that this transformation evident in many LAC countries has also been based on the strengthening of sectoral planning capacities and the development of favorable frameworks for business development associated with non-conventional renewable energies. On the other hand, the percentage of countries in the region that work consistently on energy efficiency policies, achieving very deep transformations in the efficiency of their main productive sectors is high. However, are the policy frameworks enough or do we need to deepen these actions?

Thus, OLADE, with the purpose of providing answers to the important questions posed above, has taken up again with this document the path of contributing with energy foresight studies, some of the necessary answers to support decision-makers at the political level of our region in the complex task of aligning the commitments assumed with the design of sectoral public policies that allow the achievement of the goals set. We are very pleased on this occasion to develop this prospective study with the support of EUEI PDF, and we understand that the result of the document provides important recommendations for our region to comply with the commitments derived from the Paris Agreement. The result of this study carried out in coordination and with the support of our member countries, is clear evidence of the role that OLADE must play in Latin America and the Caribbean.

1. Summary

This study aims to analyze the effectiveness of existing energy development policies in Latin American and Caribbean (LAC) countries as contribution to achieve the goals proposed in their NDCs regarding GHG emissions by 2030 and, if necessary, to propose much stronger energy efficiency measures and increased penetration by renewable energy sources that afford increased regional and sub-regional security certainty regarding fulfillment of these goals. To this end, an energy forecasting exercise was performed taking 2015 as the base year and with a horizon of 2030 for the LAC region, in turn subdivided into 2 countries and 4 subregions: Brazil, Mexico, Central America, Andean Subregion, Southern Cone and the Caribbean. Given the disparity in the references taken by countries in presenting their NDCs, for the purpose of this outlook, the first thing that was done was to build a "business as usual" (BAU) baseline scenario to serve as a base for calculating GHG emissions reductions. One of the main assumptions of this scenario is the growth trend in consumption of each energy source and preservation of the proportional structure of the supply matrix in the different energy chains.

Another working hypothesis is linked to the need to establish a correspondence between global and sectoral goals (particularly in the energy sector). In this regard, a percentage reduction in GHG emissions of the same order of magnitude as that committed by the countries in their NDCs was considered as a reference goal for the energy sector.

Through aggregation of the energy sector's expansion plans by subregion, with an emphasis on the electricity sector, as available for each of the countries, the "energy development Current Policy Scenarios (CPS)," considering the assumptions made in official forecasts on both energy supply as well as demand. When comparing the emissions reductions achieved by 2030 compared to those achieved under the BAU Scenario for the same year, with the reduction targets set by countries in their NDCs, it was revealed that the percentage reductions were quite modest in all of the subregions and far short of these targets, thus revealing the need to propose an alternative scenario with more ambitious sustainable energy development measures. This new scenario was called "Scenario aimed at fulfillment of NDCs." The NFS's assumptions included increased penetration by electricity in related end uses, replacing fossil fuels, including in transportation, increased use of biofuels for transportation, replacement of inefficient use of firewood with energy efficient technologies and modern sources, improved electricity and fuel consumption technologies and expanded penetration by renewable energy sources in the electricity generation matrix in each subregion (chapter 8). These measures made the percentage reductions in GHG emissions far more consistent with the targets set in the NDCs (chapter 10).

As a test of the proposed NFS's robustness, a sensitivity analysis was performed to simulate an eventual premature Climate Change effect on electricity demand and hydroelectric generation for the conditions of a critical climate scenario as expressed by the IPCC, the RPC 8.5 (chapter 9). This analysis showed that said CC effects would not affect the effectiveness of the NFS in fulfilling the NDCs.
Lastly, an analysis was performed regarding the effect of international fuel prices on the competitiveness of NCRE with regard to nonrenewable sources in electricity generation in terms of leveled costs of energy (LCOE). Thus, it was also proven that even under an unfavorable fuel price scenario (constant prices), NCRE, especially wind power, would continue to be very competitive (chapter 11).

As the main conclusions of the study, it can be summarized that with the premises of the current policy scenario (CPS), represented by its latest expansion plans in the energy sector, none of the sub-regions analyzed would be able to meet the emission reduction targets referenced with based on the NDCs of their countries, therefore the proposal of a more aggressive policy in terms of energy efficiency and penetration of renewable energies is justified, such as simulated in the NFS, with which at the regional level of LAC a reduction of GHG emissions in the energy sector, close to 30%, which could be considered satisfactory when compared with the individual goals of most countries (Chapter 12).

The recommendations of OLADE based on the results of the study, refer mainly to the need to strengthen the national capacities of its Member Countries, to promote, plan and implement measures of energy efficiency and penetration of renewable energies in a more efficient way, This requires the formulation of policies that better incentivize these initiatives, complemented by the appropriate institutional and legal framework and the corresponding financing mechanisms (Chapter 13).

2. Introduction

Latin America and Caribbean countries face the challenge of meeting the international climate change mitigation commitments that they made in the context of the Paris Agreement. These commitments, in particular the goals defined in the nationally determined contributions (NDCs), share the common trait of promoting an increased use of renewable energies and the promotion of energy efficiency.

The commitments made must be reflected in the strategic energy development plans in the region's countries, which will require prospective studies that are aligned with the new reality and which incorporate the latest changes in the international prices of conventional energy resources and geopolitical order of the global energy market.
Furthermore, diverse studies have shown that the long-term influence of climate change will not just affect water resources, but also the efficiency of conventional thermal power plants, which could cause an increase in the electricity sector's greenhouse gas emissions due to increased use of fossil fuels for power generation if the adequate precautions are not taken. This situation provides an additional incentive for the promotion of nonconventional renewable energies.

In this context, OLADE has undertaken this prospective study of Latin America and the Caribbean with the financial support of EUEI-PDF, disaggregated by sub-region and based on sustainable energy development scenarios, including increased nonconventional renewable energy penetration and energy efficiency programs.

Its purpose is to make an initial assessment, adjusted to what the information currently available allows, of the extent to which the energy policies and strategies that the region's countries are currently implementing, or plan to implement in the coming years, make enough of a contribution by the sector to achieve the goals established in each country's NDCs and in that way fulfill the international emissions reduction commitments made.

For the purpose of this analysis, it proceeds to construct and simulate prospective scenarios for the period 2015-2030, taking 2015 as the base year and dividing Latin America and the Caribbean into 4 sub-regions and 2 countries:

- Mexico
- Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama)
- The Caribbean (Barbados, Cuba, Grenada, Guyana, Haiti, Jamaica, Dominican Republic, Suriname and Trinidad and Tobago)
- Andean Subre-gion (Bolivia, Colombia, Ecuador, Peru and Venezuela)
- Brazil
- Southern Cone (Argentina, Chile, Paraguay and Uruguay)

To simplify the language, henceforth both the sub-regions as well as the countries analyzed individually, will be referred to as "sub-regions."

The NDCs of the vast majority of the region's countries set emissions reduction goals for 2030 based on what they have hypothetically taken as a baseline scenario. The fact is that the countries have not provided information on the characteristics that define said baseline scenarios, making it impossible to include them in this study. In addition, given that no country other than Ecuador has set specific quantitative targets for the energy sector, there is a need to assume certain working hypotheses to make an assessment of LAC countries' climate change commitments possible.

A baseline scenario (BAU) will be built to define a baseline for the energy sector's emissions, on the assumptions of freezing the energy matrix in 2015 and considering a baseline evolution in demand based on the rates recorded in the period 2005-2015, extracted information from OLADE's SieLAC.

The second working hypothesis has to do with the need to propose a correspondence between global and sectoral targets (especially those of the electricity sector). Thus, the same percentage in emissions reductions committed to in NDCs will be transferred to the energy sector, defining reference goals by sub-region and for the region as a whole.

For its part, the Current Policies Scenario (CPS) considers the energy policies in force that the region's countries have defined, which are set out in the latest national energy sector expansion plans (with the main focus being the electrical subsector). It is assumed that the commitments made under the Paris Agreement were taken into account (if not entirely at least partially) in the drafting of said plans. For cases where the reduction targets for the totality of the region cannot be achieved under the hypotheses considered in defining the CPS, an additional scenario called the Scenario Aimed at Fulfillment of the NDCs will be created, in which more aggressive premises will be proposed regarding policies for the penetration of nonconventional renewable sources and energy efficiency programs.

Although the studies that have been conducted in the region show that by 2030, the effects of CC on the electricity sector are practically negligible [21], it was considered appropriate to undertake a sensitivity analysis considering the effects of incorporating the most drastic scenario of GHG emissions concentration formulated by the IPCC, RCP 8.5, with its consequences on supply, demand for energy, supply costs, and the sector's emissions. This sensitivity was applied for the scenario aimed at fulfillment of NDCs and its respective baseline (BAU), thus creating the scenarios NDCs (RCP 8.5) and BAU (RCP 8.5). This sensitivity constitutes a test of robustness of the proposed scenario (NDCs).

To analyze the leveled costs of electricity generation (LCOE) and the total electricity supply costs, in each of the scenarios described above a common unit cost scenario for technologies and internationals fuel prices was considered, with a growing evolution according forecasts by The Energy Information Administration of the United States in the Energy Outlook 2017 [66], ultimately undertaking a sensitivity analysis with international fuel prices that are stationary or constant with regard to base year values.

The computerized prospecting tool used was the Energy Matrix Simulation and Analysis Model (SAME), developed by OLADE and whose characteristics are summarized in Annex I.

[1] The SieLAC is the Energy Information System of Latin America and the Caribbean, developed and administered by OLADE, which constitutes a consultation platform and an official database of the energy sector of the OLADE's Member Countries, which contains historical series since 1970.

3. Regional assessment in base year

3. Regional assessment in base year

3.1 Brazil

Brazil is the largest and most populated country in the LAC region, in addition to being the most powerful economy and the country with the greatest diversity in terms of the availability and use of energy resources. Table 3.1 below presents some of its economic-energy and environmental indicators.

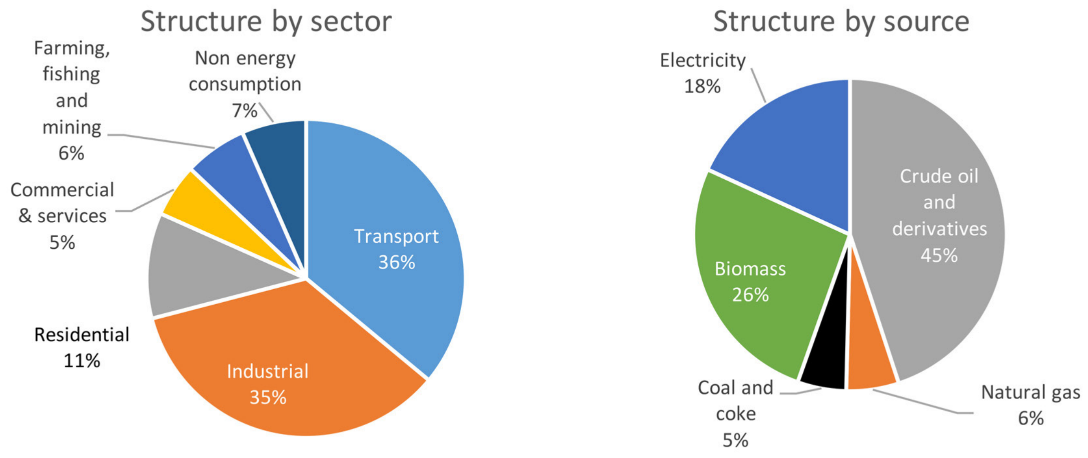
Table 3.1. Economic-energy and environmental indicators for Brazil

Indicator	Value
Total Population (million inhab.)	205.4
Nominal GDP (USD million in 2010)	2,318,135
GDP per capita (USD/ inhab.)	11,283
Final energy consumption (Mboe)	1,676
Per capita energy consumption (boe/inhab.)	8.16
Energy intensity (boe/1,000 USD in 2010)	0.72
Total electricity consumption (GWh)	491,241
Per capita electricity consumption (MWh/inhab.)	2.39
Electricity coverage (%)	99.3
Total installed capacity (MW)	133,292
Total electricity generation (GWh)	581,861
CO2e emissions factor in electricity generation (t/GWh)	123
Renewability of electricity generation (%)	74
Total energy supply (Mboe)	2,169
Renewability of total energy supply (%)	42
CO2e emissions factor in total energy supply (t/boe)	0.14
Energy self-sufficiency indicator (p.u.)	0.94
Intensity of emissions in energy matrix (kg/USD in 2010)	0.13

Sources: SieLAC - OLADE 2017, ECLAC 2017

Oil derivatives and biomass stand out in Brazil's final energy consumption matrix, as can be seen in Figure 3.1. The high consumption of biomass is due to significant use of firewood, sugarcane products and biofuels. Regarding the structure by sector, the main energy consumers are the transportation and industrial sectors, which represent over 70% of the total combined.

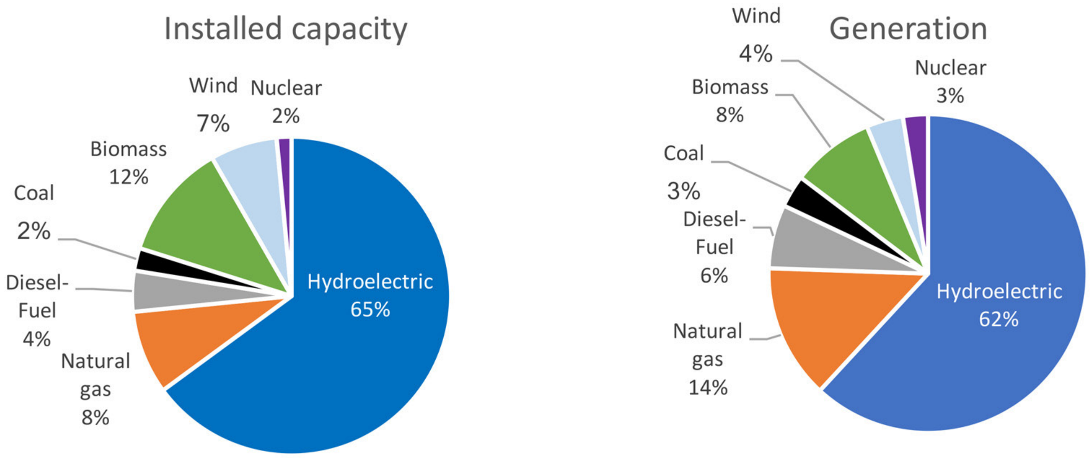
Figure 3.1. Structure of final energy consumption in Brazil (2015)



Source: OLADE - SieLAC 2017

As can be seen in the table of indicators for Brazil (Table 3.1), the share of renewable energy sources was almost three-quarters of electricity generation in the base year, with hydroelectric power being the most important resource with a 62% share of generation and 65% in installed capacity, as illustrated in Figure 3.2. Biomass and wind power generation stand out when it comes to NCRE.

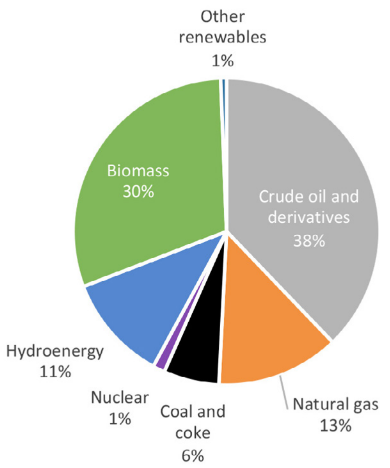
Figure 3.2. Structure of electricity generation in Brazil (2015)



Source: OLADE - SieLAC 2017

Primary hydrocarbons and their derivatives stand out in Brazil's total energy supply, with over 50%, while biomass represents around a third of the matrix. Sugarcane products are responsible for the high levels of participation on the part of biomass in Brazil's total energy supply (see Figure 3.3). Despite the significant levels of hydroenergy in electricity generation, this source of energy represents a modest 11% share of total supply, whlie other renewable sources like wind are practically imperceptible at that level.

Figure 3.3. Structure of total energy supply in Brazil (%)



Source: OLADE - SieLAC 2017

3.2 Mexico

Mexico is the LAC region's second largest country in terms of both population as well as economy. Some of its economic, energy and environmental indicators can be seen in Table 3.2.

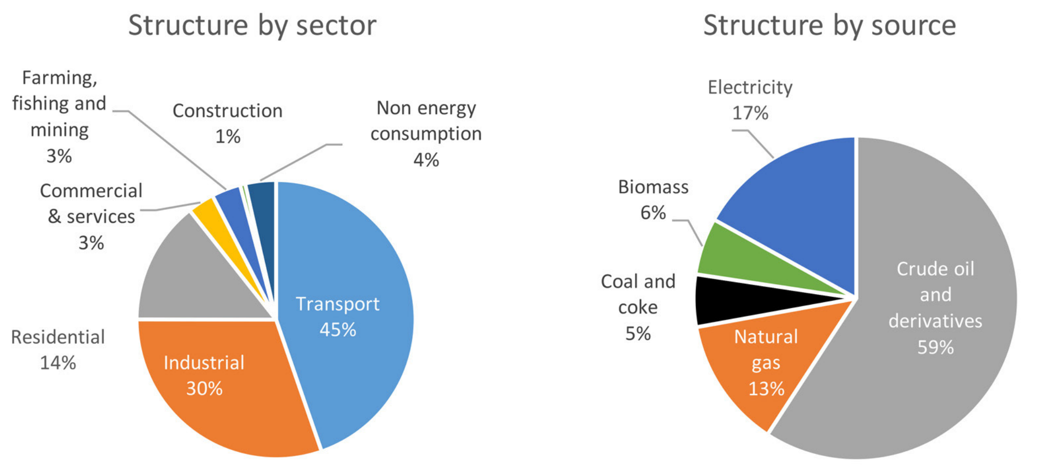
Table 3.2. Economic, energy and environmental indicators for Mexico

Indicator	Value
Total Population (million inhab.)	121.8
Nominal GDP (USD million in 2010)	1,206,154
GDP per capita (USD/ inhab.)	9,900
Final energy consumption (Mboe)	910
Per capita energy consumption (boe/inhab.)	7.47
Energy intensity (boe/1,000 USD in 2010)	0.75
Total electricity consumption (GWh)	248,895
Per capita electricity consumption (MWh/inhab.)	2.04
Electricity coverage (%)	98.5
Total installed capacity (MW)	54,853
Total electricity generation (GWh)	310,544
CO2e emissions factor in electricity generation (t/GWh)	245
Renewability of electricity generation (%)	18
Total energy supply (Mboe)	1,382
Renewability of total energy supply (%)	8
CO2e emissions factor in total energy supply (t/boe)	0.21
Energy self-sufficiency indicator (p.u.)	1.06
Intensity of emissions in energy matrix (kg/USD in 2010)	0.24

Sources: SieLAC - OLADE 2017, ECLAC 2017

As can be seen in Fiure 3.4, Mexico's total energy consumption is mainly concentrated in the transportation, industrial and residential sectors, which represent a combined 89% of the total. In addition, hydrocarbons (oil and natural gas) dominate the matrix by source, with 72% of the total.

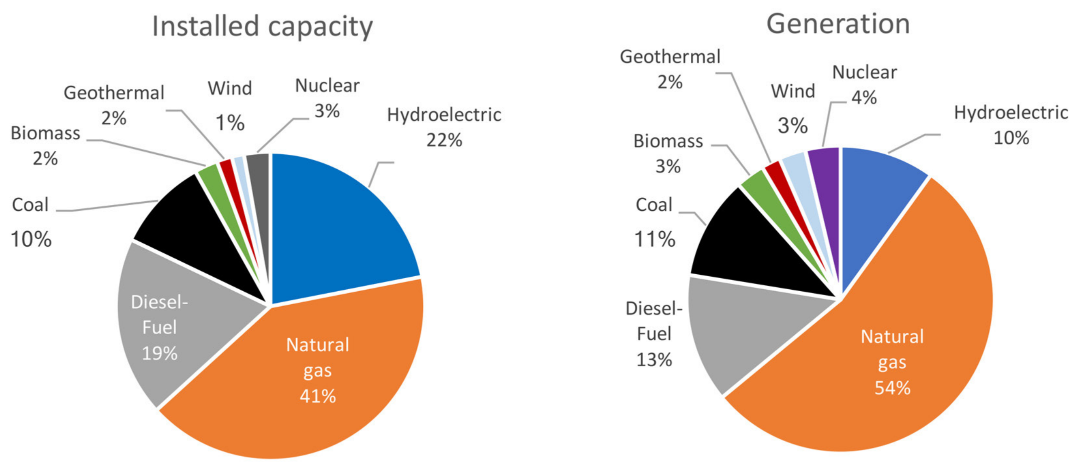
Figure 3.4. Structure of final energy consumption in Mexico (2015)



Source: OLADE - SieLAC 2017

Mexico's electricity matrix is highly gas-dependent, both in terms of installed capacity as well as in generation. Figure 3.5 shows that 41% of capacity and 54% of generation correspond to natural gas-fired power plants. Renewable energy sources, including hydroenergy, have an 18% share in generation. Mexico is one of the few countries in the LAC region to make use of its geothermal resources to produce electricity.

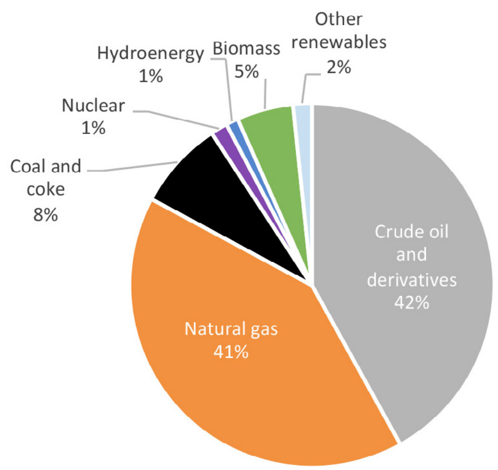
Figure 3.5. Structure of electricity generation in Mexico (2015)



Source: OLADE - SieLAC 2017

The total energy supply matrix shown in Figure 3.6 reveals that natural gas represents practically the same share as that of crude oil and its derivatives. Renewable energy sources represent just 8%, with hydroenergy contributing just 1% of the total supply.

Figure 3.6. Structure of total energy supply in Mexico (2015)



Source: OLADE - SieLAC 2017

3.3 Central America

For the purposes of this prospective study the subregion of Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) consists in the 7 countries of the Central American isthmus. Table 3.3 below presents some economic, energy and environmental indicators of the subregion as a whole.

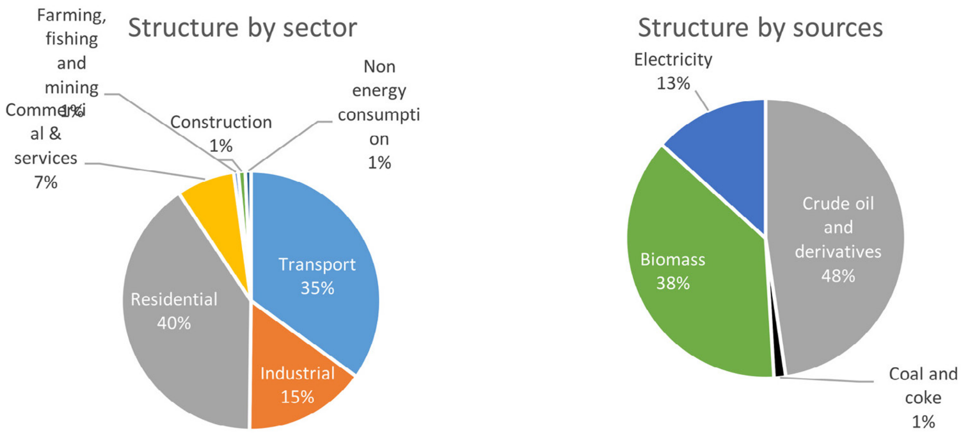
Table 3.3. Economic, Energy and environmental indicators for the subregion of Central America

Indicator	Value
Total Population (million inhab.)	46.5
Nominal GDP (USD million in 2010)	191,945
GDP per capita (USD/ inhab.)	4,124
Final energy consumption (Mboe)	205
Per capita energy consumption (boe/inhab.)	4.4
Energy intensity (boe/1,000 USD in 2010)	1.1
Total electricity consumption (GWh)	44,082
Per capita electricity consumption (MWh/inhab.)	0.95
Electricity coverage (%)	89
Total installed capacity (MW)	12,894
Total electricity generation (GWh)	51,824
CO2e emissions factor in electricity generation (t/GWh)	194
Renewability of electricity generation (%)	68
Total energy supply (Mboe)	243
Renewability of total energy supply (%)	46
CO2e emissions factor in total energy supply (t/boe)	0.14
Energy self-sufficiency indicator (p.u.)	0.5
Intensity of emissions in energy matrix (kg/USD in 2010)	0.18

Sources: SieLAC - OLADE 2017, ECLAC 2017

As can be seen in Figure 3.7, the residential and transportation sectors predominate in the structure of final energy consumption for the subregion of Central America, with a combined share of 75%. In the consumption matrix by source, the high share of biomass stands out at 38%, mainly due to the high consumption of firewood and charcoal in countries like Guatemala, Honduras and Nicaragua.

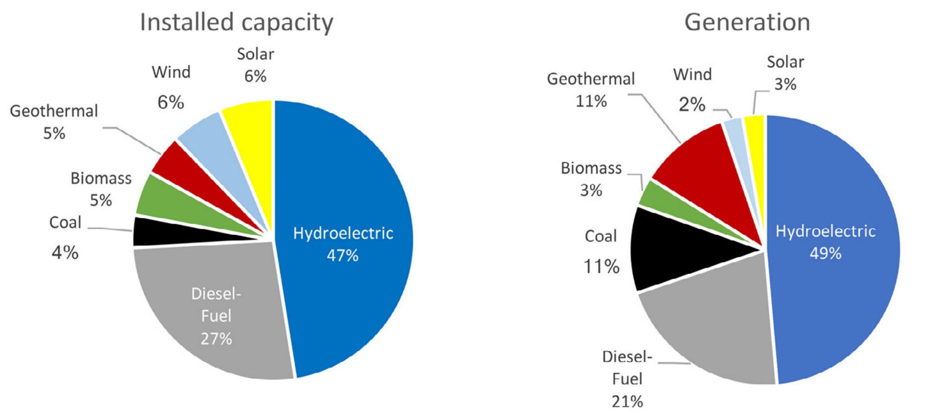
Figure 3.7. Structure of final energy consumption in Central America (2015)



Source: OLADE - SieLAC 2017

Hydroelectricity predominates electricity generation in the Central American subregion, as can be seen in Figure 3.8, where it represents 50% of the total. Other renewable energy sources like geothermal, wind, biomass and solar complement the 66% renewability that this subregion's matrix boasts of.

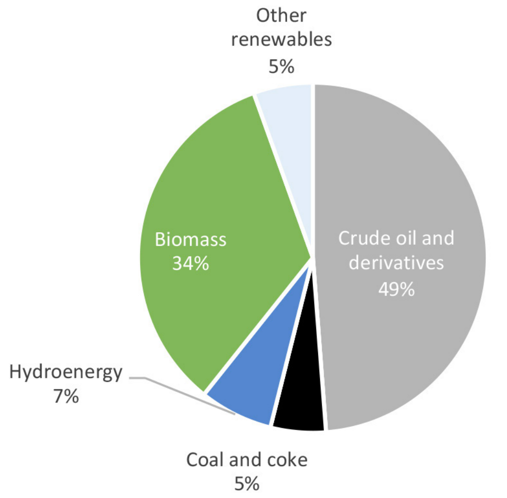
Figure 3.8. Structure of electricity generation in Central America (2015)



Source: OLADE - SieLAC 2017

As can be observed in Figure 3.9, in a way that is very similar to the consumption matrix, crude oil and its derivatives, in addition to biomass, represent the largest proportion of total energy supply. The total energy supply matrix's high level of renewability in the subregion of Central America, 46%, is fundamentally thanks to the share represented by biomass. The Central American energy matrix stands out for the absence of natural gas.

Figure 3.9. Structure of total energy supply in Central America (2015)



Source: OLADE - SieLAC 2017

3.4 Andean Subregion

The countries of the Andean Subregion (Bolivia, Colombia, Ecuador, Peru and Venezuela), are for the most part characterized by being important producers and exporters of primary sources as crude oil, natural gas and coal, in addition to possessing significant hydroenergy resources. As a subregion they come in second place after Brazil in terms of population and third in terms of the size of their economy, after Brazil and Mexico. Table 3.4 below presents some economic, energy and environmental indicators of this subregion.

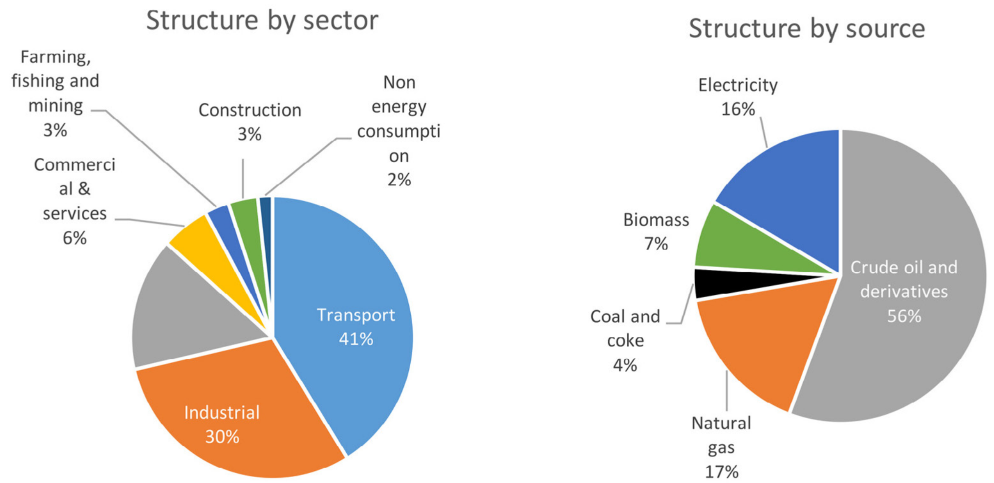
Table 3.4. Economic-energy and environmental indicators for the Andean Subregion

Indicator	Value
Total Population (million inhab.)	137.6
Nominal GDP (USD million in 2010)	899,639
GDP per capita (USD/ inhab.)	6,536
Final energy consumption (Mboe)	803
Per capita energy consumption (boe/inhab.)	5.8
Energy intensity (boe/1,000 USD in 2010)	0.9
Total electricity consumption (GWh)	215,091
Per capita electricity consumption (MWh/inhab.)	1.6
Electricity coverage (%)	96
Total installed capacity (MW)	54,738
Total electricity generation (GWh)	282,203
CO2e emissions factor in electricity generation (t/GWh)	162
Renewability of electricity generation (%)	56
Total energy supply (Mboe)	1,339
Renewability of total energy supply (%)	14
CO2e emissions factor in total energy supply (t/boe)	0.18
Energy self-sufficiency indicator (p.u.)	2.7
Intensity of emissions in energy matrix (kg/USD in 2010)	0.26

Sources: SieLAC - OLADE 2017, ECLAC 2017

As can be seen in Figure 3.10, transportation and industry are the main sectors in the Andean Subregion when it comes to consumption, while oil and natural gas products predominate the consumption matrix by sources, representing close to three quarters of the total between them.

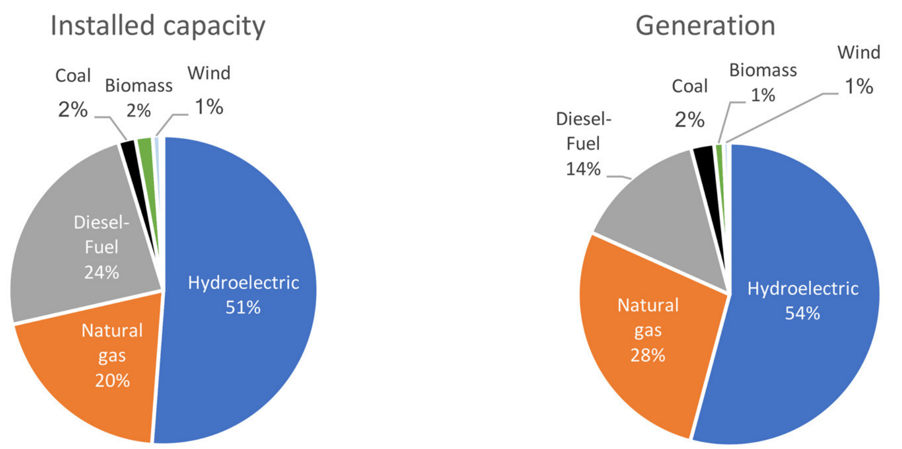
Figure 3.10. Structure of final energy consumption in the Andean Subregion



Source: OLADE - SieLAC 2017

Figure 3.11 shows the high importance of hydroelectricity in the Andean Subregion, where it represents over 50% of both the installed capacity and electricity production of the matrix. Natural gas also stands out as the second most important resource in this segment of the energy sector.

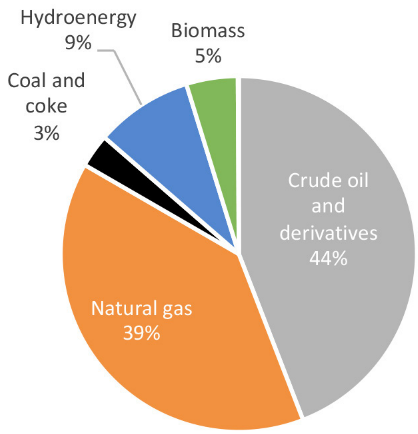
Figure 3.11. Structure of electricity generation in the Andean Subregion (2015)



Source: OLADE - SieLAC 2017

Thanks to high levels of primary hydrocarbon (crude oil and natural gas) production, these sources represent over 80% of the total energy supply matrix, as noted in Figure 3.12. It should be noted that in the sub-region there is Venezuela, the largest producer of crude oil in the LAC region.

Figure 3.12. Structure of total energy supply in Andean Subregion (2015)



Source: OLADE - SieLAC 2017

3.5 Southern Cone

The characteristics of the Southern Cone Subregion (Argentina, Chile, Paraguay and Uruguay) will mainly be determined by the greater weight of Argentina and Chile in this subregion in terms of GDP and above all energy production. Table 3.5 below presents some economic, energy and environmental indicators of the Southern Cone subregion.

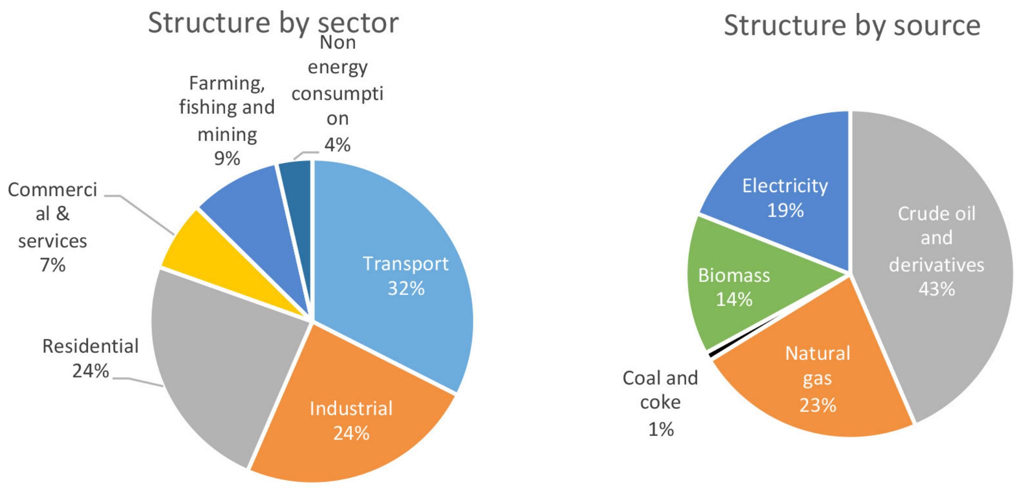
Table 3.5. Economic-energy and environmental indicators for the Southern Cone subregion

Indicator	Value
Total Population (million inhab.)	71.6
Nominal GDP (USD million in 2010)	795,357
GDP per capita (USD/ inhab.)	11,114
Final energy consumption (Mboe)	717
Per capita energy consumption (boe/inhab.)	10
Energy intensity (boe/1,000 USD in 2010)	0.9
Total electricity consumption (GWh)	219,915
Per capita electricity consumption (MWh/inhab.)	3.1
Electricity coverage (%)	99
Total installed capacity (MW)	67,104
Total electricity generation (GWh)	284,493
CO2e emissions factor in electricity generation (t/GWh)	190
Renewability of electricity generation (%)	46
Total energy supply (Mboe)	1,052
Renewability of total energy supply (%)	20
CO2e emissions factor in total energy supply (t/boe)	0.17
Energy self-sufficiency indicator (p.u.)	0.7
Intensity of emissions in energy matrix (kg/USD in 2010)	0.23

Sources: SieLAC - OLADE 2017, ECLAC 2017

As can be observed in Figure 3.13, the transportation, industrial and residential sectors represent the largest share of final energy consumption in the Southern Cone, with the latter two registering 24% each. In the structure by sources, oil and natural gas derivatives predominate with a combined share of 66%. The consumption of biomass is also significant in this subregion, mainly due to the influence to Chile and Paraguay.

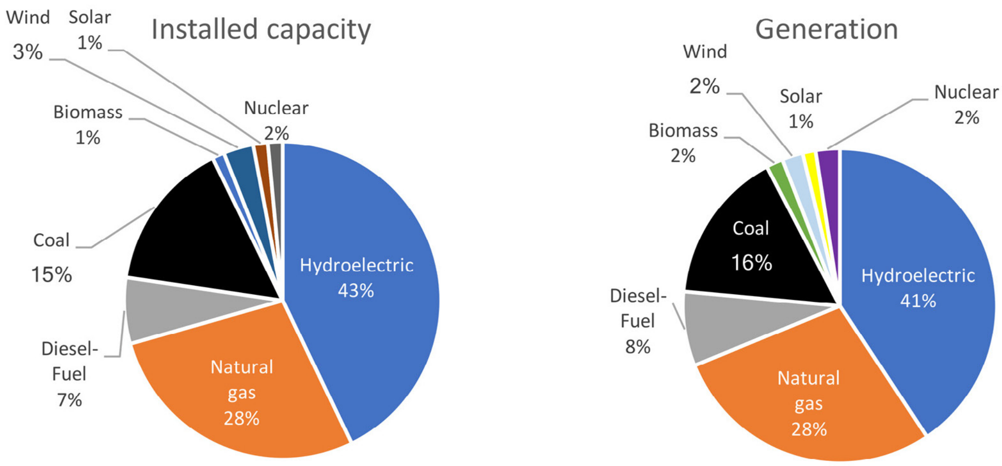
Figure 3.13. Structure of final energy consumption in the Southern Cone (2015)



Source: OLADE - SieLAC 2017

The electricity generation matrix in the Southern Cone is characterized by the high shares of hydroenergy and natural gas. These two resources cover about 70% of the matrix, both in installed capacity as well as in generation. Nonconventional renewable energies (biomass, wind and solar) represent a combined 5% share, with Chile's solar plants and the wind farms in Argentina and Uruguay standing out (see Figure 3.14).

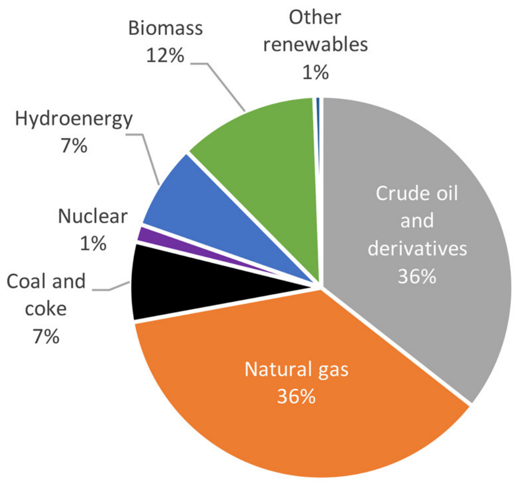
Figure 3.14. Structure of electricity generation in the Southern Cone (2015)



Source: OLADE - SieLAC 2017

The total energy supply in the Southern Cone is composed mainly of petroleum, its derivatives and natural gas. The high proportion of natural gas is mainly due to the influence of Argentina and, to a lesser degree, Chile. The renewable supply is composed of hydroenergy, biomass and other renewable sources like wind and solar, where Chile stands out for its photovoltaic generation and Uruguay for its wind generation (see Figure 3.15).

Figure 3.15. Structure of total energy supply in the Southern Cone (2015)



Source: OLADE - SieLAC 2017

3.6 Caribbean

Table 3.6. Economic-energy and environmental indicators for the Caribbean Subregion

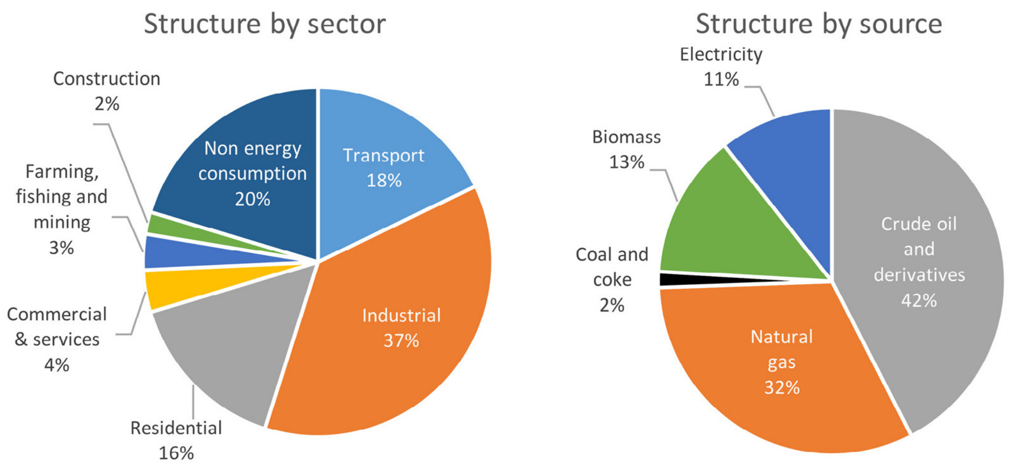
Indicator	Value
Total Population (million inhab.)	38.4
Nominal GDP (USD million in 2010)	199,299
GDP per capita (USD/ inhab.)	5,187
Final energy consumption (Mboe)	266
Per capita energy consumption (boe/inhab.)	6.9
Energy intensity (boe/1,000 USD in 2010)	1.3
Total electricity consumption (GWh)	45,722
Per capita electricity consumption (MWh/inhab.)	1.2
Electricity coverage (%)	79
Total installed capacity (MW)	14,170
Total electricity generation (GWh)	54,769
CO2e emissions factor in electricity generation (t/GWh)	331
Renewability of electricity generation (%)	8
Total energy supply (Mboe)	347
Renewability of total energy supply (%)	14
CO2e emissions factor in total energy supply (t/boe)	0.19
Energy self-sufficiency indicator (p.u.)	1
Intensity of emissions in energy matrix (kg/USD in 2010)	0.33

Sources: SieLAC - OLADE 2017, ECLAC 2017

The Caribbean Subregion (Barbados, Cuba, Grenada, Guyana, Haiti, Jamaica, Dominican Republic, Suriname and Trinidad and Tobago) is mostly made up of developing countries that are essentially energy importers. However, Trinidad and Tobago, with its significant natural gas production and export, causes the energy autonomy of the subregion. Table 3.6 below presents some economic, energy and environmental indicators of the Caribbean.

As observed in Figure 3.16, the industrial, transportation and residential sectors stand out in the final energy consumption matrix, with oil products, natural gas and biomass being the three sources in greatest demand. The high proportion of natural gas, is mainly due to the influence of Trinidad and Tobago, while biomass is related to Haiti, where firewood consumption in the residential sector stands out, and Cuba, where the consumption of sugarcane bagasse in the industrial sector is significant.

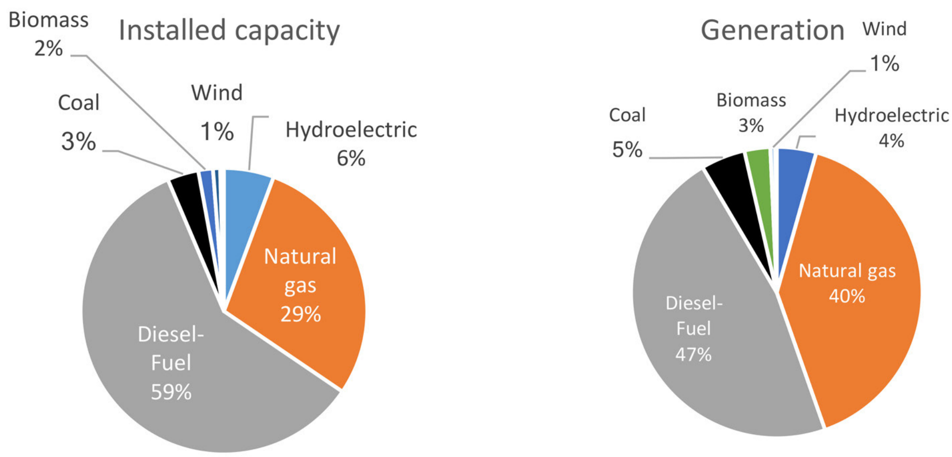
Figure 3.16. Structure of final energy consumption in the Caribbean (2015)



Source: OLADE - SieLAC 2017

The Caribbean subregion's electricity generation is fundamentally thermal, where hydrocarbons represent over 90% of the matrix in both installed capacity as well as in energy generation, as can be seen in Figure 3.17. Renewable energies represent a very small minority share in this subregion.

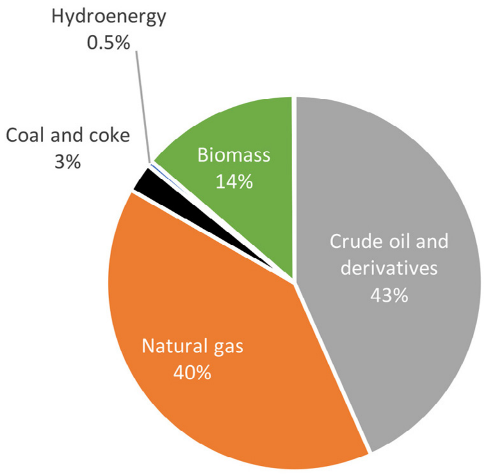
Figure 3.17. Structure of electricity generation in the Caribbean (2015)



Source: OLADE - SieLAC 2017

Consistent with the situation in the final energy consumption and the electricity generation matrixes, total energy supply in the Caribbean subregion is mostly represented by hydrocarbons, with a combined share of over 80% of the total. Regarding renewable energy sources, the only one to stand out is biomass (14%), as hydroenergy and other renewable sources represent a practically imperceptible share on the level of total energy supply (see Figure 3.18).

Figure 3.18. Structure of total energy supply in the Caribbean (2015)



Source: OLADE - SieLAC 2017

3.7 Latin America and the Caribbean (LAC)

For the purposes of this study, the region Latin America and the Caribbean consists in the 27 OLADE member countries, which include 12 countries in South America, 7 countries in Central America, Mexico in North America, 4 countries in the Greater Antilles and 3 of the Lesser Antilles. Table 3.7 below presents some economic, energy and environmental indicators of this Region in the base year (2015).

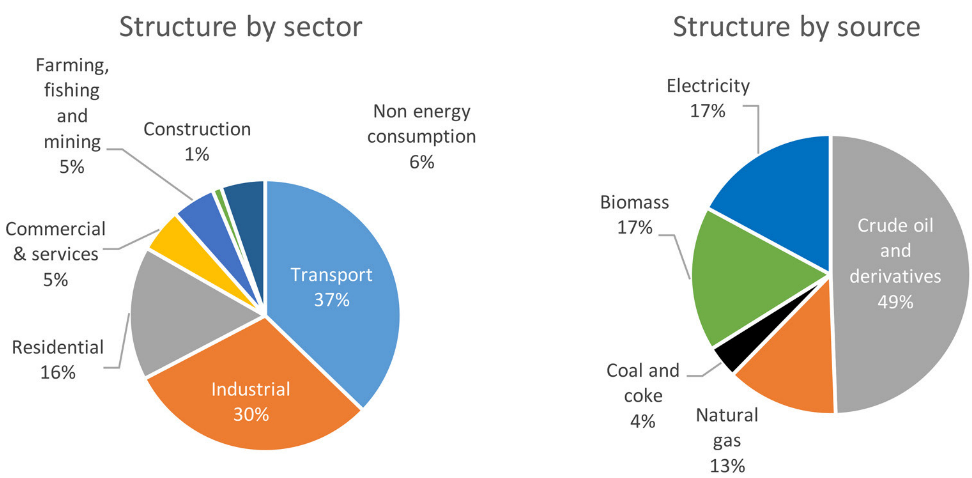
Table 3.7. Economic, Energy and environmental indicators for the LAC Region (2015)

Indicator	Value
Total Population (million inhab.)	621.3
Nominal GDP (USD million in 2010)	5,610,529
GDP per capita (USD/ inhab.)	9,030
Final energy consumption (Mboe)	4,576
Per capita energy consumption (boe/inhab.)	7.4
Energy intensity (boe/1,000 USD in 2010)	0.82
Total electricity consumption (GWh)	1,264,966
Per capita electricity consumption (MWh/inhab.)	2
Electricity coverage (%)	96
Total installed capacity (MW)	337,051
Total electricity generation (GWh)	1,565,694
CO2e emissions factor in electricity generation (t/GWh)	158
Renewability of electricity generation (%)	52
Total energy supply (Mboe)	6,532
Renewability of total energy supply (%)	24
CO2e emissions factor in total energy supply (t/boe)	0.17
Energy self-sufficiency indicator (p.u.)	1
Intensity of emissions in energy matrix (kg/USD in 2010)	0.2

Sources: SieLAC - OLADE 2017, ECLAC 2017

Close to 50% of LAC's total final energy consumption corresponds to oil derivatives, as can be seen in Figure No. 3.19. High levels of biomass consumption stand out (mainly firewood and sugarcane bagasse), whose 17% share is equal to that of electricity. The remaining share is covered by natural gas and coal.

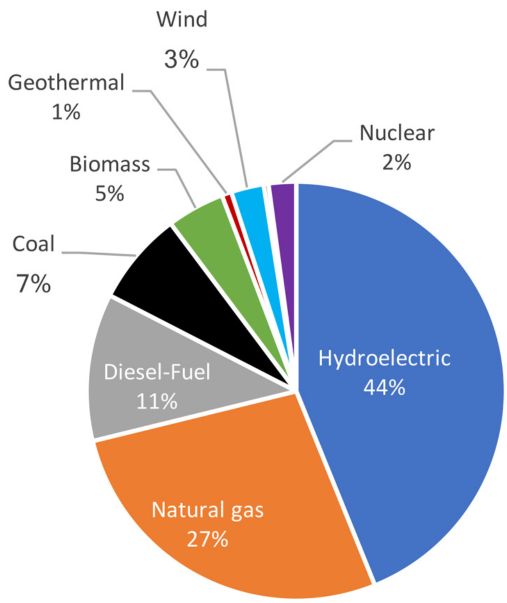
Figure 3.19 Structure of final energy consumption in LAC (2015)



Source: OLADE - SieLAC 2017

The LAC region generated a total of 1,566 TWh of electricity in 2015 with a generation matrix that is 53% renewable energy, as can be seen in Figure No. 3.20. The high proportion of hydroenergy stands out here as the main energy resource for electricity generation.

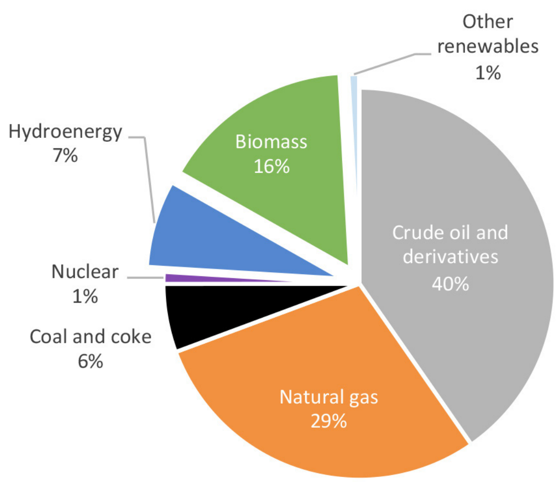
Figure 3.20 Structure of electricity generation in LAC (2015)



Fuente: OLADE - SIELAC, 2017

As far as total energy supply is concerned, as with final consumption the matrix is dominated by the high proportion of hydrocarbons (crude oil, natural gas and derivatives), which represent a combined share of about 70%. Renewable energy sources represent a 24%, of which biomass has the largest share, mainly thanks to high levels of firewood and sugarcane bagasse consumption. NCRE still represented a very marginal share of just 1% in the base year, as can be observed in Figure 3.21.

Figure 3.21 Structure of total energy supply in LAC (2015)



Fuente: OLADE - SIELAC, 2017

4. The energy sector and NDCs

4. The energy sector and NDCs

All of the region's countries are signatories of the Paris Agreement, and among them the majority have already ratified it (only Trinidad and Tobago and Suriname have not yet done so). Regarding the NDCs made by the region's countries, one can see that in general terms these commitments are expressed in diverse modalities (See summarized table in Annex II).

4.1 General Considerations

In general terms, considering all other sectors in addition to energy, some countries have proposed reducing GHG emissions by a certain percentage by 2030 compared those projected for that year in a BAU scenario. This is the case with Argentina, Barbados, Colombia, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Paraguay, Peru, Trinidad and Tobago and Venezuela. For their part, Brazil, Grenada and the Dominican Republic made the commitment to achieve a given GHG emissions reduction target compared to emissions in a reference year (2005, 2010 and 2010, respectively). The case of Costa Rica is a hybrid of the above, as by 2030 it has proposed achieving a given reduction in GHG emissions compared to a BAU scenario, while at the same time committing to cutting said emissions by 25% with regard to 2012 emissions (which entails achieving net absolute maximum emissions of 9,374,000 TCO2eq by 2030). For its part Chile proposes a GHG emissions reduction target for 2030 by unit of GDP compared to 2007 levels. Uruguay projects reducing energy intensity by 25% through 2030 with regard to 1990 levels. Lastly, it should be noted that countries like Bolivia, Cuba, El Salvador, Guyana and Suriname present policies and activities to be undertaken, which in the vast majority of cases are provided for in their national development and/or sectoral plans, but do not define targets for GHG mitigation in quantitative terms.

Many countries have expressed their conditional willingness to achieve more ambitious goals, subject to receiving international support. The following table illustrates the countries whose NDCs have set conditional and unconditional targets and whether they are by nature quantifiable or merely descriptive.

Table 4.1. Type of general targets (not just energy sector) related to the NDCs of LAC countries

Country	General Goals	
	Conditional	Inconditional
Argentina	●	●
Barbados		●
Belice		●
Bolivia		○
Brasil		●
Chile	●	●
Colombia	●	●
Costa Rica		●
Cuba		○
Ecuador	●	●
El Salvador		○
Granada		●
Guatemala	●	●
Guyana		○
Haiti	●	●
Honduras		●
Jamaica	●	●
Mexico	●	●
Panama		○
Paraguay	●	●
Peru	●	●
Rep. Dominicana	●	
Surinam		○
Trinidad y Tobago	●	●
Uruguay	●	●
Venezuela	●	

○ Descriptive target
● Quantifiable target

4.2 Observations on the energy sector

With regard to the energy sector's contribution to achievement of the goals set out in NDCs, practically no country in the region proposes such a contribution in quantitative terms. Ecuador is the exception, proposing a reduction of between 20 and 25% of GHG emissions from the energy sector compared to the BAU scenario. Grenada also presents a different situation, to the extent that it proposes reducing emissions by 30% compared to those projected in 2025, of which it estimates that 10% will come from the incorporation of renewable sources and the remaining 20% from energy efficiency measures. In contrast, the explicit commitments made by a significant number of countries to promote energy efficiency activities and renewable energies to help fulfill the targets set in the context of the Paris Agreement stand out.

Thus, the NDCs of Argentina, Barbados, Belize, Costa Rica, Cuba, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Honduras, Panama, Suriname, Uruguay and Venezuela, include their willingness to undertake diverse types of activities in the area of energy efficiency. Some of the specific activities that stand out include programs to reduce the use of firewood, the promotion of hybrid and electric vehicles; programs to modernize passenger and freight transport systems, efficient lighting initiatives, promotion of the use of efficient equipment and encouraging the construction and municipal recycling with energy efficiency criteria. In the case of Brazil, in addition to expressing a willingness to promote diverse energy efficiency actions in the industrial and transportation sectors, it commits to improving the electricity sector's efficiency by 10% through 2030. For its part, Barbados proposes cutting electricity consumption by 22% through the application of energy efficiency policies and reducing non-electrical consumption of energy (including transportation) by 29% compared to the BAU scenario. Meanwhile, Chile has proposed a 20% reduction in energy consumption by 2030 compared to the BAU scenario. Belize proposes achieving a reduction of at least 20% in conventional transportation fuel use by 2030, while simultaneously seeking to reduce its per capita energy intensity by at least 30% in 2033. For its part, through the efficient stoves NAMA, Honduras hopes to cut domestic firewood consumption by 39% compared to the baseline.

In the area of renewable energies, an important number of countries have set targets to be met within the context of the Paris Agreement. Thus, countries like Bolivia, Brazil, Chile, Jamaica and Paraguay have proposed significant increases in the proportion of renewable energies in the global energy mix by 2030 compared to a given base year. In the case of Brazil, this target is added to the objective of achieving an 18% share of biofuels in the energy mix by 2030.

Another group of countries composed of Belize, Bolivia, Barbados, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Guyana, Haiti and Panama have set themselves targets a proportion of renewable energies or to incorporate such capacities in their systems, but focused specifically on their electricity generation matrixes. These countries propose resorting to a wide range of policies, instruments and activities to achieve these goals. The creation of frameworks that foster the development of solar, wind, geothermal, hydro and biomass energies stand out among these, in addition to replacing fossil fuels with biofuels and incorporating energy storage systems that allow electrical systems with a significant presence of energies that are fluctuating to be managed better. For example, in the case of Barbados, renewable energy is to contribute 65% of peak demand by 2030, in Bolivia the share of alternative energies in total electricity production increases from 2 to 8% (reaching 79% for all renewables combined) and in Chile 20% of the electricity generation matrix is to be based on NCRE by 2025.

Table 4.2. RE and EE targets related to the NDCs of LAC countries

Country	Renewable Energy Targets		Energy Efficiency Targets	
	Conditional	Unconditional	Conditional	Unconditional
Argentina				
Barbados		●○		●
Belice				
Bolivia	●	●		
Brasil		●○		●○
Chile		●		
Colombia				
Costa Rica				
Cuba	○	●○	○	●
Ecuador				
El Salvador				
Granada		●○	●○	●
Guatemala				
Guyana	●	●○		○
Haiti	●	●		○
Honduras				
Jamaica		●	○	
Mexico				
Panama				
Paraguay		●○		○
Peru				
Rep. Dominicana				
Surinam	●	○		○
Trinidad y Tobago				
Uruguay		○		○
Venezuela				

○ Descriptive target
● Quantifiable target

The fact that virtually no country sets a quantitative target for the energy sector's contribution at fulfillment of the GHG emissions reduction objectives committed to in the Paris Agreement, is evidence of the difficulty monitoring the contributions made by this particular sector to the achievement of general goals. However, countries that has numerical targets both when it comes to energy efficiency as well as the promotion of renewable energies offer the chance to follow up on them, to evaluate their impact in terms of mitigating emissions, and consequently obtain an estimate of the sector's contribution. Likewise, in those cases where the targets are descriptive in nature, the construction of scenarios must assume that their implementation will have given consequences in terms of GHG emissions.

4.3 Work hypothesis

Although, due to the lack of homogeneity in the formulation of the NDCs of the countries, the geographic aggregation of the proposed goals and to identify the required contribution of the energy sector is very difficult, the reductions proposed for 2030 can be taken as reference. in their respective NDCs by four of the countries with the greatest economic weight: Brazil (43% compared to 2005), Mexico (25% with respect to the BAU), Argentina (20-40% with respect to the BAU) and Colombia (20-30% respect to BAU). Given these magnitudes, and taking into account that most other countries have more modest goals, it can be considered as a reference goal for the energy sector of the LAC region, achieving between 25 and 30% emission reduction for the year 2030, with respect to the baseline, represented by the BAU scenario.

As noted in the introduction, the final objective of this study is to carry out a first approach to the issue of coherence between energy and environmental goals in the LAC region. This is because, as we have just seen in this chapter, the region does not have emission reduction targets expressed in quantitative values. As targets against which to compare the results obtained in the different scenarios developed for this study, only the values expressed as a percentage contained in the NDCs are available, which are summarized in Annex II. These are values which, moreover, are not always specific to the energy sector. When the latter happens, it can be taken into account that, according to the national communications on climate change, the energy sector's share of total GHG emissions is relatively high in some countries, as shown in Annex VI. These observations are relevant to the analyses in Chapter 7 and Chapter 10.

Finally, and given the lack of consistency in the definition of the baselines of CO2e emissions used by LAC countries as a reference for the formulation of their NDCs, it has been considered, for the purposes of this study, that this baseline is represented by the CO2e emissions resulting from the simulation of the BAU scenario. This hypothesis is important for the analysis of Chapter 8.

5. Construction of the baseline scenario (BAU)

5. Construction of the baseline scenario (BAU)

5.1 General Considerations

As mentioned in the introduction, the purpose of constructing a BAU baseline scenario is to establish a baseline for CO2 emissions projections in the study period using a common methodology for all subregions that allows the effectiveness of current energy development policies (CPS) for fulfilling countries commitments as established in their NDCs to be analyzed.
The BAU scenario is built under the following energy supply and demand considerations:

- The projection of domestic energy demand corresponds to the final consumption of the main groups of energy sources, which are: oil and its derivatives, natural gas, coal and coke, biomass and electricity; adding own consumption and losses.

- Final energy consumption is projected using average annual growth rates for the different sources, calculated by applying a linear logarithmic regression to the time series for the past 10 years (2005-2015), extracted from OLADE's SieLAC.

- Own consumption and losses are calculated for each projected year, maintaining the percentages that these segments represented in the base year with regard to the total supply of each source.

- Energy supply, including electricity generation, covers projected demand for each source, preserving the structural ratios in the balance of energy of the base year (technical coefficients). That is, it represents an inertial projection of the energy supply matrix in the absence of any policy to change or diversify said matrix.

The results obtained from the BAU scenario simulation are presented comprehensively for each subregion below.

5.2 Brazil

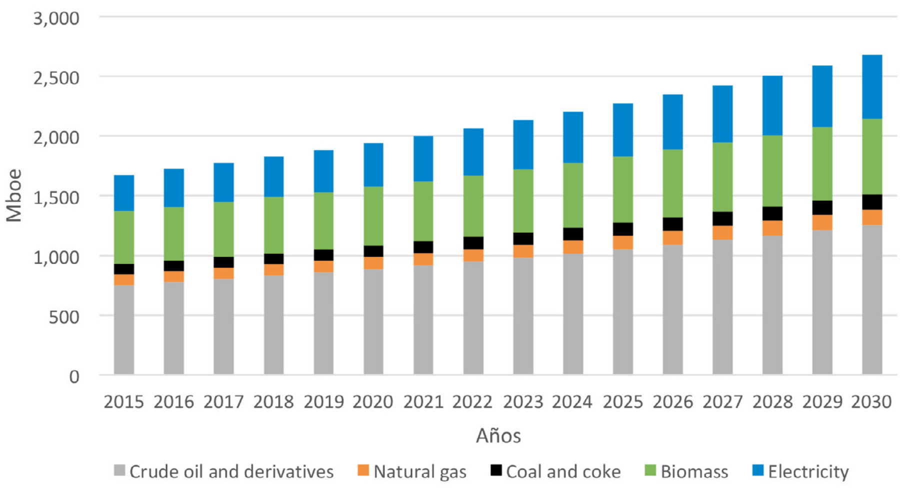
5.2.1 Projected final energy consumption

Table 5.1. Projected final energy consumption in Brazil (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	753	886	1,051	1,254	3.5%
Natural gas	91	101	114	129	2.4%
Coal and coke	84	97	111	127	2.8%
Biomass	443	490	552	630	2.4%
Electricity	304	367	444	536	3.8%
TOTAL	**1,676**	**1,942**	**2,272**	**2,677**	**3.2%**

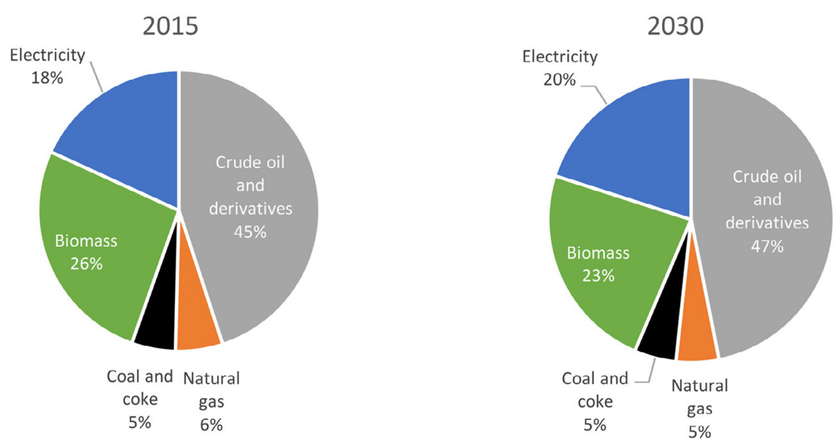
Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.1. Projected final energy consumption in Brazil, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.2. Evolution of final energy consumption matrix in Brazil, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

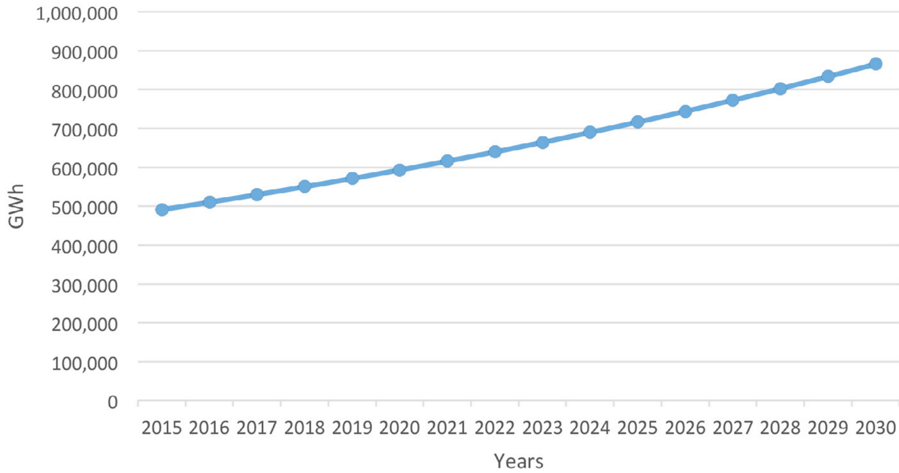
As can be seen in Figure 5.2, in a baseline projection electricity and oil products would gain participation in the final consumption matrix by 2030 compared to the base year.

Table 5.2. Projected final electricity consumption in Brazil, BAU scenario (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	491,241	593,010	716,258	865,592	3.8%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.3. Projected final electricity consumption in Brazil, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

At an average annual growth rate of 3.8%, electricity consumption during the projection period would increase by a total of 76%.

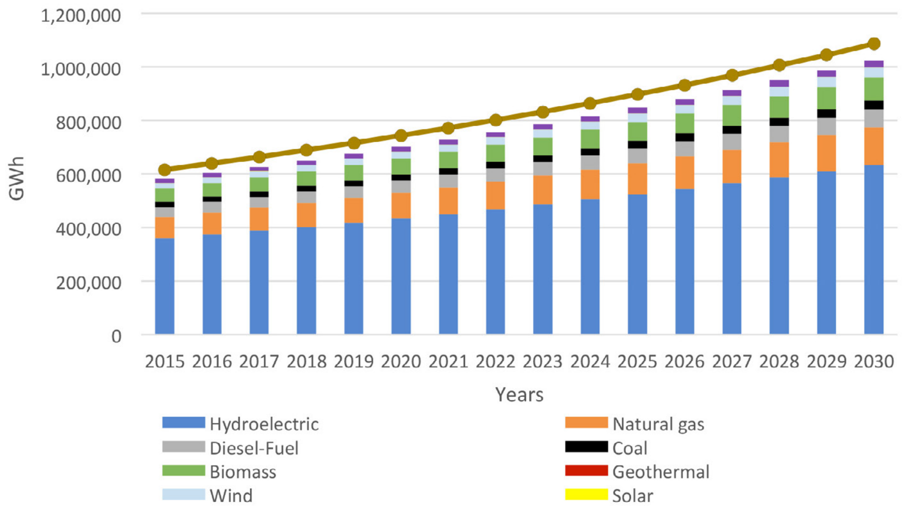
5.2.2 Projected electricity generation

Table 5.3. Projected electricity generation in Brazil, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	359,975	434,567	524,885	634,319
Natural gas	79,541	96,023	115,980	140,161
Diesel-Fuel Oil	37,735	45,555	55,022	66,494
Coal	19,108	23,068	27,862	33,671
Biomass	49,059	59,224	71,533	86,447
Wind	21,640	26,124	31,554	38,132
Solar	59	71	86	104
Nuclear	14,744	17,799	21,498	25,980
TOTAL	**581,861**	**702,431**	**848,420**	**1,025,309**

Source: Simulation results

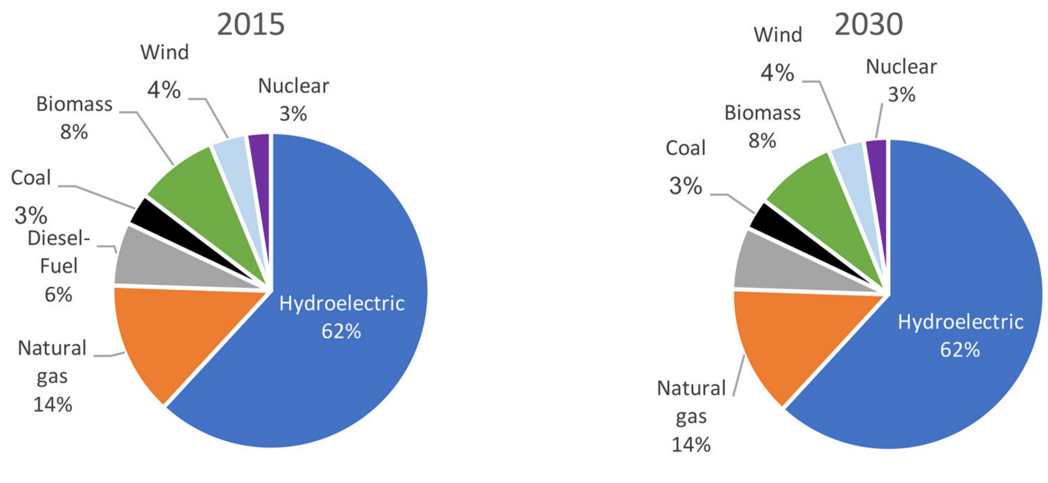
Figure 5.4. Projected electricity generation in Brazil, BAU scenario



Source: Simulation results

The difference that can be observed between domestic electricity demand (final consumption + own consumption + losses) and total generation from this source in Figure 5.4 corresponds to Brazil's imports, mainly generation from the Itaipú Binational power plant corresponding to Paraguay.

Figure 5.5. Evolution of electricity generation matrix in Brazil, BAU scenario



Source: Simulation results

By preserving the technical coefficients of supply for each source, and assuming the BAU scenario, one can see that the structure of the electricity generation matrix is maintained throughout the projection period (Figure 5.5).

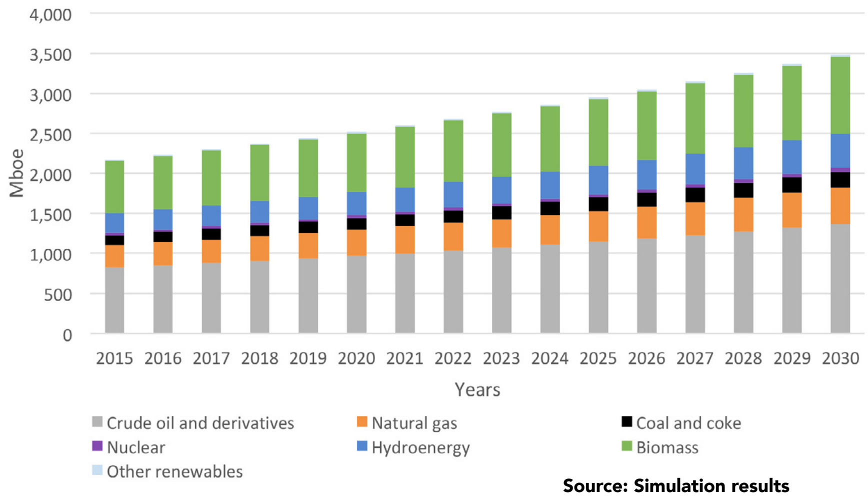
5.2.3 Projected total energy supply

Table 5.4. Projected total energy supply in Brazil, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	821	966	1,146	1,366	3.5%
Natural gas	281	327	384	452	3.2%
Coal and coke	127	148	172	200	3.1%
Nuclear	28	33	40	49	3.8%
Hydroenergy	244	294	355	429	3.8%
Biomass	655	733	833	960	2.6%
Other renewables	13	16	20	24	3.8%
TOTAL	**2,169**	**2,518**	**2,949**	**3,479**	**3.2%**

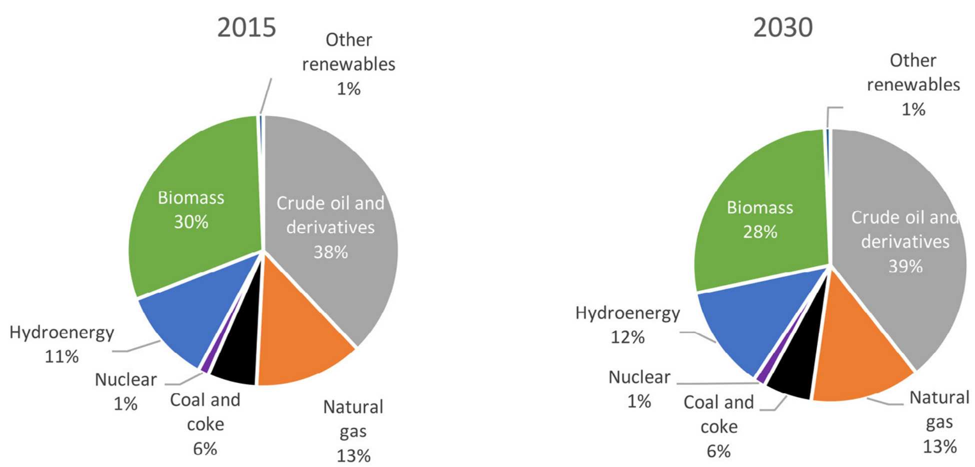
Source: Simulation results

Figure 5.6. Projected total energy supply in Brazil, BAU scenario



Source: Simulation results

Figure 5.7. Evolution of total energy supply matrix in Brazil, BAU scenario



Source: Simulation results

Though the technical coefficients in energy supply are maintained, the different growth trends in final consumption of the different sources cause a slight variation in the structure of the total energy supply matrix, as shown in Figure 5.7.

5.3 Mexico

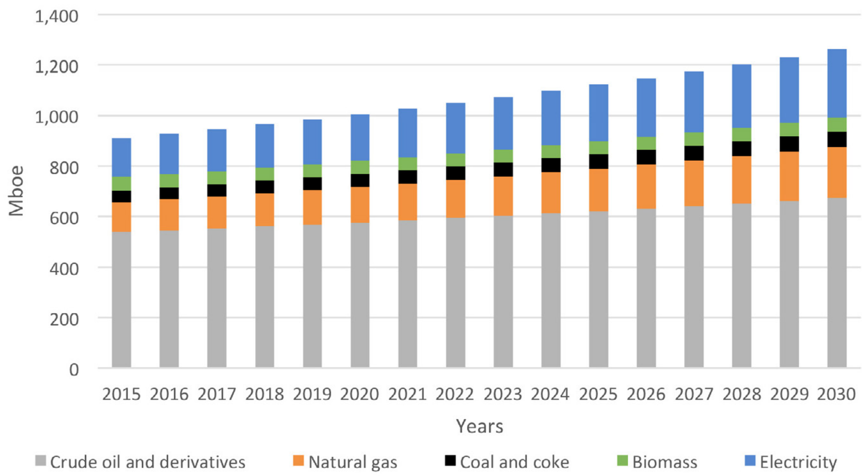
5.3.1 Projected final energy consumption

Table 5.5. Projected final energy consumption in Mexico (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	539	576	622	674	1.5%
Natural gas	118	141	168	201	3.6%
Coal and coke	47	52	56	61	1.7%
Biomass	52	51	52	54	0.3%
Electricity	154	186	224	271	3.8%
TOTAL	**910**	**1,006**	**1,122**	**1,261**	**2.2%**

Source: By authors based on information from OLADE SieLAC (2016)

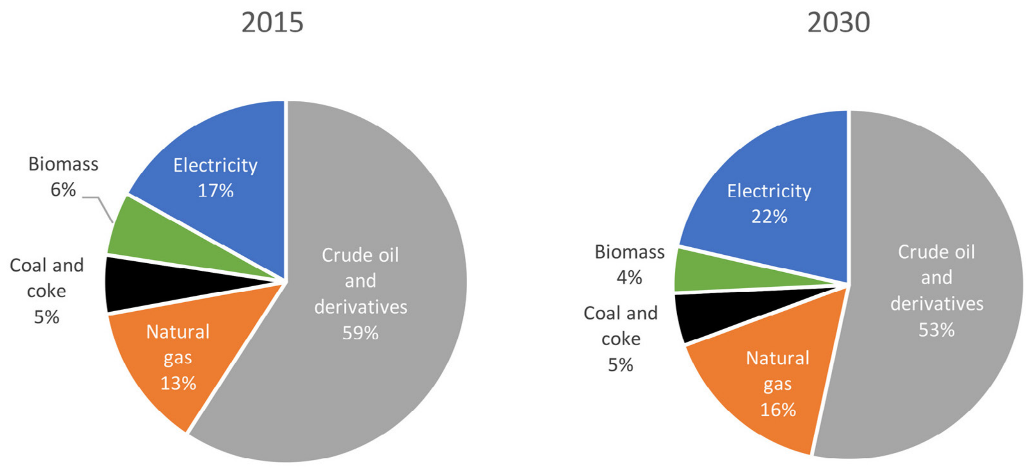
Figure 5.8. Projected final energy consumption in Mexico, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

The baseline evolution of final consumption in Mexico reveals a significant increase in the proportion of electricity and natural gas, to the detriment of oil products (Figure 5.9).

Figure 5.9. Evolution of final energy consumption matrix in Mexico, BAU scenario



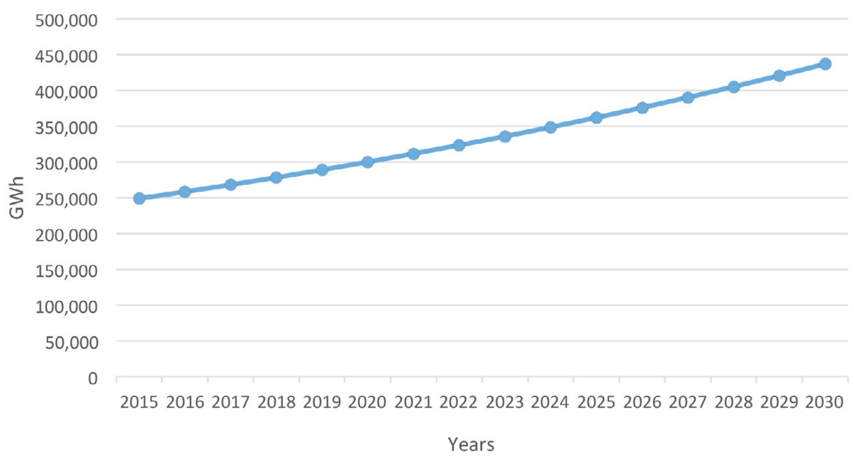
Source: By authors based on information from OLADE SieLAC (2016)

Table 5.6. Projected final electricity consumption in Mexico, BAU scenario (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	248,888	300,174	362,113	436,931	3.8%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.10. Projected final electricity consumption in Mexico, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Like Brazil, annual baseline growth in Mexican electricity consumption is 3.8%, which means a total increase of 76% in the study period (figure 5.10).

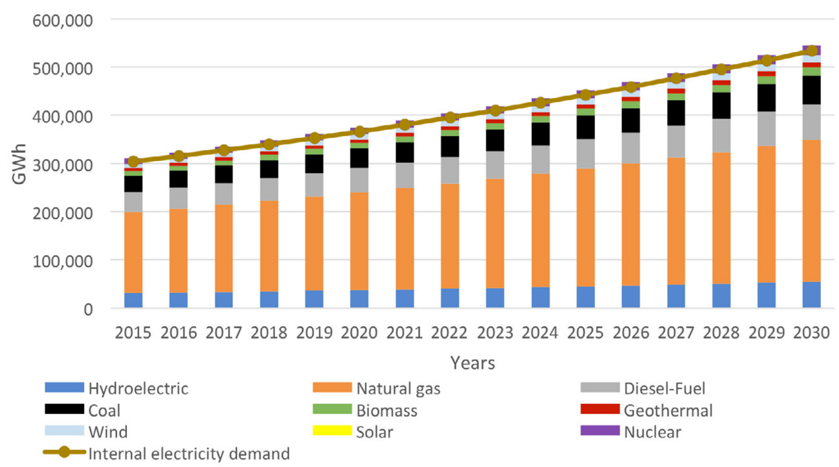
5.3.2 Projected electricity generation

Table 5.7. Projected electricity generation in Mexico, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	30,955	37,330	45,033	54,337
Natural gas	167,842	202,409	244,175	294,625
Diesel-Fuel Oil	42,099	50,769	61,245	73,899
Coal	33,741	40,690	49,086	59,228
Biomass	9,503	11,460	13,825	16,681
Geothermal	6,191	7,466	9,007	10,867
Wind	8,667	10,452	12,609	15,214
Solar	93	112	135	163
Nuclear	11,453	13,812	16,662	20,105
TOTAL	**310,544**	**374,499**	**451,776**	**545,120**

Source: Simulation results

Figure 5.11. Projected electricity generation in Mexico, BAU scenario

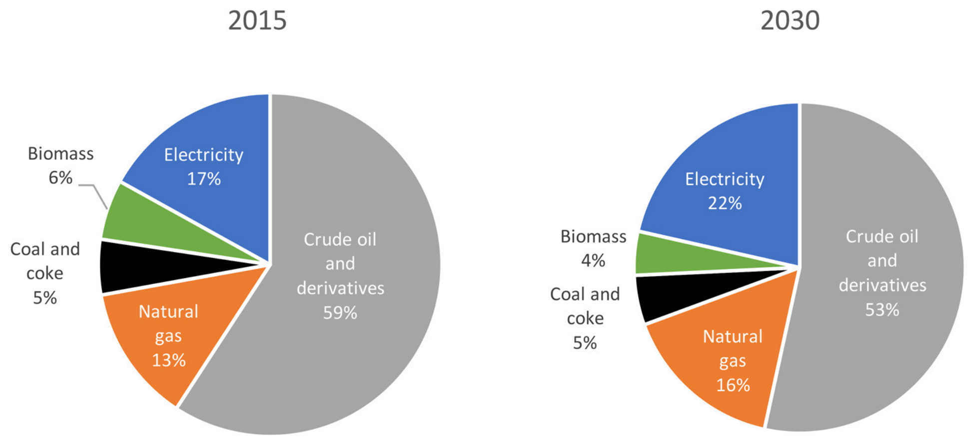


Source: Simulation results

As can be seen in Figure 5.11, in a baseline scenario Mexico is and will be practically self-sufficient in the supply of domestic electricity demand: imports and exports with North and Central America would be very marginal.

The electricity generation matrix in the BAU scenario remains unchanged throughout the study period, with natural gas being the main resource for this energy activity.

Figure 5.12. Evolution of electricity generation matrix in Mexico, BAU scenario



Source: Simulation results

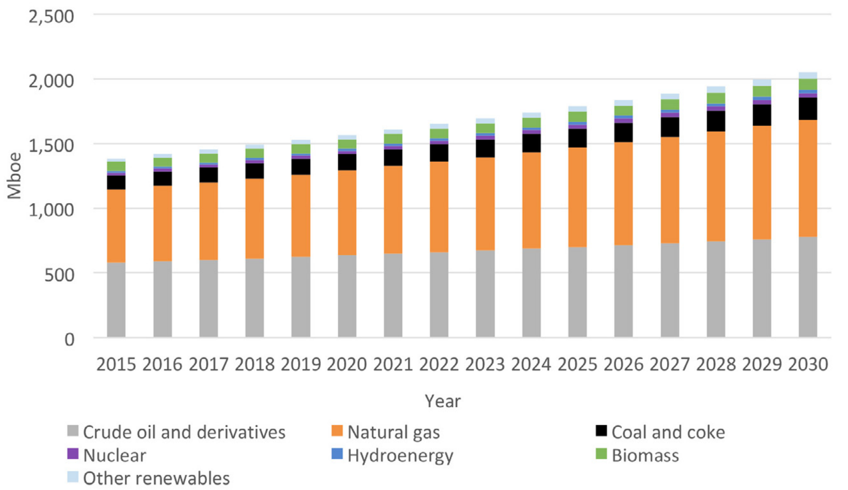
5.3.3 Projected total energy supply

Table 5.8. Projected total energy supply in Mexico, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	580	635	701	778	2.0%
Natural gas	566	658	769	905	3.2%
Coal and coke	109	126	147	171	3.1%
Nuclear	21	25	30	36	3.8%
Hydroenergy	15	18	22	26	3.8%
Biomass	69	72	77	85	1.4%
Other renewables	23	34	41	50	5.3%
TOTAL	**1,382**	**1,569**	**1,788**	**2,052**	**2.7%**

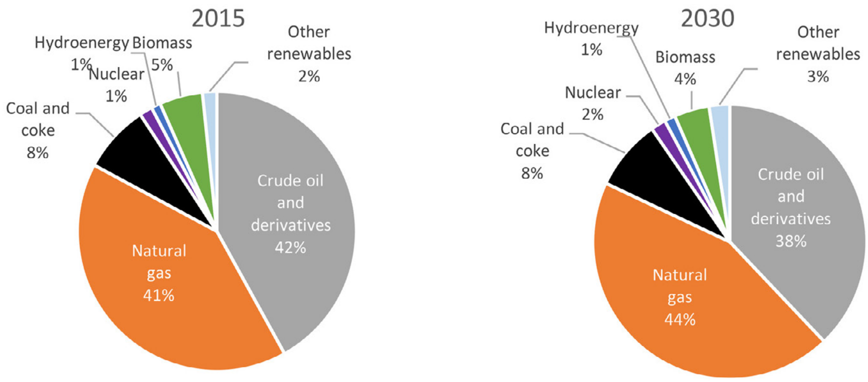
Source: Simulation results

Figure 5.13. Projected total energy supply in Mexico, BAU scenario



Source: Simulation results with SAME, BAU scenario

Figure 5.14. Evolution of total energy supply matrix in Brazil, BAU scenario



Source: Simulation results with SAME, BAU scenario

The substitution of oil products with natural gas stands our in the evolution of Mexico's energy matrix in the BAU scenario (Figure 5.14).

5.4 Central America

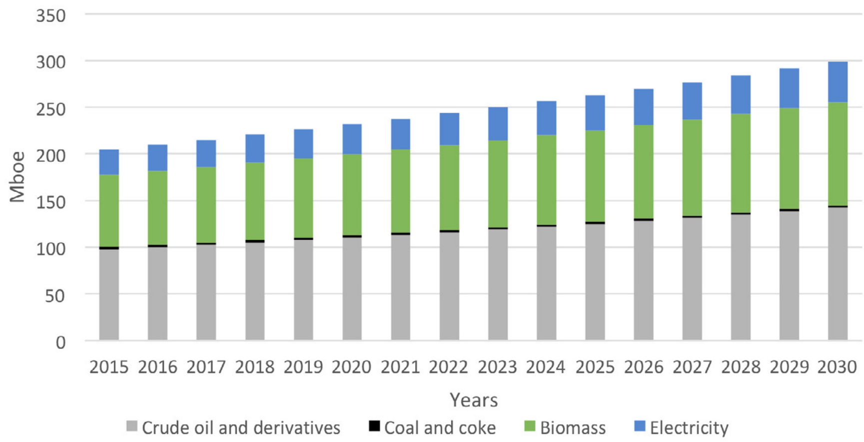
5.4.1 Projected final energy consumption

Table 5.9. Projected final energy consumption in Central America, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	98	110	125	142	2.5%
Coal and coke	3	3	3	2	-0.9%
Biomass	77	87	98	110	2.4%
Electricity	27	32	37	44	3.2%
TOTAL	**205**	**232**	**263**	**299**	**2.6%**

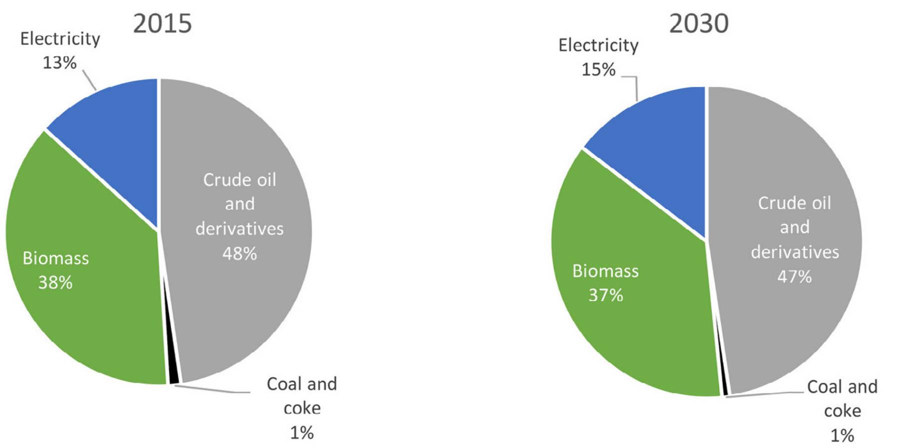
Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.15. Projected final energy consumption in Central America, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.16. Evolution of final energy consumption matrix in Central America, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

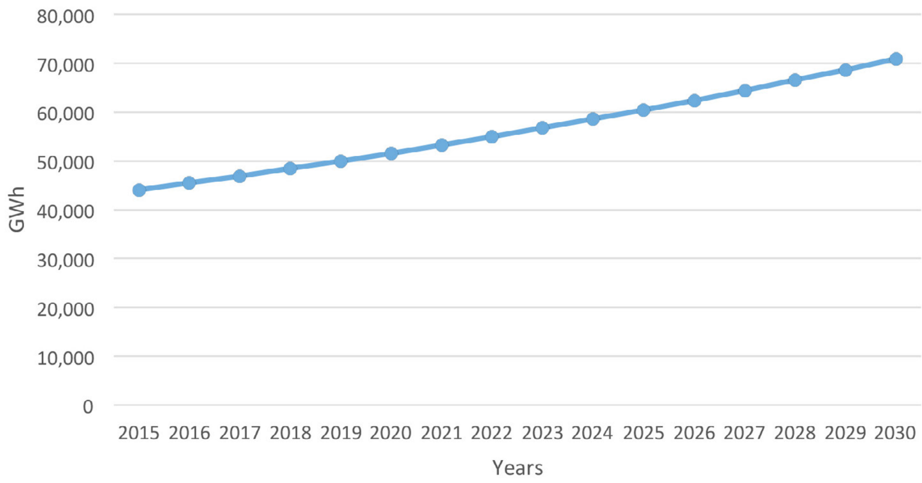
The baseline evolution of final consumption in Central America which is characterized by a shif in consumption away from biomass and oil, thanks to increased penetration by electricity, as illustrated in figure 5.16.

Table 5.10. Projected final electricity consumption in Central America, BAU scenario (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	44,082	51,602	60,466	70,919	3.2%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.17. Projected final electricity consumption in Central America, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Central American electricity consumption increases by a total of 61% during the projection period.

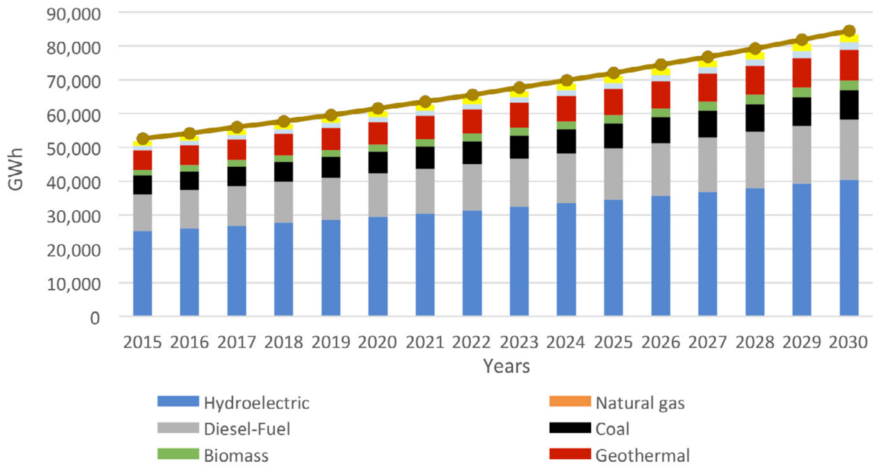
5.4.2 Projected electricity generation

Table 5.11. Projected electricity generation in Central America, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	25,195	29,494	34,560	40,535
Natural gas	0	0	0	0
Diesel-Fuel Oil	11,004	12,881	15,094	17,703
Coal	5,446	6,375	7,470	8,761
Biomass	1,810	2,119	2,483	2,912
Geothermal	5,670	6,637	7,777	9,122
Wind	1,291	1,511	1,771	2,077
Solar	1,408	1,648	1,932	2,266
TOTAL	**51,824**	**60,666**	**71,087**	**83,376**

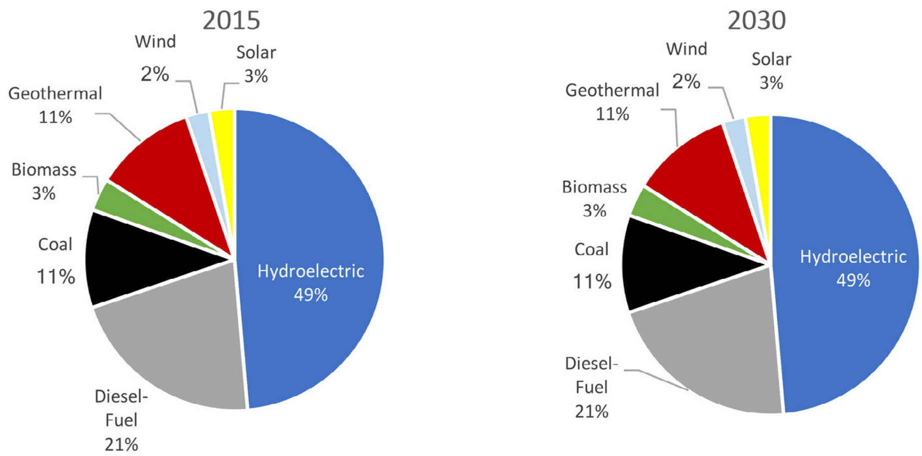
Source: Simulation results

Figure 5.18. Projected electricity generation in Central America, BAU scenario



Source: Simulation results

Figure 5.19. Evolution of electricity generation matrix in Central America, BAU scenario



Source: Simulation results

As a subregion Central America remains self-sufficient in the supply of domestic electricity demand in the baseline scenario, with hydroenergy being the main resource used for that purpose.

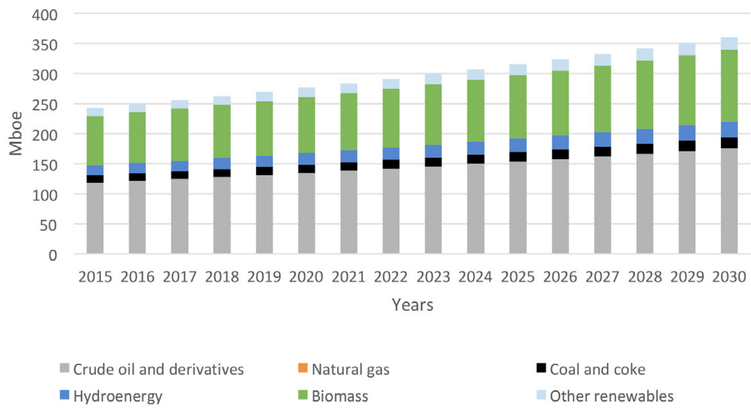
5.4.3 Projected total energy supply

Table 5.12. Projected total energy supply in Central America, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	118	135	154	176	2.7%
Coal and coke	12	14	16	18	2.5%
Hydroenergy	17	19	23	27	3.2%
Biomass	82	93	105	119	2.5%
Other renewables	13	16	18	21	3.2%
TOTAL	**243**	**277**	**316**	**361**	**2.7%**

Source: Simulation results

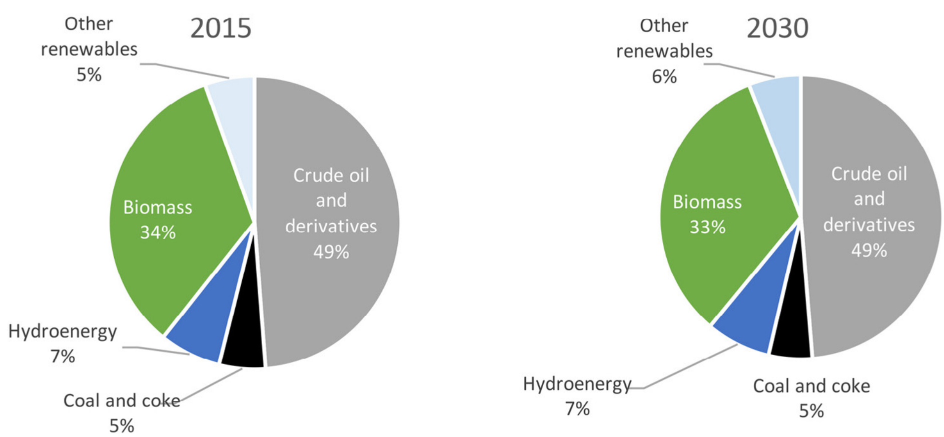
Figure 5.20. Projected total energy supply in Central America, BAU scenario



Source: Simulation results

The total energy supply matrix for Central America under the BAU scenario does not experience significant variations in the projection period, as can be seen in Figure 5.21.

Figure 5.21. Evolution in total energy supply matrix in Central America, BAU scenario



Fuente: Resultados de la simulación

5.5 Andean Subregion

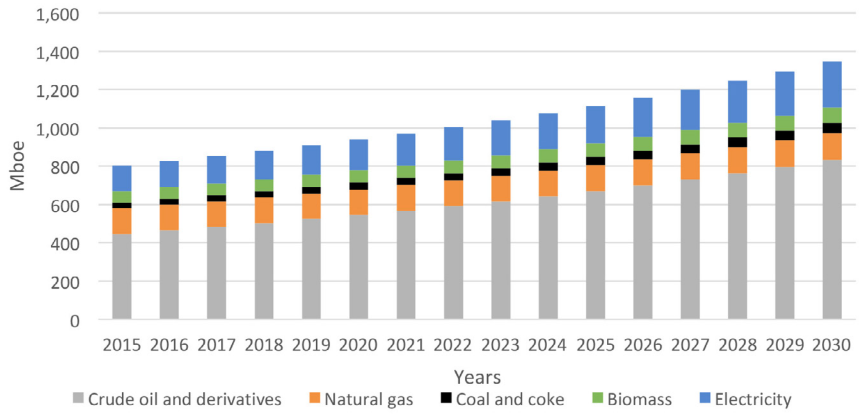
5.5.1 Projected final energy consumption

Table 5.13. Projected final energy consumption in the Andean Subregion, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	447	544	670	832	4.2%
Natural gas	134	133	135	140	0.3%
Coal and coke	29	36	44	54	4.2%
Biomass	60	64	71	79	1.9%
Electricity	133	161	196	240	4.0%
TOTAL	**803**	**939**	**1,115**	**1,346**	**3.5%**

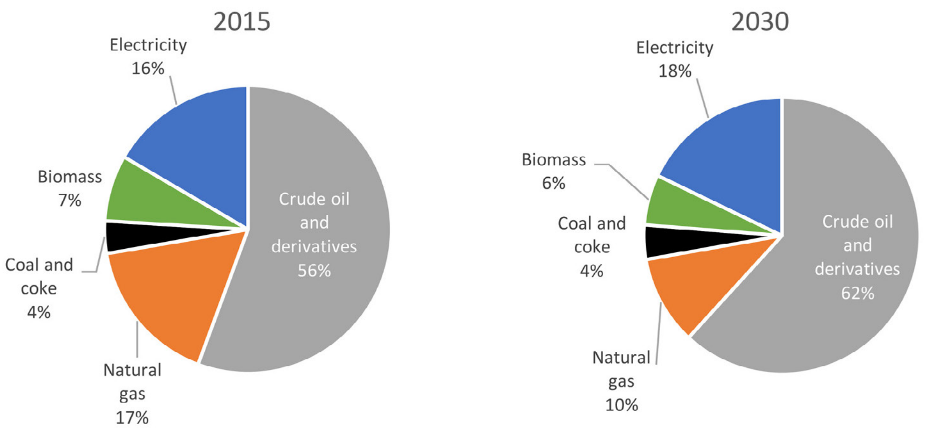
Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.22. Projected final energy consumption in the Andean Subregion, BAU scenario (Mboe)



Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.23. Evolution of final energy consumption matrix in the Andean Subregion, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

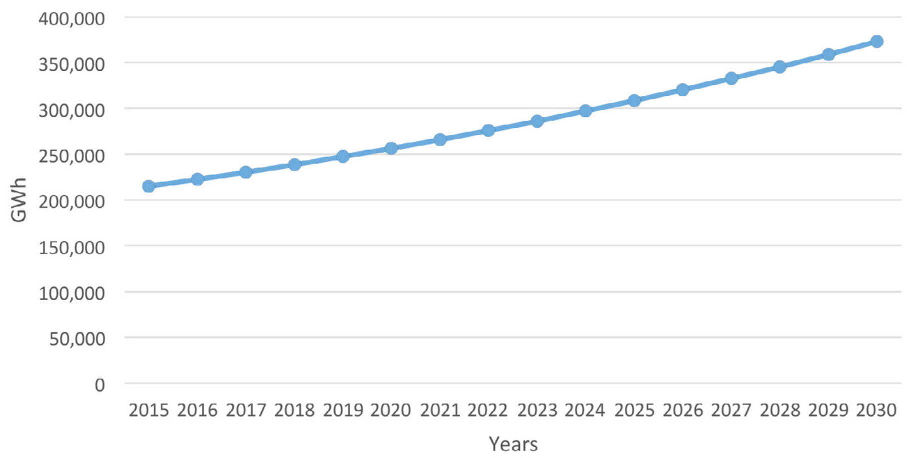
In the baseline scenario, oil products and electricity gain in terms of their share of the final consumption matrix of the Andean Subregion, while participation by natural gas and biomass declines. (see Figure 5.23)

Table 5.14. Projected final energy consumption in the Andean Subregion, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Electricity	215,097	259,898	316,389	387,884	4.0%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.24. Projected final energy consumption in the Andean Subregion, BAU scenario (Mboe)



Source: By authors based on information from OLADE SieLAC (2016)

Baseline growth in the Andean Subregion's electricity consumption represents a total increase of 80% during the projection period. At an average annual rate of 4.0%, it is the subregion with the fastest growth in electricity consumption of the six subregions analyzed.

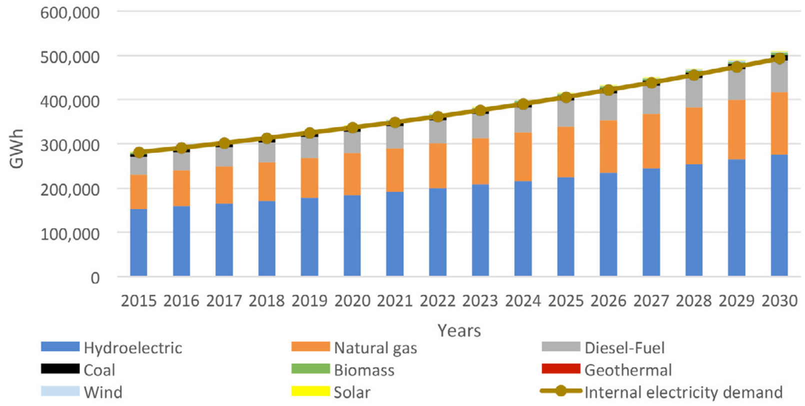
5.5.2 Projected electricity generation

Table 5.15. Projected electricity generation in the Andean Subregion, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	152,886	184,859	225,039	275,892
Natural gas	77,709	93,961	114,384	140,231
Diesel-Fuel Oil	39,985	48,347	58,856	72,156
Coal	6,953	8,407	10,235	12,548
Biomass	2,844	3,439	4,186	5,132
Wind	1,503	1,817	2,212	2,712
Solar	323	390	475	582
TOTAL	**282,203**	**341,220**	**415,387**	**509,253**

Source: Simulation results

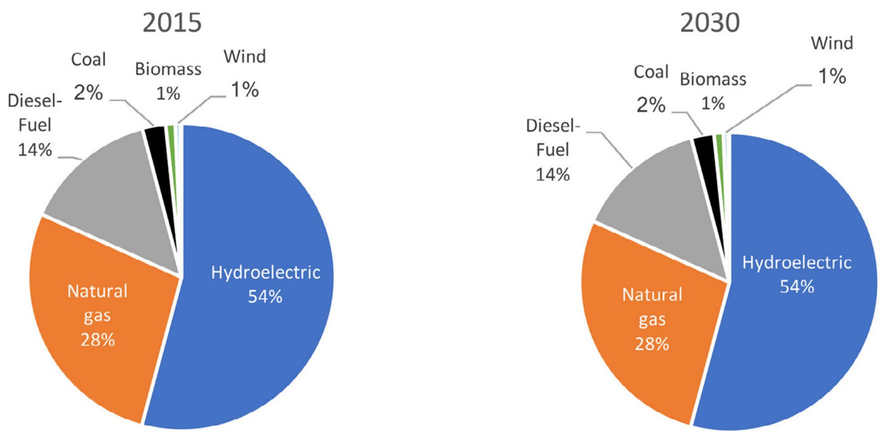
Figure 5.25. Projected electricity generation in the Andean Subregion, BAU scenario (GWh)



Source: Simulation results

The Andean Subregion's electricity generation matrix is mainly based on hydroelectricity and naturla gas and it is self-sufficient when it comes to supplying domestic electricity demand.

Figure 5.26. Evolution of electricity generation matrix in the Andean Subregion, BAU scenario



Source: Simulation results

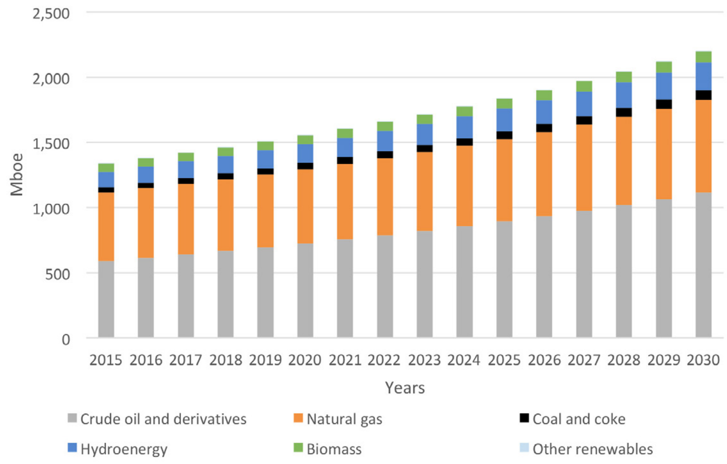
5.5.3 Projected total energy supply

Table 5.16. Projected total energy supply in the Andean Subregion, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	591	724	895	1,114	4.3%
Natural gas	525	570	631	711	2.0%
Coal and coke	41	50	61	75	4.1%
Hydroenergy	118	143	174	214	4.0%
Biomass	63	68	76	86	2.1%
Other renewables	1	1	2	2	4.0%
TOTAL	1,339	1,557	1,838	2,202	3.4%

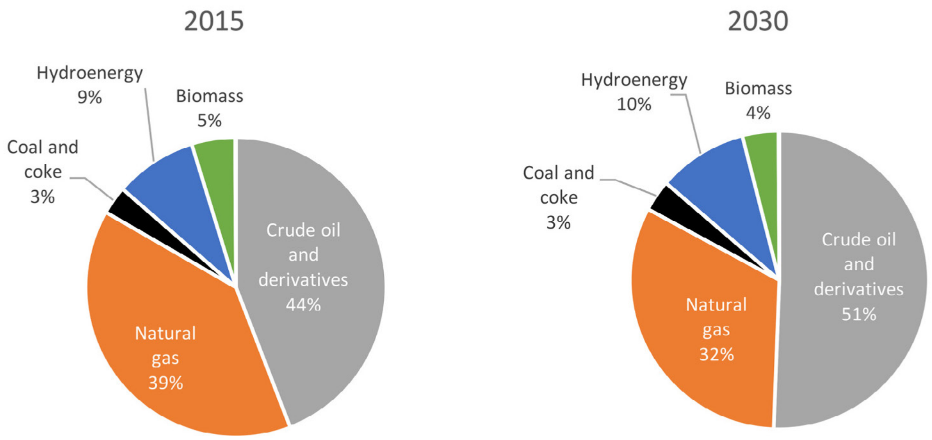
Source: Simulation results

Figure 5.27. Projected total energy supply in the Andean Subregion, BAU scenario (Mboe)



Source: Simulation results

Figure 5.28. Evolution in total energy supply matrix in the Andean Subregion, BAU scenario



Source: Simulation results

In a similar way to evolution in the final consumption matrix, in the energy supply matrix there is an increase in the proportion of oil products, which gain on natural gas (Figure 5.28).

5.6 Southern Cone

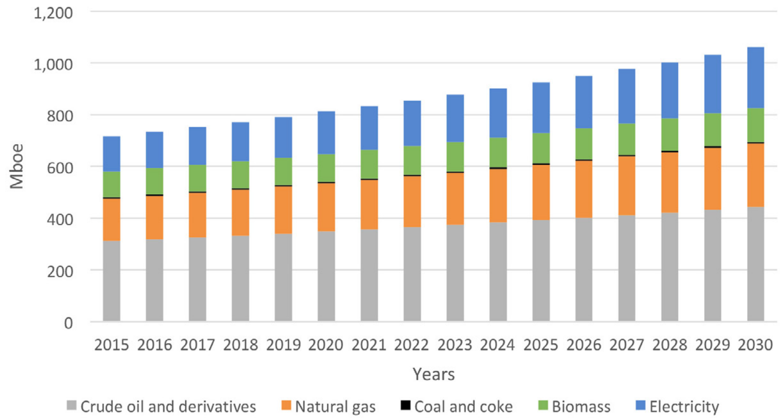
5.6.1 Projected final energy consumption

Table 5.17. Projected final energy consumption in the Southern Cone, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	312	348	392	443	2.4%
Natural gas	163	186	214	247	2.8%
Coal and coke	6	6	6	6	-0.4%
Biomass	100	108	118	130	1.8%
Electricity	136	163	196	235	3.7%
TOTAL	717	812	925	1061	2.6%

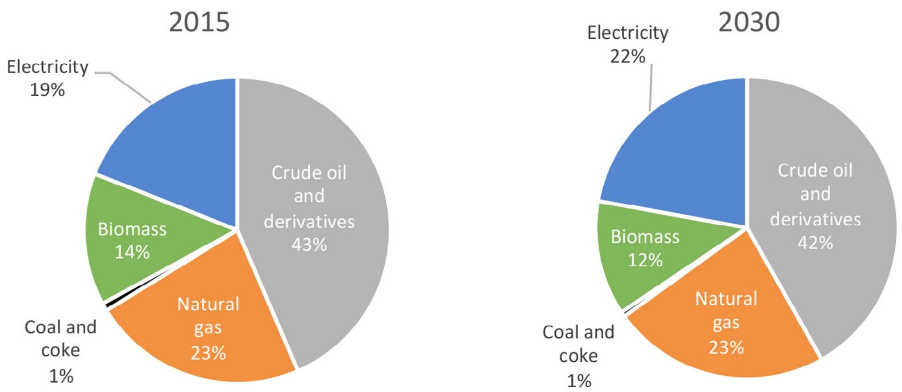
Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.29. Projected final energy consumption in the Southern Cone, BAU scenario (Mboe)



Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.30. Evolution of final energy consumption matrix in the Southern Cone, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

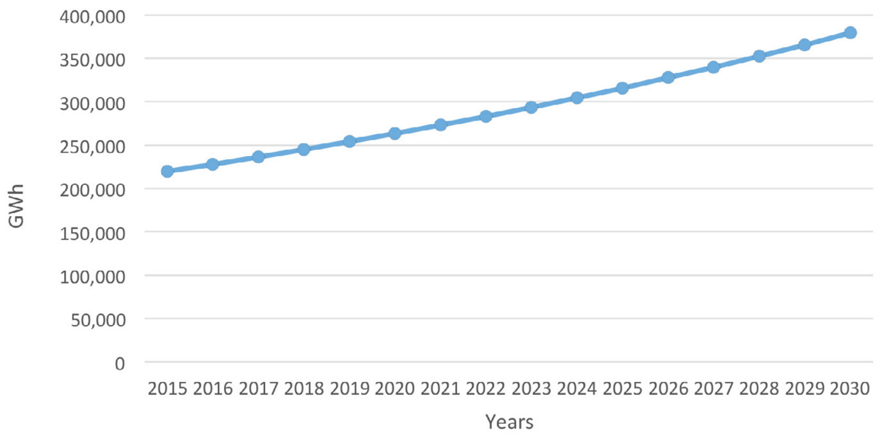
The most relevant variation that can be observed in the evolution of the Southern Cone consumption matrix in the BAU scenario is the increased penetration by electricity, displacing biomass and the oil products by several percentage points (Figure 5.30).

Table 5.18. Projected final energy consumption in the Southern Cone, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Electricity	219,915	263,434	315,940	379,356	3.7%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.31. Projected final energy consumption in the Southern Cone, BAU scenario (Mboe)



Source: By authors based on information from OLADE SieLAC (2016)

In the BAU scenario the Southern Cone's annual electricity consumption increases by 73% over the study period.

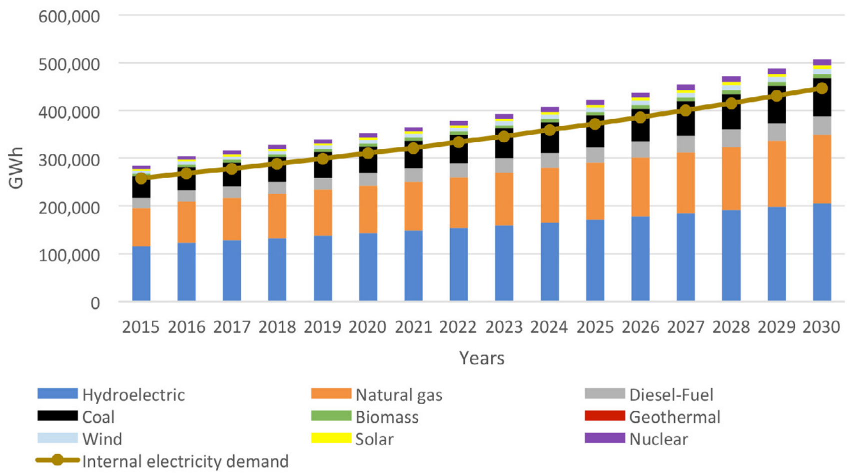
5.6.2 Projected electricity generation

Table 5.19. Projected electricity generation in the Southern Cone, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	115,574	142,967	171,463	205,879
Natural gas	80,222	99,237	119,016	142,905
Diesel-Fuel Oil	21,789	26,953	32,325	38,813
Coal	44,972	55,632	66,720	80,112
Biomass	4,944	6,115	7,334	8,806
Wind	6,112	7,561	9,068	10,888
Solar	3,799	4,700	5,636	6,768
Nuclear	7,081	8,759	10,505	12,613
TOTAL	**284,493**	**351,923**	**422,067**	**506,784**

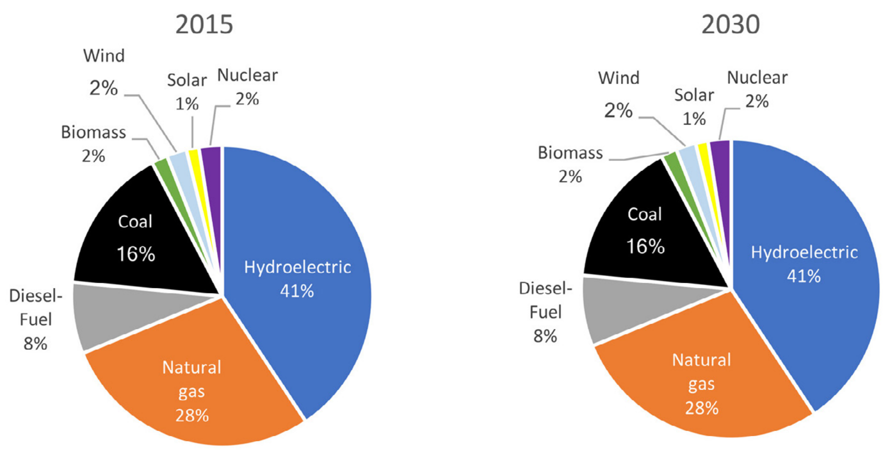
Source: Simulation results

Figure 5.32. Projected electricity generation in the Southern Cone, BAU scenario (GWh)



Source: Simulation results

Figure 5.33. Evolution of electricity generation matrix in the Southern Cone, BAU scenario



Source: Simulation results

As shown in figure 5.32, the Southern Cone subregion is a net exporter of electricity, since total generation is higher than domestic demand. The main export is represented by the power that Paraguay sells to Brazil from its share of generation from the Itaipú Binational Hydroelectric power plant. The main resources used for electricity generation are hydroenergy and natural gas, though it is worth noting that it is the subregion where coal has the greatest relevance to electricity generation (Figure 5.33).

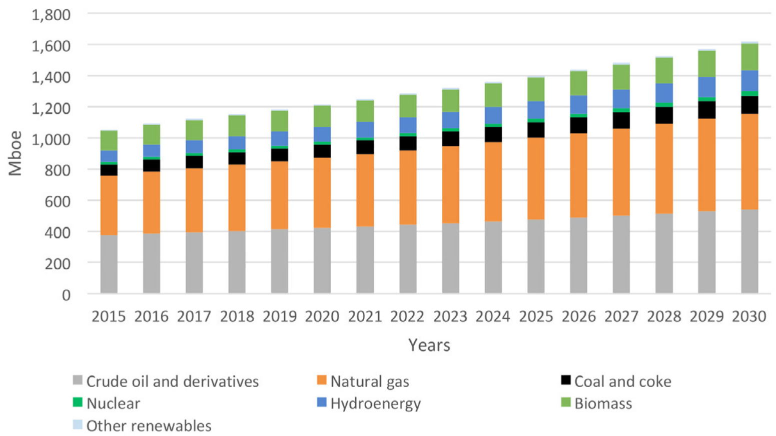
5.6.3 Projected total energy supply

Table 5.20. Projected total energy supply in the Southern Cone, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	374	422	476	541	2.5%
Natural gas	384	451	525	614	3.2%
Coal and coke	71	84	98	116	3.3%
Nuclear	16	20	24	28	3.9%
Hydroenergy	76	94	113	135	3.9%
Biomass	124	138	153	172	2.2%
Other renewables	6	8	9	11	3.9%
TOTAL	1,052	1,216	1,398	1,618	2.9%

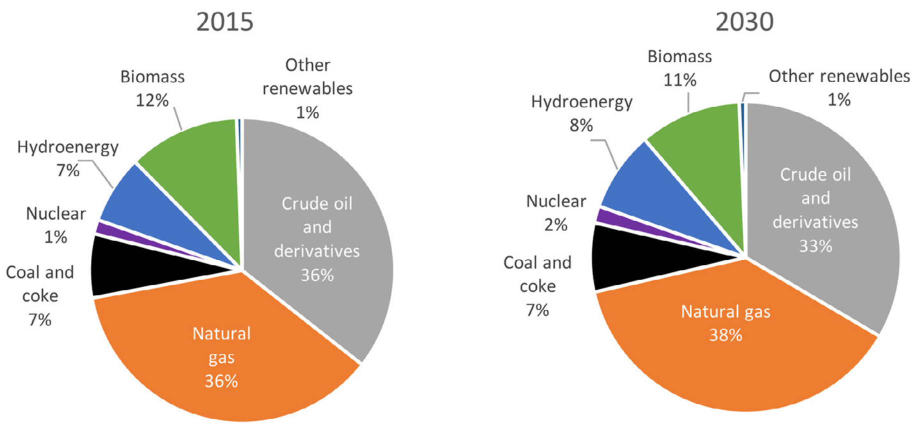
Source: Simulation results

Figure 5.34. Projected total energy supply in the Southern Cone, BAU scenario (Mboe)



Source: Simulation results

Figure 5.35. Evolution of final energy consumption matrix in the Southern Cone, BAU scenario



Source: Simulation results

In the baseline BAU scenario the total energy supply matrix of the Southern Cone does not experience very significant variations over the projection period, though a certain replacement of oil products with natural gas can be observed (Figure 5.35).

5.7 The Caribbean

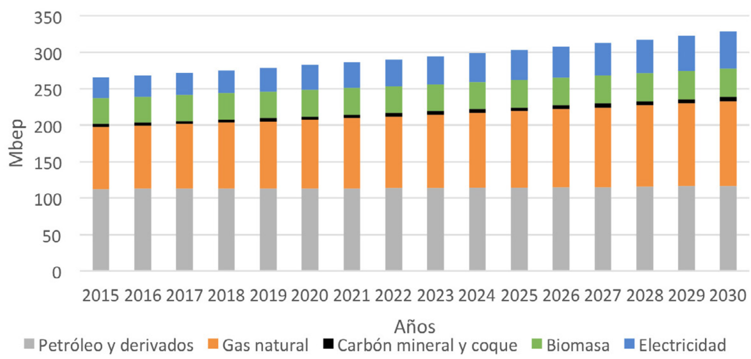
5.7.1 Projected final energy consumption

Table 5.21. Projected final energy consumption in the Caribbean, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	113	113	114	117	0.2%
Natural gas	85	94	105	116	2.1%
Coal and coke	4	5	5	6	3.1%
Biomass	36	37	38	39	0.6%
Electricity	28	34	41	50	3.9%
TOTAL	**266**	**283**	**303**	**328**	**1.4%**

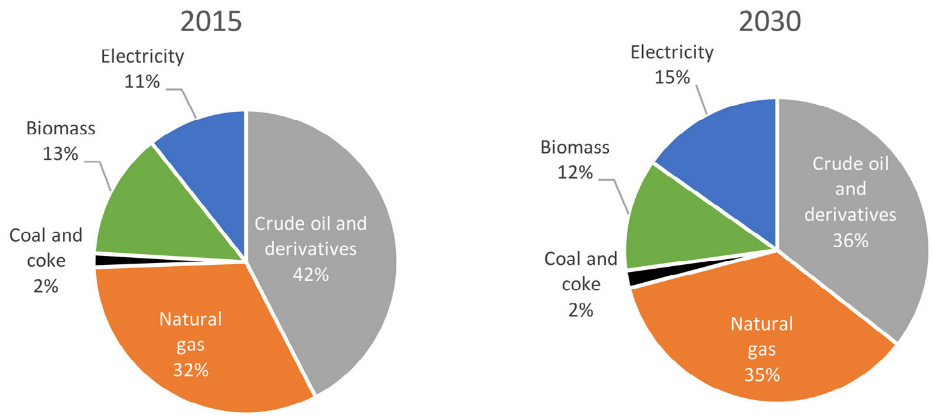
Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.36. Projected final energy consumption in the Caribbean, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.37. Evolution of final energy consumption matrix in the Caribbean, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

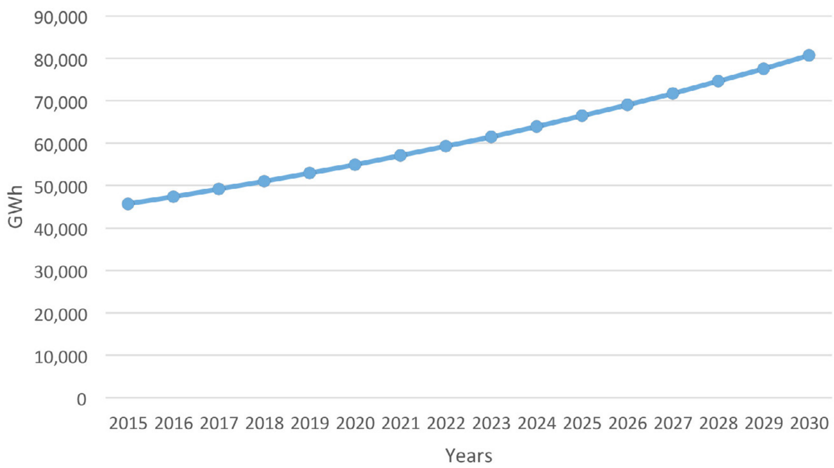
Final energy consumption in the Caribbean increases at a relatively slow pace (1.4% annually), with the main sources consumed being oil products and natural gas. The penetration of electricity and natural gas stands out in the evolution of the consumption matrix, reducing the share represented by oil products (Figure 5.37).

Table 5.22. Projected final electricity consumption in the Caribbean, BAU scenario (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	45,722	54,961	66,436	80,745	3.9%

Source: By authors based on information from OLADE SieLAC (2016)

Figure 5.38. Projected final electricity consumption in the Caribbean, BAU scenario



Source: By authors based on information from OLADE SieLAC (2016)

Despite the fact that, as mentioned, total energy consumption grows slowly in the Caribbean subregion, electricity consumption shows accelerated growth in this subregion, with the second highest annual rate after the Andean Subregion. This is because many of the countries that belong to this subregion are currently in the process of electrifying their more isolated regions.

5.7.2 Projected electricity generation

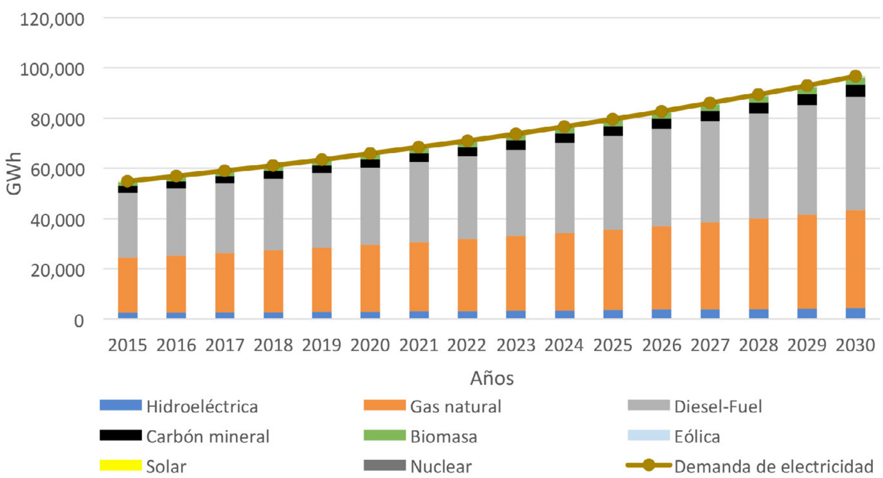
Table 5.23. Projected electricity generation in the Caribbean, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	2,398	2,882	3,484	4,235
Natural gas	22,039	26,493	32,025	38,922
Diesel-Fuel Oil	25,674	30,862	37,306	45,341
Coal	2,696	3,241	3,918	4,762
Biomass	1,573	1,891	2,286	2,778
Wind	0	0	0	0
Solar	308	371	448	544
Nuclear	81	97	117	143
TOTAL	**54,769**	**65,837**	**79,583**	**96,724**

Source: Simulation results

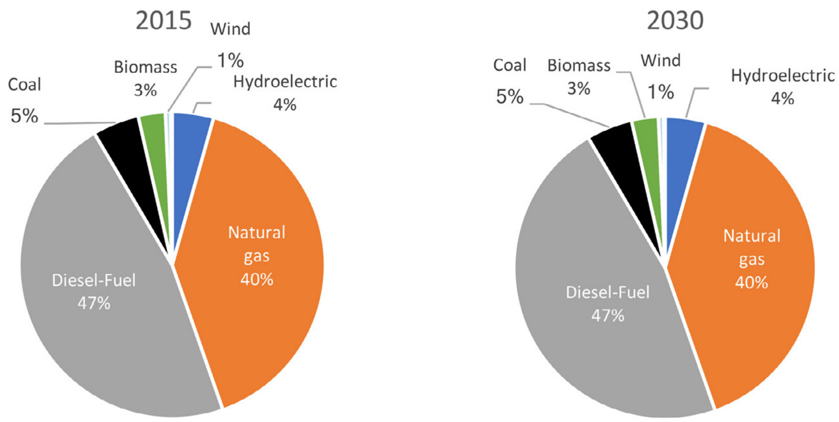
The Caribbean subregion is self-sufficient in energy supplies, whose generation depends primarily on natural gas and oil products which together represent close to 90% of the matrix (Figures 5.39 and 5.40).

Figure 5.39. Projected electricity generation in the Caribbean, BAU scenario



Source: Simulation results

Figure 5.40. Evolution of electricity generation matrix in the Caribbean, BAU scenario



Source: Simulation results

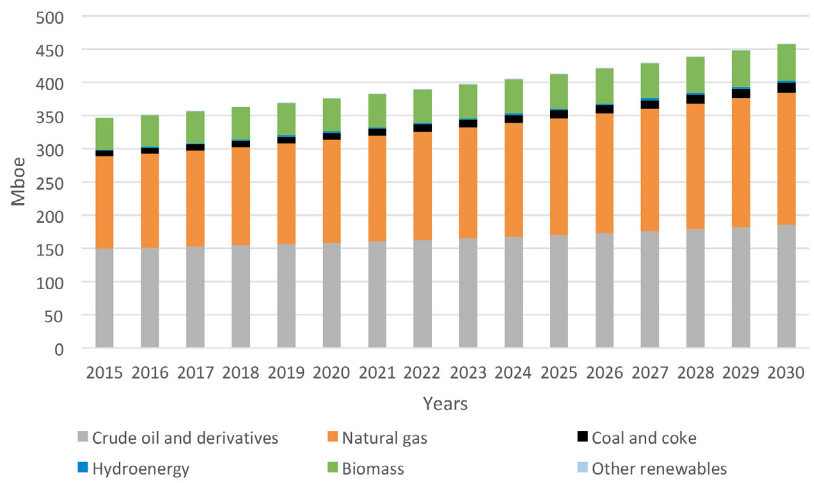
5.7.3 Projected total energy supply

Table 5.24. Projected total energy supply in the Caribbean, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	150	158	170	185	1.4%
Natural gas	138	155	176	199	2.5%
Coal and coke	9	10	12	15	3.5%
Hydroenergy	2	2	2	3	3.9%
Biomass	47	50	52	55	1.0%
Other renewables	0,2	0,3	0,4	0,4	3.9%
TOTAL	**347**	**376**	**413**	**458**	**1.9%**

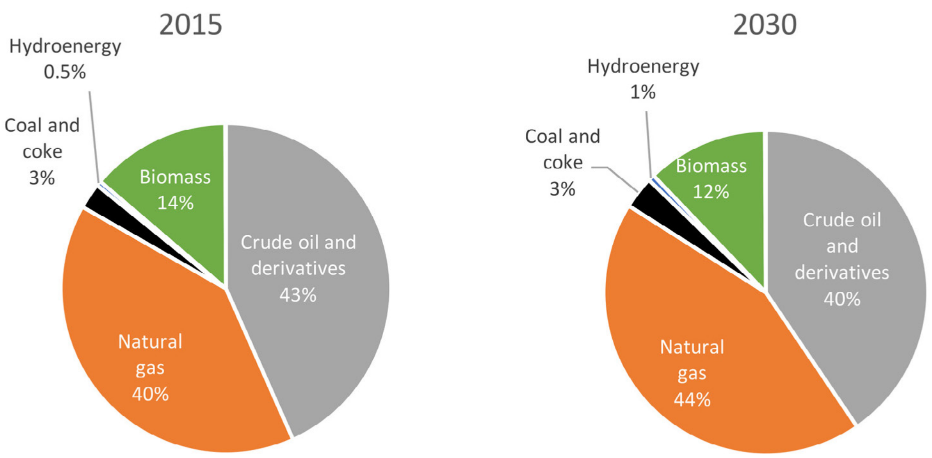
Source: Simulation results

Figure 5.41. Projected total energy supply in the Caribbean, BAU scenario



Source: Simulation results

Figure 5.42. Evolution of total energy supply matrix in Brazil, BAU scenario



Source: Simulation results

One can see the increased proportion of natural gas in the baseline evolution in the total energy supply matrix of the Caribbean, displacing oil products and biomass. (Figure 5.42).

5.8 Latin America and the Caribbean (LAC)

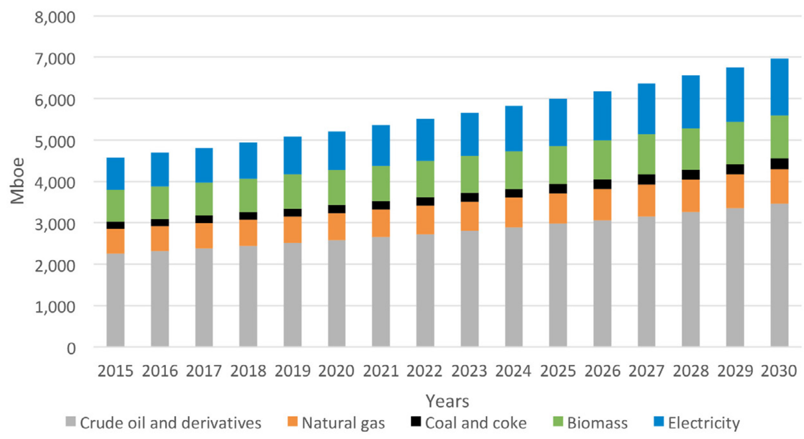
5.8.1 Projected final energy consumption

Table 5.25. Projected final energy consumption in LAC, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	2,261	2,579	2,974	3,462	2.9%
Natural gas	590	656	736	834	2.3%
Coal and coke	174	197	224	256	2.6%
Biomass	767	837	928	1042	2.1%
Electricity	784	944	1139	1376	3.8%
TOTAL	**4,576**	**5,212**	**6,000**	**6,971**	**2.8%**

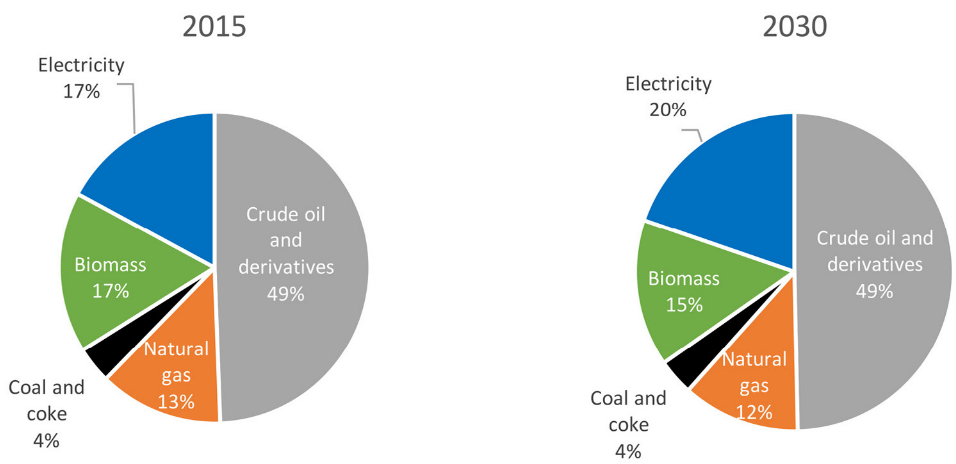
Source: Simulation results

Figure 5.43. Projected final energy consumption in LAC, BAU scenario



Source: Simulation results

Figure 5.44. Evolution of final energy consumption matrix in LAC, BAU scenario



Source: Simulation results

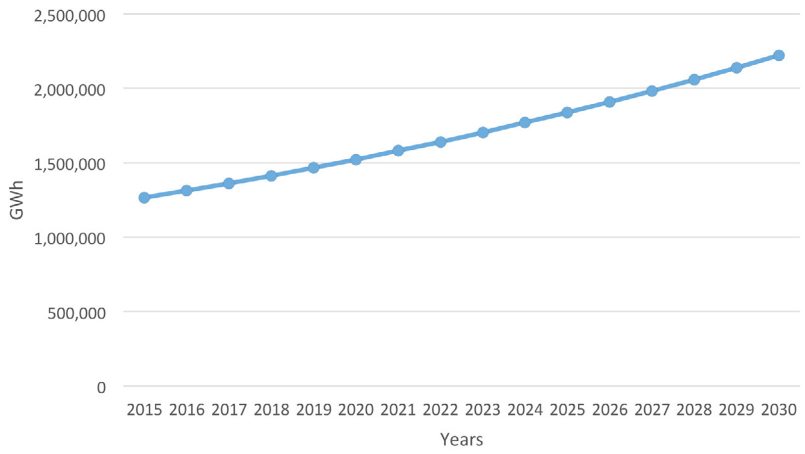
The most important variation in the final energy consumption matrix in LAC during the projection period consists in a reduced proportion of biomass and natural gas due to increased penetration by electricity (Figure 5.44)

Table 5.26. Projected final electricity consumption in LAC, BAU scenario (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	1,264,966	1,523,104	1,837,631	2,221,463	3.8%

Source: Simulation results

Figure 5.45. Projected final electricity consumption in LAC, BAU scenario



Source: Simulation results

The growth rate in annual average electricity consumption in LAC is relatively high (3.8%), which causes said consumption to increase by a total of 76% in the projection period.

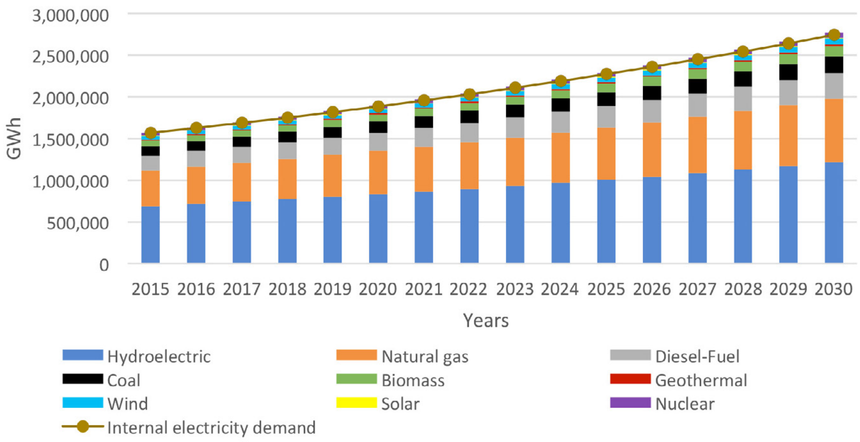
5.8.2 Projected electricity generation

Table 5.27. Projected electricity generation in LAC, BAU scenario (GWh)

Source	2015	2020	2025	2030
Hydroelectric	686,983	832,100	1,004,464	1,215,196
Natural gas	427,355	518,122	625,579	756,844
Diesel-Fuel Oil	178,285	215,367	259,847	314,406
Coal	112,917	137,413	165,291	199,082
Biomass	69,732	84,248	101,647	122,757
Geothermal	11,861	14,103	16,784	19,989
Wind	39,521	47,836	57,661	69,567
Solar	5,763	7,019	8,382	10,025
Nuclear	33,277	40,369	48,664	58,698
TOTAL	**1,565,695**	**1,896,577**	**2,288,319**	**2,766,565**

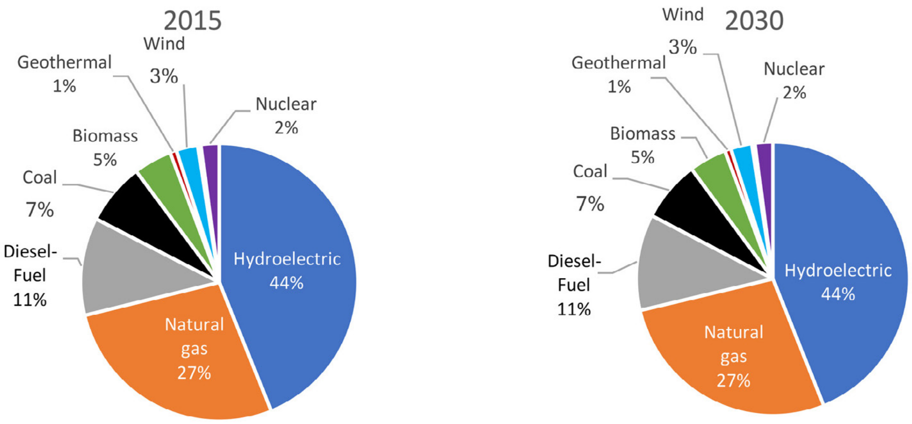
Source: Simulation results

Figura 5.46. Projected electricity generation in LAC, BAU scenario



Source: Simulation results

Figure 5.47. Evolution of electricity generation matrix in LAC, BAU scenario



Source: Simulation results

The Latin American and Caribbean electricity generation matrix primarily depends on hydroelectricity and natural gas and according to the premises the BAU scenario the structure of this matrix is maintained throughout the study period.

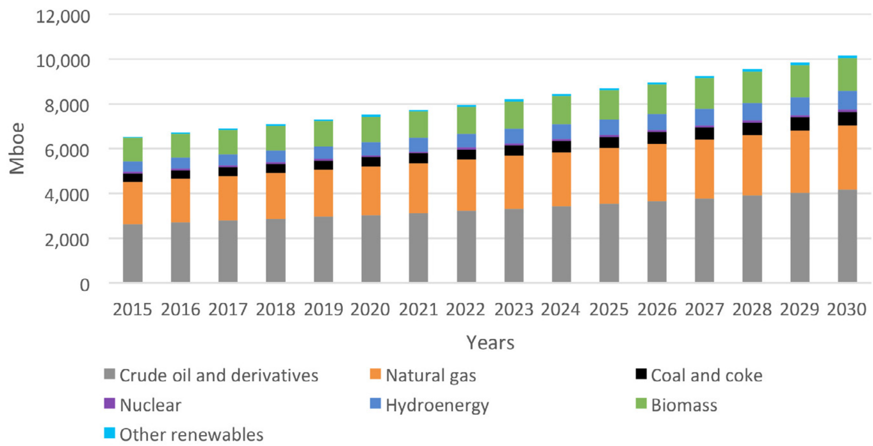
5.8.3 Projected total energy supply

Table 5.28. Projected total energy supply in LAC, BAU scenario (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	580	635	701	778	2.0%
Natural gas	566	658	769	905	3.2%
Coal and coke	109	126	147	171	3.1%
Hydroenergy	21	25	30	36	3.8%
Biomass	15	18	22	26	3.8%
Other renewables	69	72	77	85	1.4%
TOTAL	23	34	41	50	5.3%

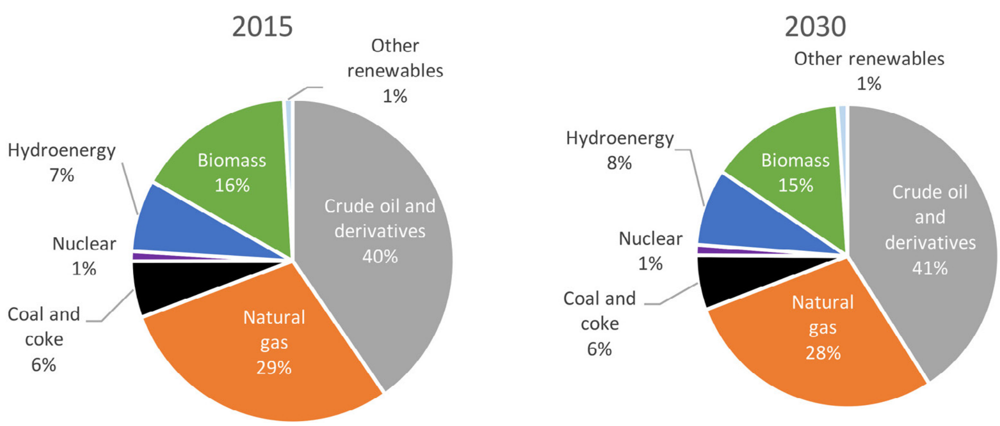
Source: Simulation results

Figure 5.48. Projected total energy supply in LAC, BAU scenario



Source: Simulation results

Figure 5.49. Evolution of total energy supply matrix in Brazil, BAU scenario



Source: Simulation results

In the BAU baseline scenario, variations in the total energy supply matrix for LAC are irrelevant; the proportional structure of the base year is practically maintained.

6. Construction of the Current Policies Scenario (CPS)

6. Construction of the Current Policies Scenario (CPS)

6.1 General Considerations

The purpose of the CPS is to simulate the evolution in the energy matrix in the different subregions according to official energy development policies, with an emphasis on the electricity sector, as represented by the sector's expansion plans, and to analyze whether this evolution is consistent with GHG emissions targets as formulated in countries' (I) NDCs.

The following assumptions were used to construct the CPS:

- To project energy consumption in the CPS, first the average annual growth rates countries proposed in their comprehensive energy sector expansion plans were used.
- Given that the majority of countries in the region only publish expansion plans for the electricity sector, consumption for energy sources for which no official projections are available was estimated based on linear and logarithmic regressions of historical series, but in contrast with the BAU scenario, given that the CPS is a scenario of active policies, in particular with regard to the promotion of energy efficiency, said rates were affected by an estimated damping factor , according to the decrease in energy intensity in the region over the last 5 years.
- For cases where expansion plans include more than one projected consumption scenario, the one defined as the middle, recommended or reference scenario was considered.
- Electricity supplies are projected based on the schedules presented in countries' expansion plans for the installation/decommissioning of installed capacity. Using a dispatch simulation by order of merit for the available capacity of each technology for each year in the projection period.
- The dispatch order for the electricity supply technologies in each sub-region mainly responds to economic criteria, though there are also environmental and technological considerations that prioritize the dispatch of renewable energies. That is to say, the technologies that generally occupy the base of monotonous load curves , such as nuclear, geothermal and hydroelectric, have the first positions in the order

[2] A single factor in the entire region was considered 0.03 percentage points less for the growth rates in relation to the tendencies of the BAU, for the main energy consumption. This resulted in savings of between 2 and 3% in projected consumption by 2035, depending on the subregion. This difference is small enough so that it does not have a significant influence on the comparative analysis with the goals of the NDCs.

[3]The monotonous load is a curve that presents, for a given period, the distribution of the capacity demand over time, ordered from highest to lowest; and it is used to characterize de load and establish the electricity generation dispatch policy.

of dispatch. Then, by an environmental criterion, priority is given to wind, solar and biomass, so that these technologies, with renewable sources, can be used to their maximum available capacity; Later, technologies fostered with fossil fuels are given rise, in order of operating costs: coal-fired plants, natural gas and diesel, and fuel oil. Finally, with the exception of Brazil, whose case is explained in section 6.2.2, dispatch closes with electricity imports, which is applied only if the installed capacity of the sub-region's electricity generation is insufficient to cover domestic demand for electricity. electricity and if there is interconnection with other sub-regions.

- Given that the national expansion plans consulted consider different base years and projection periods, the electricity sector's expansion timelines were adjusted according to this study's base year and projection period.

- Though there are doubts regarding whether or not countries have considered the effects of climate change on electricity supply and demand when formulating their respective expansion plans, we are confident that, according to the OLADE study of Central America [21] and certain technical articles consulted on this issue [65] [69], these effects can be considered imperceptible for the horizon of this study (2030) and would therefore not have a significant effect on the results obtained in the CPS simulation.

The main features of the energy matrix's evolution for each of the subregions analyzed under the CPS assumptions are presented below.

6.2 Brazil

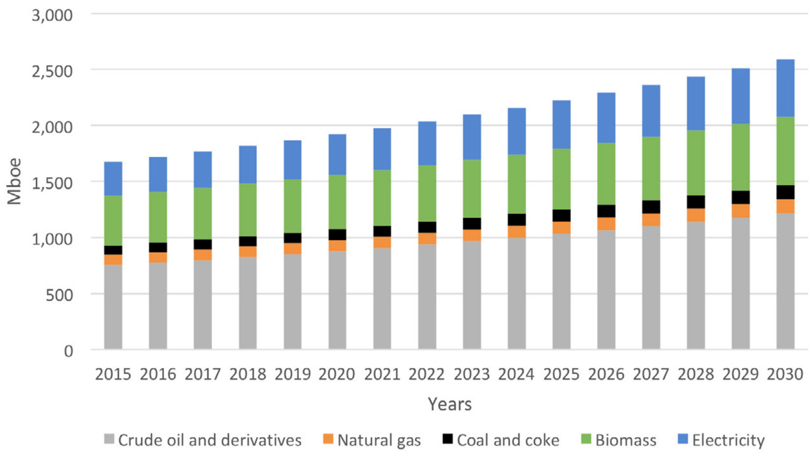
6.2.1 Projected final energy consumption

Table 6.1. Projected final energy consumption in Brazil, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	753	878	1,031	1,217	3.3%
Natural gas	91	100	111	125	2.1%
Coal and coke	84	96	110	125	2.7%
Biomass	443	485	540	609	2.2%
Electricity	304	362	431	514	3.6%
TOTAL	**1,676**	**1,922**	**2,223**	**2,590**	**2.9%**

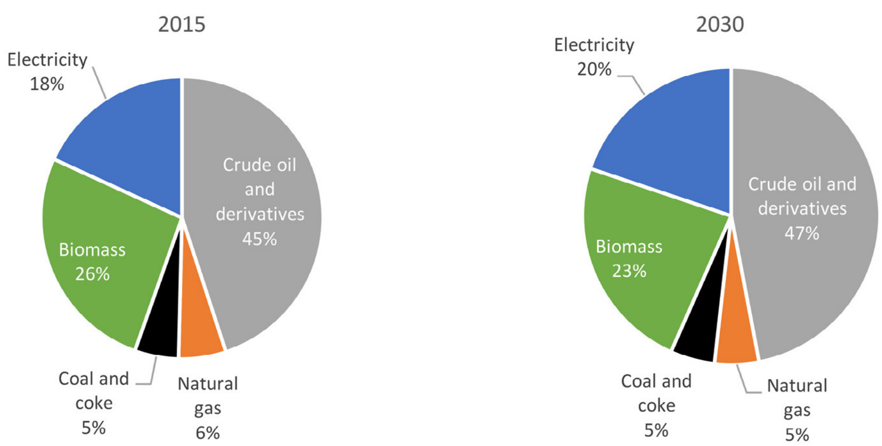
Source: 2016-2026 Ten-Year Energy Expansion Plan (PDE 2026)

Figure 6.1. Projected final energy consumption in Brazil, CPS



Source: 2016-2026 Ten-Year Energy Expansion Plan (PDE 2026)

Figure 6.2. Evolution of final energy consumption matrix in Brazil, CPS



Source: 2016-2026 Ten-Year Energy Expansion Plan (PDE 2026)

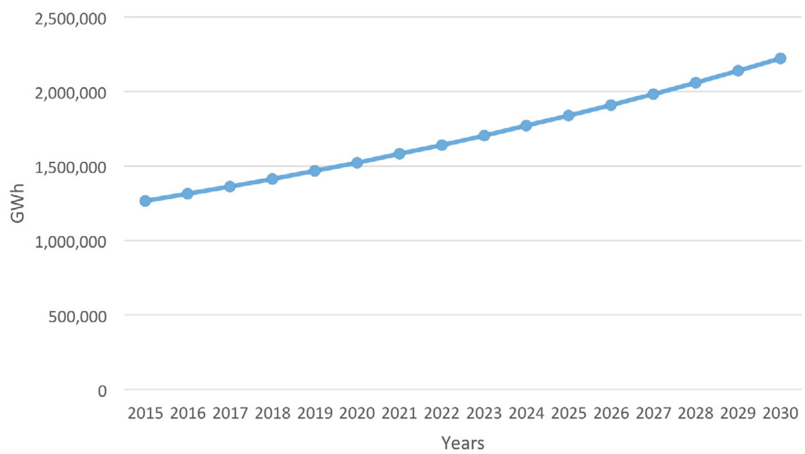
The evolution of Brazil's final consumption matrix under the CPS is no different in structural terms from what was already presented in the BAU scenario. However, in absolute terms there is a decline in the average annual growth rate for total energy consumption from 3.2% in the BAU scenario to 2.9% in the CPS.

Table 6.2. Projected final electricity consumption in Brazil, CPS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	491,241	584,529	695,921	828,996	3.6%

Source: 2016-2026 Ten-Year Energy Expansion Plan (PDE 2026)

Figure 6.3. Projected final electricity consumption in Brazil, CPS



Source: 2016-2026 Ten-Year Energy Expansion Plan (PDE 2026)

Electricity consumption in the CPS grows at an annual rate of 3.6%, which is two-tenths of a percentage point less than the rate under the BAU scenario. By the end of the study period, this difference reduces annual electricity consumption by 4%, which can be attributed to efficiency measures in the electricity sector produced by current development policies for the sector.

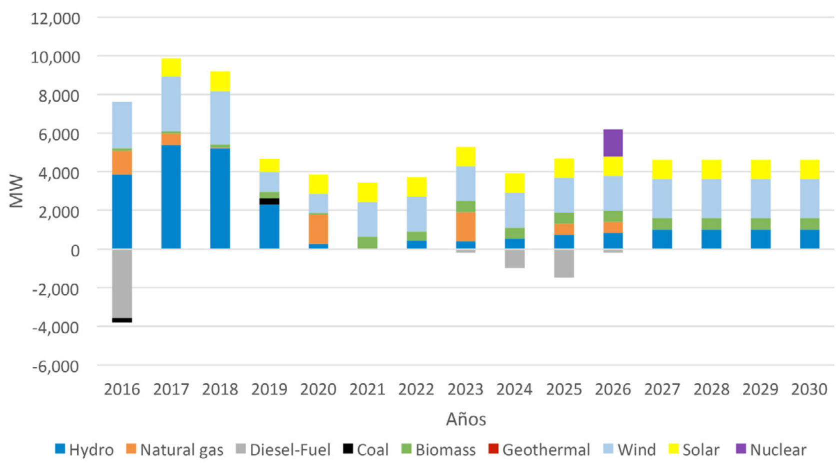
6.2.2 Projected electricity generation

Table 6.3. Timelines for installation/decommissioning of installed capacity (MW) in Brazil

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	3,868	1,215	-3,577	-215	137.0	0	2,392	0	0
2017	5,380	591	0	0	129	0	2,818	939	0
2018	5,218	28	0	0	172	0	2,755	1,030	0
2019	2,285	0	0	340	324	0	1,047	670	0
2020	265	1,521	0	0	71	0	1,000	1,000	0
2021	0	0	0	0	622	0	1,805	1,000	0
2022	442	0	0	0	467	0	1,804	1,000	0
2023	418	1,500	-193	0	568	0	1,804	1,000	0
2024	533	0	-984	0	568	0	1,804	1,000	0
2025	736	584	-1,482	0	566	0	1,804	1,000	0
2026	829	583	-206	0	568	0	1,804	1,000	1,405
2027	1,000	0	0	0	600	0	2,000	1,000	0
2028	1,000	0	0	0	600	0	2,000	1,000	0
2029	1,000	0	0	0	600	0	2,000	1,000	0
2030	1,000	0	0	0	600	0	2,000	1,000	0

Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2026)

Figure 6.4. Timelines for installation/decommissioning of installed capacity in Central America



Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2026)

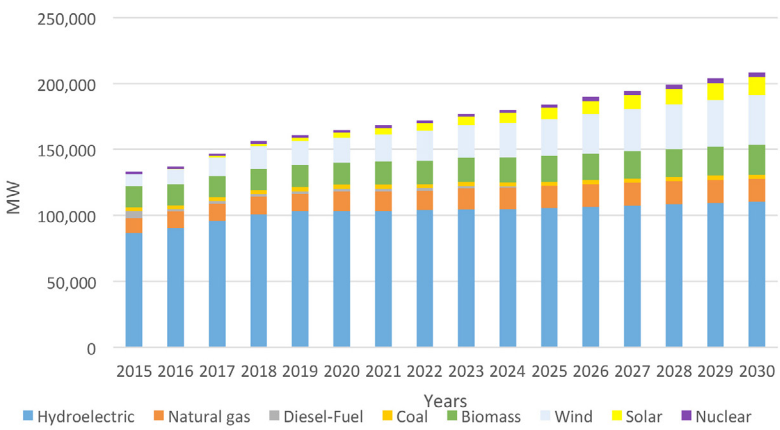
Given that Brazil's last Ten-Year Energy Plan (PDE) [1] only makes projections through 2026, for the remaining three years of the study period (2027-2030) were estimated according to the expansion trends for he different electricity generation technologies identified in the period 2016-2026. As can be seen in Figure 6.4, the technologies that will expand the most in installed capacity are, in order of importance, wind, solar, hydro and biomass.

Table 6.4. Projected Installed capacity in Brazil, CPS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	82,186	103,556	105,685	110,514
Natural gas	11,317	14,672	16,756	17,339
Diesel-Fuel Oil	5,542	1,965	0	0
Coal	3,064	3,189	3,189	3,189
Biomass	15,773	16,606	19,397	22,365
Wind	6,176	19,041	28,062	37,866
Solar	28	3,676	8,676	13,676
Nuclear	1,990	1,990	1,990	3,395
TOTAL	**126,076**	**164,696**	**183,756**	**208,345**

Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2026)

Figure 6.5. Projected Installed capacity in Brazil, CPS



Source: Simulation results

According to the installation/decommissioning timeline implemented, Brazil's installed capacity for electricity generation will increase by 65%, with a substantial increase in the proportion of NCRE, from a 17% in base year to 35% in 2030.

Unlike other subregions analyzed, where imports are considered to be the last priority in dispatch order, in Brazil electricity imports mainly correspond to the part of Paraguay's share of the Binational Plant's generation that Brazil consumes. For this reason, this energy is assigned a dispatch priority that follows domestic hydroelectric power plants.

Table 6.5. Dispatch priority of electricity generation technologies in Brazil

Dispatch order	Technology
1	Nuclear
2	Hydroelectric
3	Imports from Paraguay
4	Wind
5	Solar
6	Biomass
7	Coal
8	Natural gas
9	Diesel-Fuel Oil

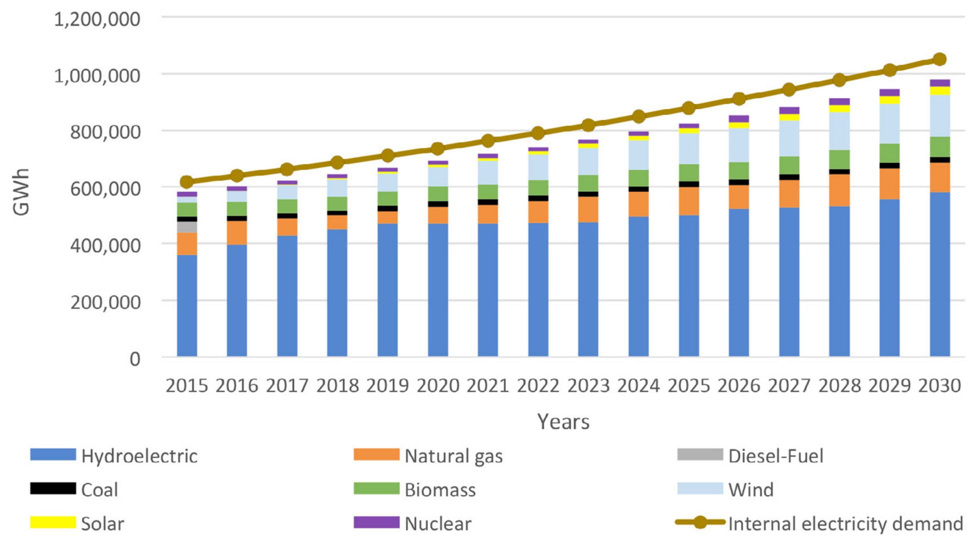
Source: Authors' compilation

Table 6.6. Projected electricity generation in Brazil, CPS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	359,975	471,718	499,932	580,862
Natural gas	79,541	59,342	99,149	105,909
Diesel-Fuel Oil	37,735	0	0	0
Coal	19,108	19,888	19,888	19,888
Biomass	49,059	51,649	60,330	69,561
Wind	21,640	66,721	110,622	149,269
Solar	59	7,729	18,241	28,753
Nuclear	14,744	14,744	14,744	25,153
TOTAL	**581,861**	**691,791**	**822,906**	**979,395**

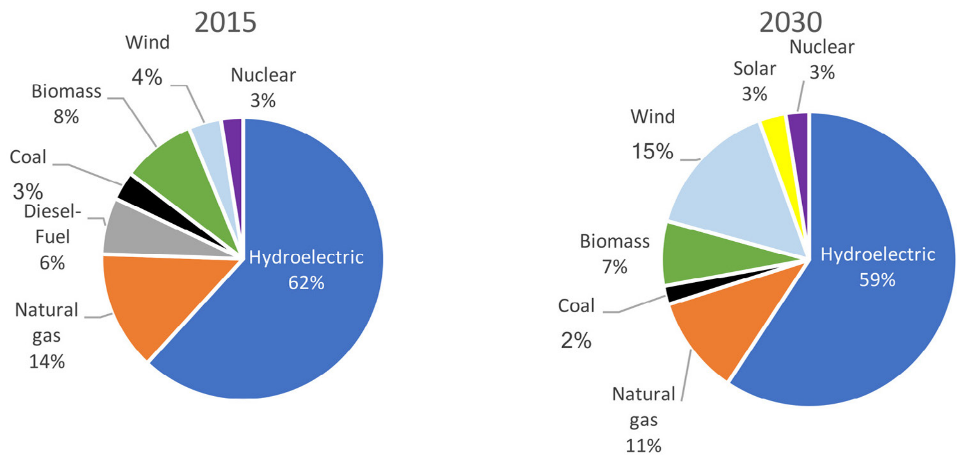
Source: Simulation results

Figure 6.6. Projected electricity generation in Brazil, CPS



Source: Simulation results

Figure 6.7. Evolution of electricity generation matrix structure in Brazil, CPS



Source: Simulation results

As shown in figure 6.6, Brazil continues to be a net importer of electricity throughout the projection period, maintaining imports mainly from Paraguay's share of generation from the Itaipú Binational power plant.

Consistent with expansion of installed capacity, electricity generation in Brazil evolves toward a significant increase in the share represented by NCRE, especially wind power, which rises from m4% in the base year to a 15% in 2030, which together with hydroenergy biomass and solar power means that the electricity generation matrix will be 85% renewable in 2030, compared to 74% in the base year (see figure 6.7).

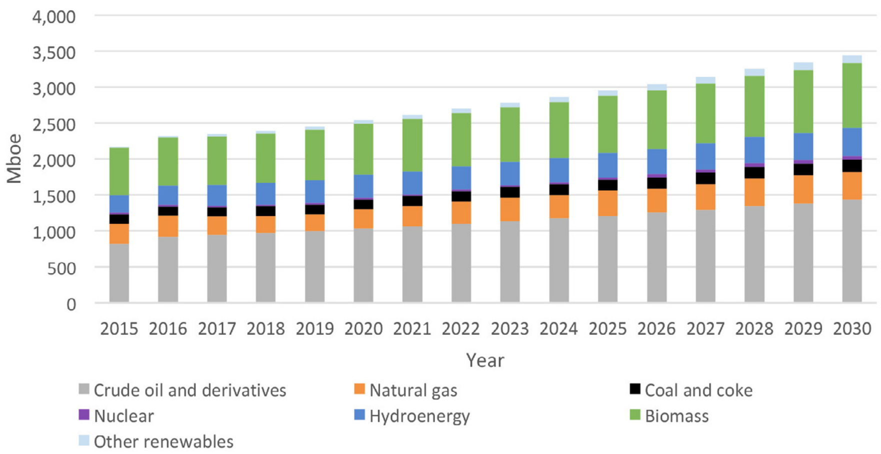
6.2.3 Projected total energy supply

Table 6.7. Projected total energy supply in Brazil, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	821	1,035	1,210	1,432	3.8%
Natural gas	281	264	353	389	2.2%
Coal and coke	127	139	154	171	2.0%
Nuclear	28	28	28	47	3.6%
Hydroenergy	244	317	340	396	3.3%
Biomass	655	711	795	898	2.1%
Other renewables	13	46	80	110	11.2%
TOTAL	**2,169**	**2,539**	**2,959**	**3,444**	**3.1%**

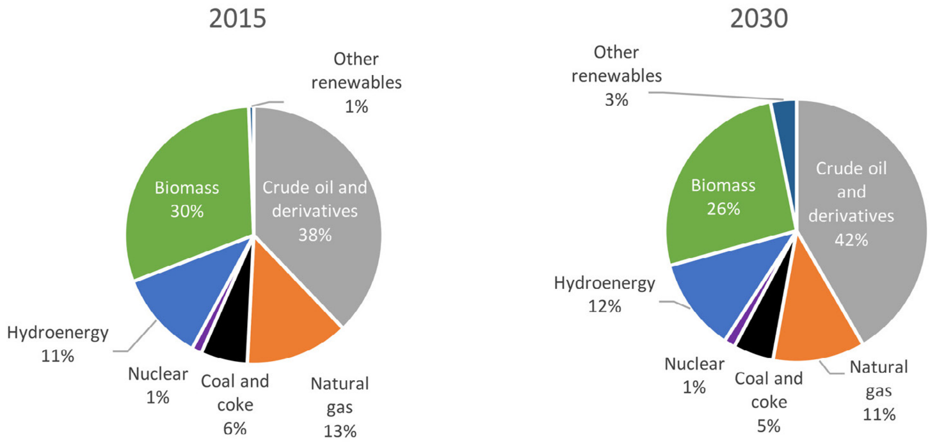
Source: Simulation results

Figure 6.8. Projected total energy supply in Brazil, CPS



Source: CPS simulation results

Figure 6.9. Evolution of total energy supply matrix in Brazil, CPS



As can be seen in figure 6.9, the energy supply matrix does not undergo major structural changes over the projection period, as the predominance of hydrocarbons (oil and natural gas) and biomass continues. Though there is a very significant increase in the proportion of NCRE like wind and solar (other renewables), they represent a marginal share of the total energy supply matrix, including at the end of the projection period, registering just 3%.

6.3 Mexico

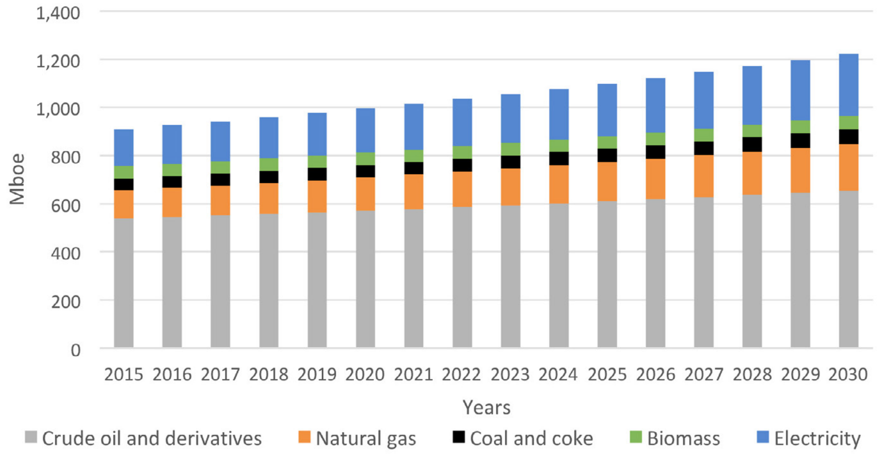
6.3.1 Projected final energy consumption

Table 6.8. Projected final energy consumption in Mexico, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	539	571	610	654	1.3%
Natural gas	118	139	164	193	3.3%
Coal and coke	47	52	56	61	1.7%
Biomass	52	51	52	54	0.3%
Electricity	154	184	218	260	3.5%
TOTAL	**910**	**996**	**1,099**	**1,223**	**2.0%**

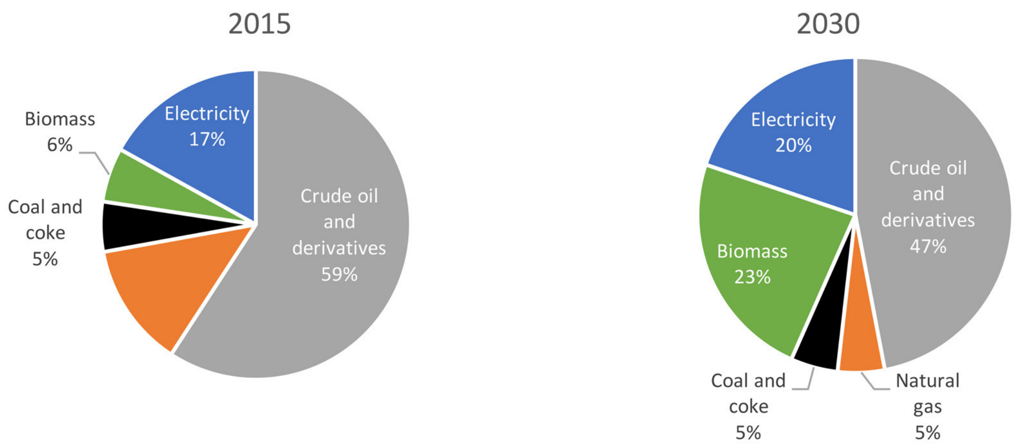
Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 6.10. Projected final energy consumption in Mexico, CPS (Mboe)



Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 6.11. Evolution of final energy consumption matrix in Mexico, CPS



Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

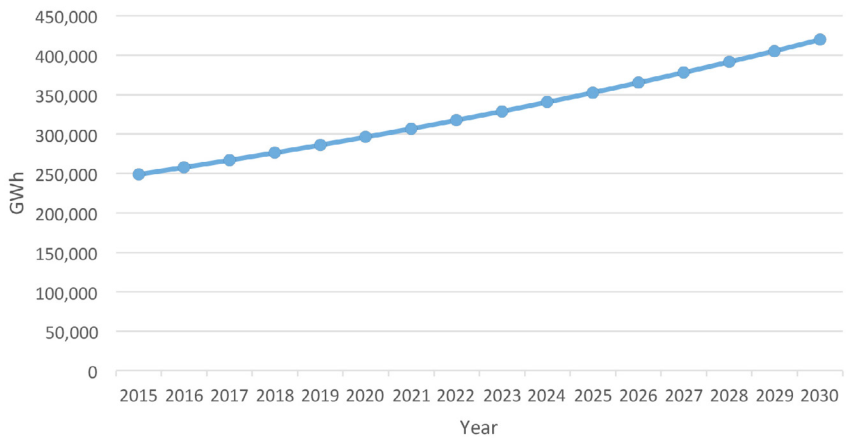
Given that electricity and natural gas are the sources that show the fastest growth in terms of final energy consumption, they also gain in their proportional share of the matrix, while oil products decline, as can be seen in Figure 6.11.

Table 6.9. Projected final electricity consumption in Mexico CPS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	248,895	296,206	352,571	419,730	3.5%

Source: By authors, based on national electricity sector expansion plans

Figure 6.12. Projected final electricity consumption in Mexico, CPS



Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

The industrial and residential sectors are the main drivers of electricity consumption in Mexico. At an annual growth rate of 3.5%, this consumption increases by a total of 69% over the base during the projection period.

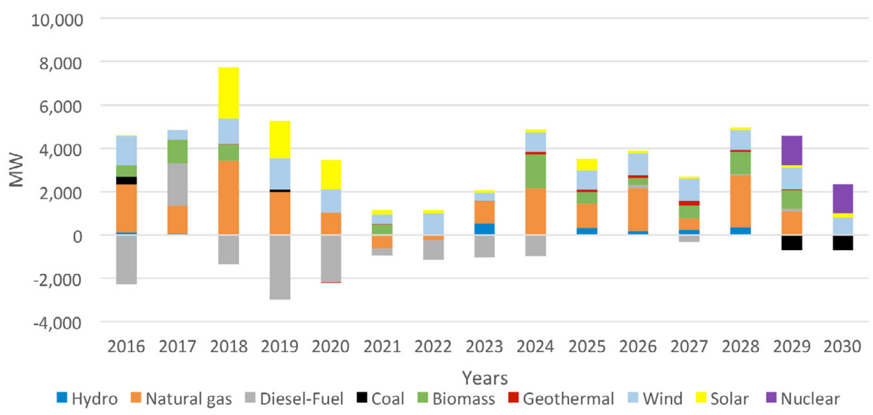
6.3.2 Projected electricity generation

Table 6.10. Timelines for installation/decommissioning of installed capacity (MW) in Mexico, CPS (MW)

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
Mexico	2016	101	2,211	-2,280	378	527		1,361	14	
	2017	53	1,284	1,958		1,096		468		
	2018	29	3,404	-1,355		750	10	1,176	2,364	
	2019		1,965	-2,974	129			1,452	1,727	
	2020		1,017	-2,189			-30	1,093	1,335	
	2021	27	-640	-320		452	25	450	205	
	2022		-245	-899			50	944	162	
	2023	516	1,034	-1,058			30	356	130	
	2024		2,143	-992		1,574	116	910	120	
	2025	327	1,109			533	108	891	537	
	2026	186	1,963	137		336	130	1,026	120	
	2027	230	539	-341		580	230	1,013	102	
	2028	351	2,403	42		1,040	82	941	110	
	2029		1,074	118	-700	875	30	1,021	100	1,360
	2030				-700		30	786	174	1,361

Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 6.13. Timelines for installation/decommissioning of installed capacity in Mexico, CPS



Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

The country's expansion plans show a strong push for natural gas-based electricity generation, with 19,261 MW of this technology to be added during the projection period (see Table 6.10). Likewise, a significant increase in the installed capacity of NCRE can be observed, especially wind, followed by biomass, solar and geothermal.

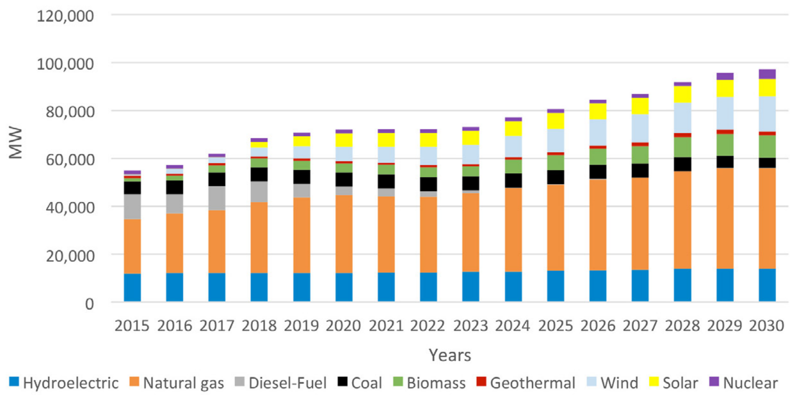
With regard to fossil fuel sources, a clear downward trend can be seen in the share represented by diesel-fuel oil, with 12,408 MW in installed capacity of this technology decommissioned, the majority plants that have completed their useful life cycles. Similarly, in the case of coal, despite having added 507 MW in capacity between 2016 and 2019, by the end of the analysis period we can observe the withdrawal of 1,400 MW between 2029 and 2030, which represents a 893 MW net reduction in total capacity.

Table 6.11. Projected Installed capacity in Mexico, CPS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	12,028	12,211	13,081	13,848
Natural gas	22,658	32,539	35,940	41,919
Diesel-Fuel Oil	10,353	3,513	244	200
Coal	5,378	5,885	5,885	4,485
Biomass	1,347	3,720	6,279	9,110
Geothermal	874	854	1,183	1,685
Wind	699	6,249	9,800	14,587
Solar	6	5,446	6,600	7,206
Nuclear	1,510	1,510	1,510	4,231
TOTAL	**54,853**	**71,927**	**80,522**	**97,271**

Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 6.14. Projected Installed capacity in Mexico, CPS



Source: Simulation results

Table 6.12 shows the electricity generation dispatch priority used in the simulation.

Table 6.12. Dispatch priority considered for Mexico, CPS

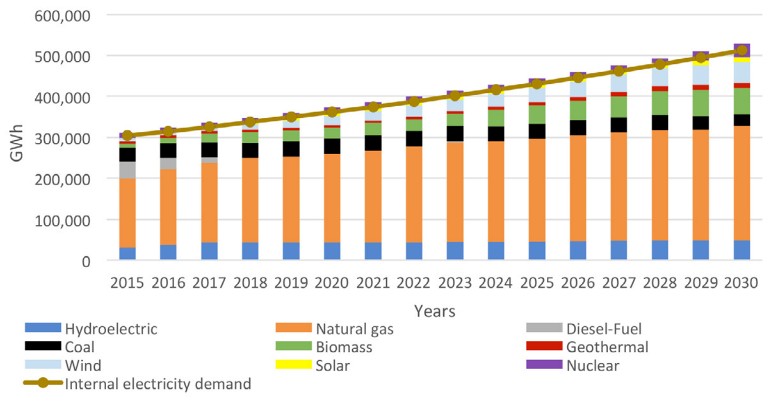
Dispatch order	Technology
1	Nuclear
2	Geothermal
3	Hydroelectric
4	Wind
5	Solar
6	Biomass
7	Coal
8	Natural gas
9	Diesel-Fuel Oil
10	Imports

Table 6.13. Projected electricity generation in Mexico, CPS (GWh)

Technology	2015	2020	2025	2030
Hydroelectric	30,955	42,787	45,836	48,523
Natural gas	167,842	217,287	250,361	279,009
Diesel-Fuel Oil	42,099	0	0	0
Coal	33,741	37,118	37,118	28,288
Biomass	9,503	26,396	44,553	64,641
Geothermal	6,191	6,060	8,394	11,956
Wind	8,667	21,897	34,340	51,113
Solar	93	9,541	11,563	12,625
Nuclear	11,453	11,508	11,508	32,245
TOTAL	**310,544**	**372,594**	**443,673**	**528,401**

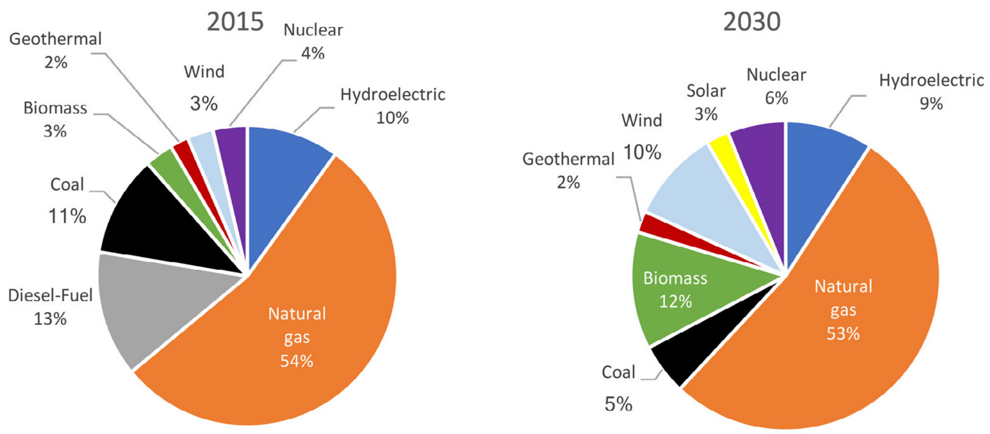
Source: Simulation results

Figure 6.15. Projected electricity generation in Mexico, CPS



Source: Simulation results

Figure 6.16. Evolution of electricity generation matrix structure in Mexico, CPS



Source: CPS simulation results

As shown in Figure 6.15, Mexico has sufficient generation capacity to satisfy domestic energy demand (final consumption + own consumption + losses) and a slight surplus in supplies can even be detected, which reflects Mexico's capacity to export to neighboring countries, especially in Central American subregion countries like Belize and Guatemala.

For its part, Figure 6.16 illustrates the evolution of the Mexican electricity generation matrix in the projection period, where diesel-fuel oil thermoelectric technology's replacement by increased penetration by NCRE like wind, geothermal and solar stands out. It is also worth highlighting that Mexico has bet on expanding its thermonuclear capacity by the final years of the projection period, which is reflected in the proportional increase in this technology's share of the electricity generation matrix.

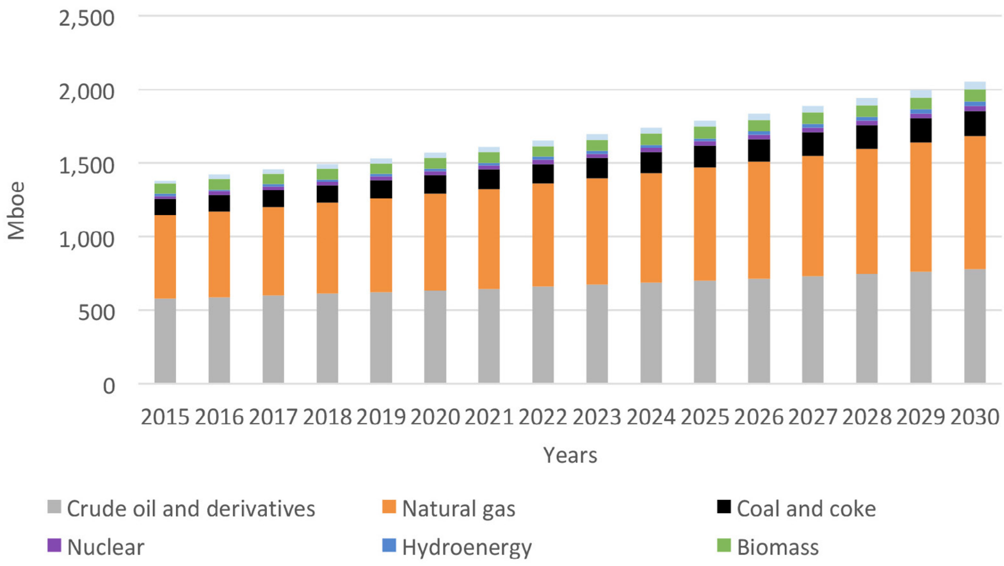
6.3.3 Projected total energy supply

Table 6.14. Projected total energy supply in Mexico, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	580	555	608	650	0.8%
Natural gas	566	701	793	893	3.1%
Coal and coke	109	130	140	144	1.9%
Nuclear	21	23	23	62	7.5%
Hydroenergy	15	14	14	14	-0.5%
Biomass	69	68	83	100	2.5%
Other renewables	23	50	68	92	9.7%
TOTAL	1,382	1,542	1,729	1,956	2.3%

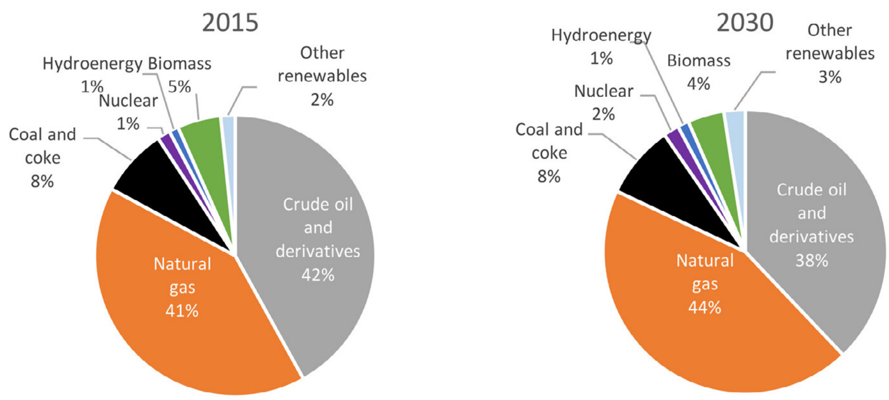
Source: Simulation results

Figure 6.17. Projected total energy supply in Mexico, CPS



Source: Simulation results

Figure 6.18. Evolution of total energy supply matrix in Mexico, CPS



Source: Simulation results

With regard to evolution in the total energy supply, presented in Table 6.14 and Figure 6.17, increased penetration by natural gas over the projection period can be observed, consolidating it as the predominant source in the Mexico's total energy supply matrix. NCRE, specifically wind, solar and geothermal power, show a very significant increase in primary energy supplies thanks to its increased share in electricity generation.

6.4 Central America

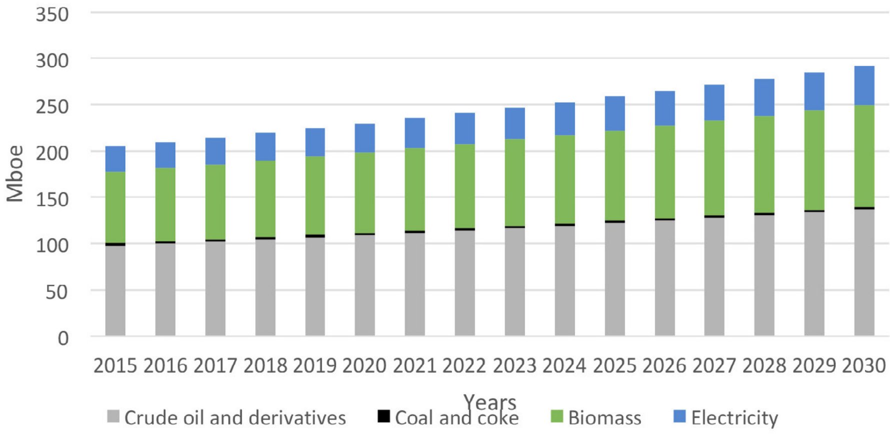
6.4.1 Projected final energy consumption

Table 6.15. Projected final energy consumption in Central America, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	98	109	122	137	2.3%
Coal and coke	3	3	3	2	-0.9%
Biomass	77	87	98	110	2.4%
Electricity	27	32	36	42	2.9%
TOTAL	**205**	**230**	**259**	**292**	**2.4%**

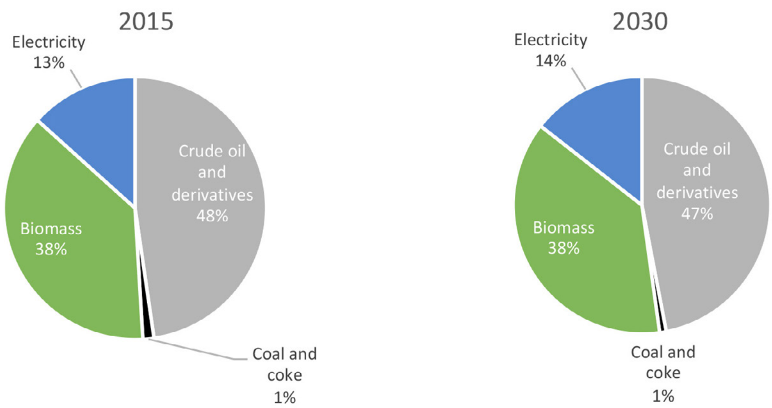
Source: Simulation results

Figure 6.19. Projected final energy consumption in Central America, CPS



Source: Simulation results

Figure 6.20. Evolution of final energy consumption matrix in Central America, CPS



Source: Simulation results

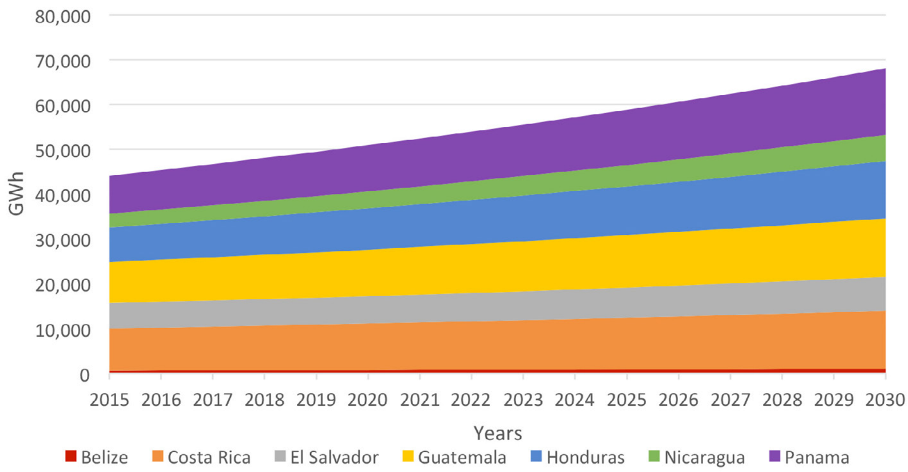
Even in the CPS, the Central American subregion continues to be dominated by the consumption of oil products and biomass throughout the projection period, though electricity gains ground as the source that shows the highest average annual growth rate, as can be seen in Table 6.15.

Table 6.16. Projected final electricity consumption by country, CPS (GWh)

Country	2015	2020	2025	2030	a.a.r.
Belize	599	725	871	1,040	599
Costa Rica	9,359	10,368	11,546	12,922	9,359
El Salvador	5,725	6,130	6,703	7,513	5,725
Guatemala	9,114	10,362	11,692	13,101	9,114
Honduras	7,753	9,224	10,884	12,744	7,753
Nicaragua	3,049	3,807	4,755	5,942	3,049
Panama	8,482	10,272	12,351	14,753	8,482
TOTAL	**44,082**	**50,888**	**58,803**	**68,014**	**44,082**

Source: By authors, based on national electricity sector expansion plans

Figure 6.21. Projected final electricity consumption in Central America, CPS



Source: By authors, based on national electricity sector expansion plans

As can be seen in table 6.16 and Figure 6.21, final consumption of electricity in the Central American subregion in the CPS shows an average annual growth rate of close to 3%, with Nicaragua, Panama and Belize being the countries where it shows the highest proportional growth rate during the study period. It is also worth noting that while in the base year the 3 main electricity consumers are, in order of importance, Costa Rica, Guatemala and Panama, Panama will become the biggest consumer of electricity by 2030, surpassing Costa Rica and Guatemala. This is justified, considering that Panama is the country whose economy has experienced the strongest growth to the region over the last decades (Banco Mundial, 2017).

6.4.2 Projected electricity generation

Table 6.17. Timelines for installation/decommissioning of installed capacity (MW) in Central America, CPS (MW)

Country	Year	Hydro	Natural Gas	Diesel / Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Belice	2016					8			15
	2017					8			
	2018					18			
	2019	9							
	2020								
	2021								
	2022								
	2023								
	2024								
	2025	15							
	2026								
	2027								
	2028								
	2029								
	2030								

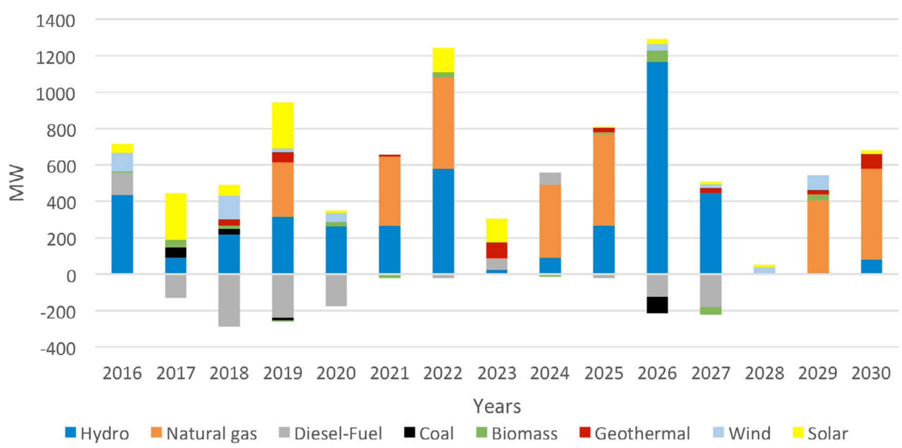
Costa Rica	2016	379		-20				100	
	2017								
	2018	28							5
	2019						55		
	2020								
	2021								
	2022								
	2023			60			52		
	2024			65					
	2025								
	2026	650		-125					
	2027								
	2028								
	2029								
	2030						55		
El Salvador	2016								
	2017					35			80
	2018								34
	2019								210
	2020	66						50	
	2021		380				8		
	2022								
	2023								50
	2024								
	2025								
	2026					60			
	2027								
	2028								
	2029								
	2030								

Country	Year	Hydro	Natural Gas	Diesel / Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Guatemala	2016	58							10
	2017	75		15					101
	2018	162			50			30	
	2019								31
	2020	100							
	2021	10							
	2022	150							
	2023								
	2024	74							
	2025	253							
	2026								
	2027	140							
	2028								
	2029								
	2030	60							
Honduras	2016								25
	2017	16		-147	55				62
	2018	30		-286	-20	-12	35	57	10
	2019	305		-137	-16	-8			
	2020	98				-5			
	2021	156				-22			
	2022	419	500	-22					
	2023								
	2024	-4				-14			
	2025	-1	500	-20		-16			
	2026	264			-90				
	2027	144		-180		-43			
	2028								
	2029	-3							
	2030		500			-3			
Nicaragua	2016			140		2			
	2017								12
	2018					13		40	12
	2019		300	-100				23	12
	2020			-177		30			12
	2021	100							
	2022					32			
	2023	21				3	35		
	2024	22							
	2025					29	25		
	2026							40	26
	2027	150					25		
	2028							40	
	2029					30	25		
	2030						25		

Country	Year	Hydro	Natural Gas	Diesel / Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Panama	2016								
	2017								
	2018								
	2019								
	2020								
	2021								
	2022	10							133
	2023	5							80
	2024		400						
	2025								7
	2026	252							
	2027	14						25	10
	2028								10
	2029	10	400					80	
	2030	20							20
Total Central America	2016	437		120		10		100	50
	2017	91		-132	55	43			255
	2018	220		-286	30	19	35	127	61
	2019	314	300	-237	-16	-8	55	23	253
	2020	263		-177		25		50	12
	2021	266	380			-22	8		
	2022	579	500	-22		32			133
	2023	26		60		3	87		130
	2024	92	400	65		-14			
	2025	267	500	-20		13	25		7
	2026	1166		-125	-90	60		40	26
	2027	448		-180		-43	25	25	10
	2028							40	10
	2029	7	400			30	25	80	
	2030	80	500			-3	80		20

Source: By authors, based on national electricity sector expansion plans

Figure 6.22. Timelines for installation/decommissioning of installed capacity in Central America, CPS



Source: By authors, based on national electricity sector expansion plans

With regard to electricity supplies, Central American countries will continue to expand their hydroelectric capacities, complementing this with the use of NCRE like biomass, geothermal, wind and solar power (see Table 6.17). Natural gas power plants begin to appear in 2019 and their implementation will continue to expand throughout the next decade (2020-2030). The countries planning to make use of this source are El Salvador, Honduras, Nicaragua and Panama. The natural gas projects are mainly related to combined cycle power plants that will use imported LNG as a fuel. Other fossil fuel generation technologies like coal and diesel-fuel oil are more marked by the withdrawal of capacity. Solar energy stands out among the NCRE technologies to be added to the subregion's electricity production in countries like Guatemala, El Salvador, Honduras, Nicaragua and Panama.

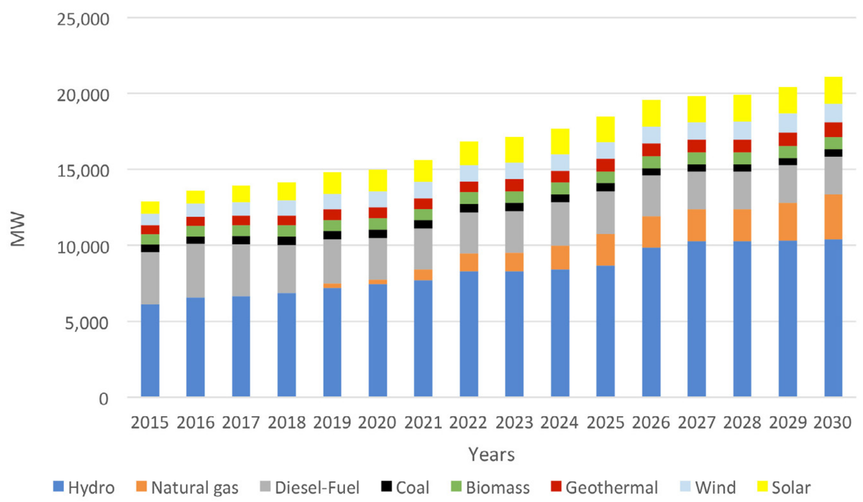
Wind power shows the strongest expansion in Nicaragua, Costa Rica, Honduras and Panama; biomass in Nicaragua, El Salvador and Belize, and geothermal in Costa Rica and Nicaragua.

Table 6.18. Projected Installed capacity in Central America, CPS (MW)

Source	2015	2020	2025	2030
Hydroelectric	6,122	7,447	8,677	10,379
Natural gas	0	300	2,080	2,980
Diesel-Fuel Oil	3,436	2,724	2,807	2,502
Coal	482	551	551	461
Biomass	667	756	768	812
Geothermal	610	700	820	950
Wind	773	1,073	1,073	1,258
Solar	804	1,434	1,704	1,770
TOTAL	**12,894**	**14,985**	**18,479**	**21,111**

Source: Simulation results based on installation/decommissioning timelines.

Figure 6.23. Projected Installed capacity in Central America, CPS



Source: Simulation results based on installation/decommissioning timelines.

With the installation/decommissioning timelines considered for the Central American subregion, total electricity generation capacity increases by 64% over the projection period and it it worth noting that natural gas technology goes from representing practically zero participation in the base year to being the second most important technology in 2030 after hydroelectric, contributing 14% of total installed capacity that year (Figure 6.23).

Table 6.19 shows the order of priority in dispatch order used to calculate electricity generation by technology, which responds to technical-economic criteria.

Table 6.19. Dispatch priority of electricity generation technologies in Central America

Dispatch order	Technology
1	Geothermal
2	Hydroelectric
3	Wind
4	Solar
5	Biomass
6	Coal
7	Natural gas
8	Diesel-Fuel Oil
9	Imports

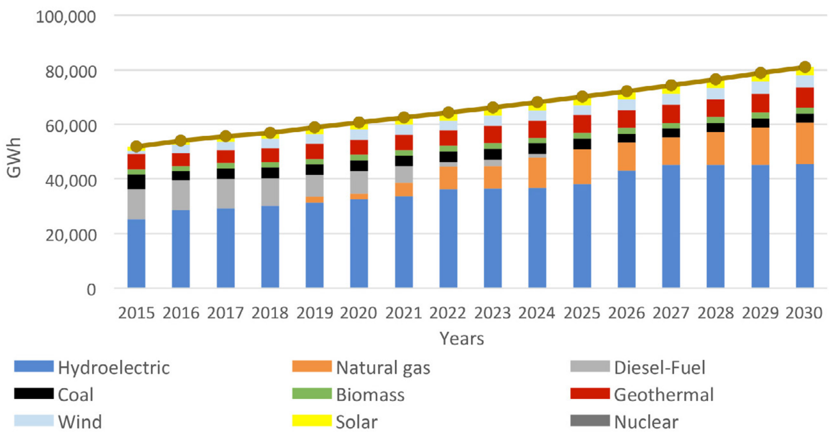
Source: Authors' compilation

Table 6.20. Projected electricity generation in Central America, CPS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	25,195	32,616	38,005	45,460
Natural gas	0	2,102	12,961	15,212
Diesel-Fuel Oil	11,004	8,258	0	0
Coal	5,446	3,860	3,860	3,229
Biomass	1,810	2,054	2,084	2,205
Geothermal	5,670	5,519	6,465	7,490
Wind	1,291	3,760	3,760	4,408
Solar	1,408	2,513	2,985	3,100
TOTAL	**51,824**	**60,682**	**70,120**	**81,104**

Source: Simulation results

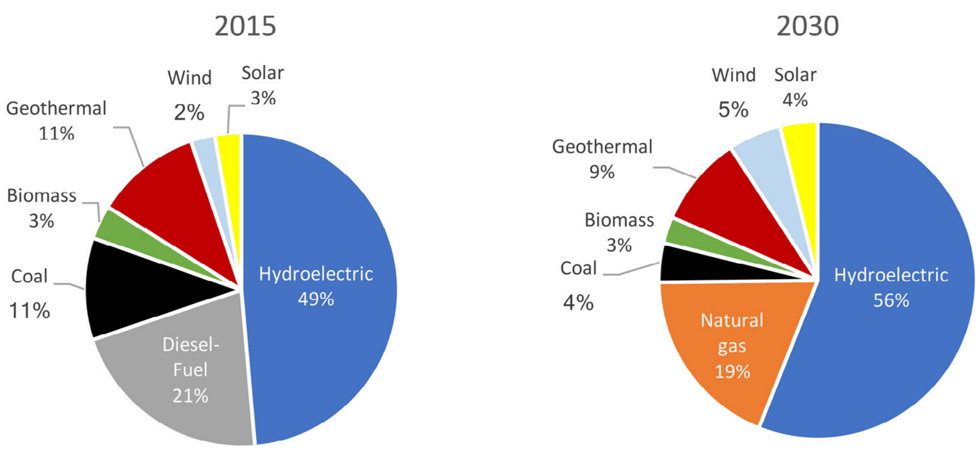
Figure 6.24. Projected electricity generation in Central America, CPS



Source: Simulation results

One can see that Central America as a subregion is self-sufficient in total electricity production throughout the study period. While in the base year Belize imports electricity from Mexico, these imports disappear over the course of the projection period because that energy could easily be supplied by other countries in the subregion, assuming that the necessary transmission capacities existed. It should be noted that the simulation did not consider eventual electricity imports from Colombia via a feasible future interconnection between the South American country and Panama.

Figure 6.25. Evolution of electricity generation matrix in Central America, CPS



Source: Simulation results

Consistent with the evolution in installed capacity, the graphs contained in Figure 6.25 show that natural gas will become the second most important source of electricity generation in the Central American subregion's matrix by 2030, displacing oil products, while renewable sources such as hydro, wind and solar power will increase their percentage share in said matrix.

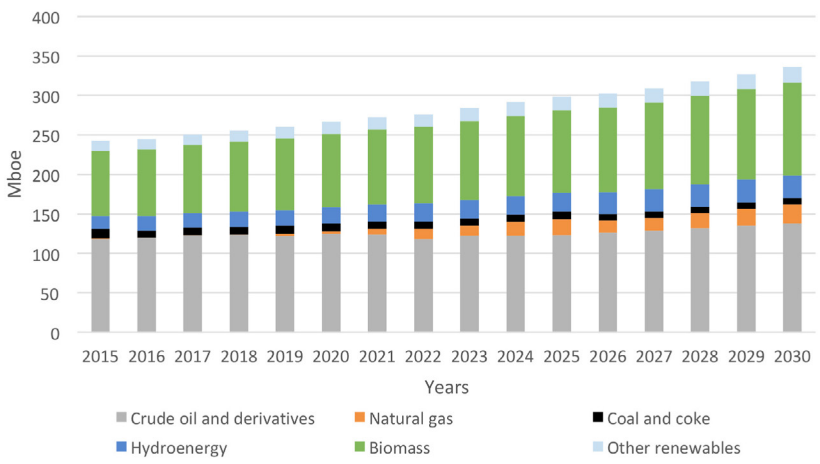
6.4.3 Projected total energy supply

Table 6.21. Projected total energy supply in Central America, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	118	125	123	138	1.0%
Natural gas	0,01	3	20	24	73.1%
Coal and coke	12	9	9	8	-2.8%
Hydroenergy	17	21	24	29	3.8%
Biomass	82	93	104	117	2.4%
Other renewables	13	15	17	20	2.8%
TOTAL	**243**	**267**	**299**	**336**	**2.2%**

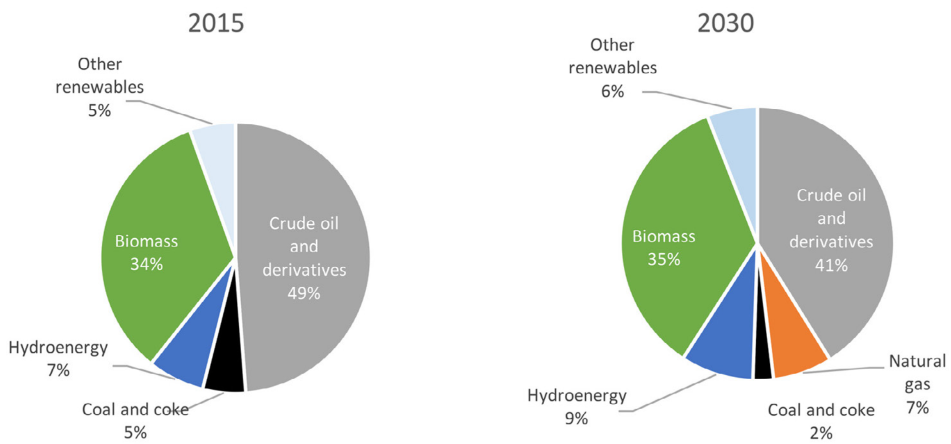
Source: Simulation results

Figure 6.26. Projected total energy supply in Central America, CPS



Source: Simulation results

Figure 6.27. Evolution in total energy supply matrix in Central America, CPS



Source: Simulation results

The evolution in total energy supply presented in Figure 6.27 shows that oil products and biomass still predominate in the projection horizon, but natural gas, hydroenergy and other renewable sources (geothermal, wind and solar power) replace a share of the oil products and coal.

6.5 Andean Subregion

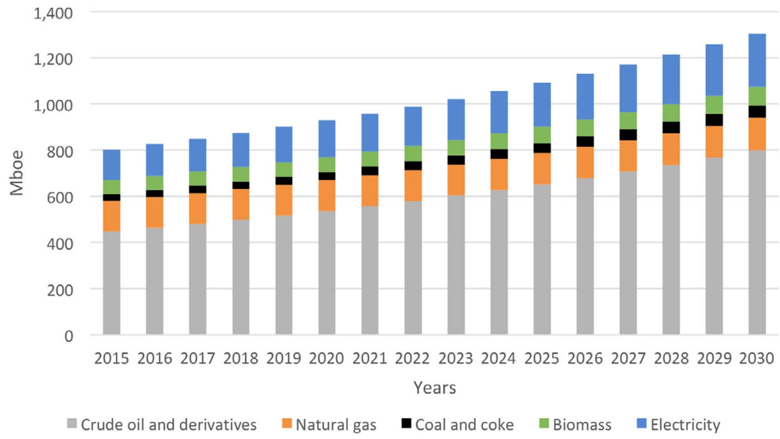
6.5.1 Projected final energy consumption

Table 6.22. Projected final energy consumption in the Andean Subregion, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	447	537	652	800	4.0%
Natural gas	134	133	135	140	0.3%
Coal and coke	29	36	44	54	4.1%
Biomass	60	64	71	79	1.9%
Electricity	133	159	191	231	3.7%
TOTAL	**803**	**929**	**1,093**	**1,304**	**3.3%**

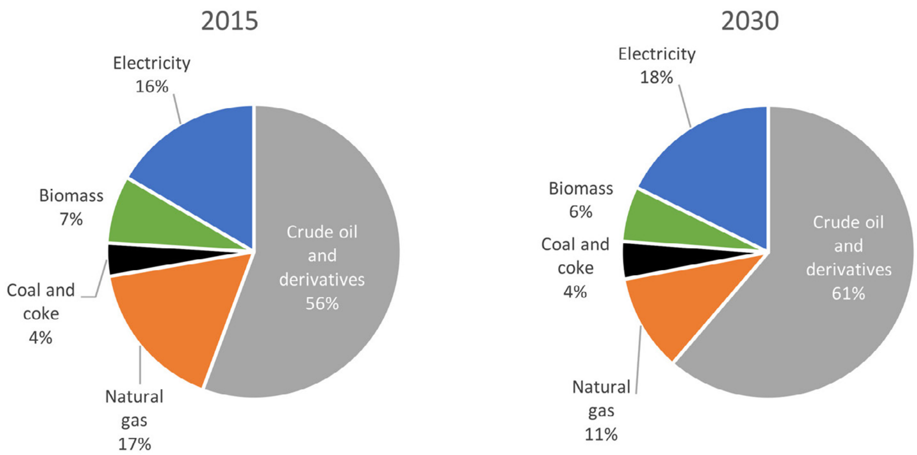
Source: Simulation results

Figure 6.28. Projected final energy consumption in the Andean Subregion, CPS



Source: Simulation results

Figure 6.29. Evolution of final energy consumption matrix in the Andean Subregion, CPS



Source: Simulation results

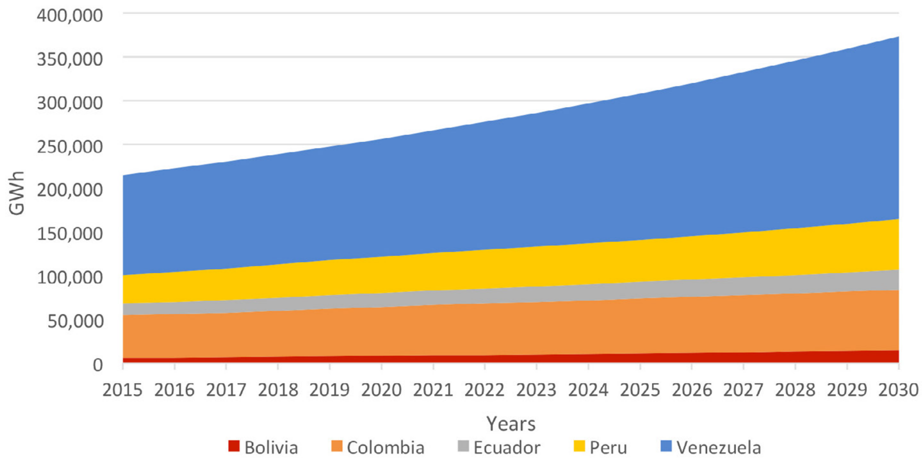
Evolution in the final consumption matrix in the CPS is very similar to the BAU baseline scenario, where oil products and electricity show high average annual growth rates allowing them to gain a percentage share in that matrix, at the expense of natural gas and biomass.

Table 6.23. Projected final electricity consumption by country, CPS (GWh)

Country	2015	2020	2025	2030	a.a.r.
Bolivia	5,953	8,510	11,169	14,927	6.3%
Colombia	48,697	55,562	62,566	69,223	2.4%
Ecuador	13,815	16,172	19,248	22,655	3.4%
Peru	31,910	41,668	47,524	58,123	4.1%
Venezuela	114,716	134,622	167,874	208,550	4.1%
TOTAL	**215,091**	**256,534**	**308,383**	**373,478**	**3.7%**

Source: By authors, based on national electricity sector expansion plans

Figure 6.30. Projected final energy consumption in the Andean Subregion, CPS



Source: By authors, based on national electricity sector expansion plans

Venezuela is the Andean Subregion's biggest electricity consumer, due to its large oil industry, but the country where growth in consumption is strongest is Bolivia, thanks to its accelerated economic growth.

6.5.2 Projected electricity generation

Table 6.24. Timelines for installation/decommissioning of installed capacity (MW) in the Andean Subregion

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Bolivia	2016	484						24	5
	2017	597	50			10	51	100	65
	2018		52					36	50
	2019	203	980			20			
	2020	508							
	2021	347					5		
	2022	1200	300				21	37	
	2023	300	137	200		20	3	20	
	2024	800	250			20	3	20	
	2025	990	73				1		9
	2026								
	2027								
	2028								
	2029								
	2030								

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Colombia	**2016**				-14			62	9
	2017	100				58			
	2018	600							
	2019	900			-124	171		99	
	2020				265			709	54
	2021	600			327		95	180	
	2022	1000			74	34			
	2023	313		198	100	26		23	
	2024	581		200	104	28		23	21
	2025				47	21		24	
	2026								
	2027								
	2028								
	2029								
	2030								
Ecuador	**2016**	750	-181	471		2		9	28
	2017	750	150			13			
	2018	300							3
	2019		-342	-467					
	2020		173	245					
	2021		72	102				7	5
	2022	100		-334					15
	2023	1000	200	200				7	20
	2024			223				10	
	2025			110					
	2026								
	2027								
	2028								
	2029								
	2030								
Peru	**2016**								
	2017								
	2018	1842	1200					246	137
	2019								
	2020	300							
	2021								
	2022	298	197						
	2023		300						
	2024	300	113	200					
	2025	1200	383	171					
	2026								
	2027								
	2028								
	2029								
	2030								

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Venezuela	**2016**		801	139	557				
	2017		173	98	143				
	2018	382	206	36	144				
	2019	585	500	92	367			424	113
	2020								
	2021								
	2022								
	2023								
	2024								
	2025								
	2026								
	2027								
	2028								
	2029								
	2030								

Andean Subregion	**2016**	1234	620	610	543	2	0	95	42
	2017	1447	373	98	143	81	51	100	65
	2018	3124	1458	36	144	0	0	282	190
	2019	1688	1138	-375	243	191	0	523	113
	2020	808	173	245	265	0	0	709	54
	2021	947	72	102	327	0	100	187	5
	2022	2598	497	-334	74	34	21	37	15
	2023	1613	637	598	100	46	3	50	20
	2024	1681	363	623	104	48	3	53	21
	2025	2190	456	281	47	21	1	24	9
	2026	0	0	0	0	0	0	0	0
	2027	0	0	0	0	0	0	0	0
	2028	0	0	0	0	0	0	0	0
	2029	0	0	0	0	0	0	0	0
	2030	0	0	0	0	0	0	0	0

Source: By authors, based on national electricity sector expansion plans

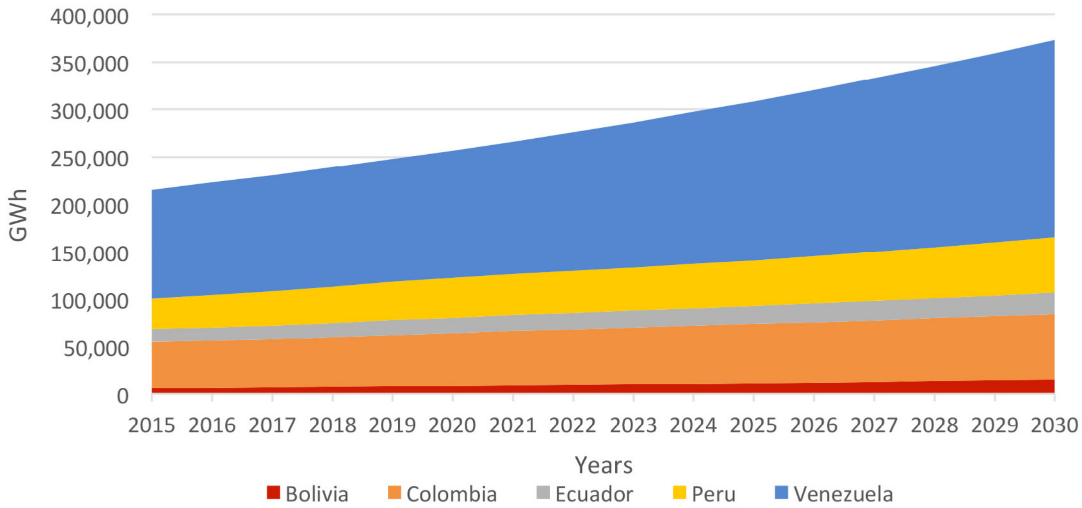
Given that not all of the years covered by the study period are included in every Andean Subregion country's electricity sector expansion plans, the subregional timeline was adjusted and extended according to the trends detected in the plans available, leaving the subregional timeline as shown in table 6.25.

Table 6.25. Timelines for installation/decommissioning of installed capacity (MW) in the Andean Subregion

Region	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Andean Subregion	**2016**	1.234	620	610	543	2	0	95	42
	2017	1.447	373	98	143	81	51	100	65
	2018	3.124	1.458	36	144	0	0	282	190
	2019	1.688	1.138	-375	243	191	0	523	113
	2020	808	173	245	265	0	0	709	54
	2021	947	72	102	327	0	100	187	5
	2022	2.598	497	-334	74	34	21	37	15
	2023	1.613	637	598	100	46	3	50	20
	2024	1.681	363	623	104	48	3	53	21
	2025	2.19	456	281	47	21	1	24	9
	2026	1.844	423	661	111	50	3	56	22
	2027	1.921	453	689	115	53	4	58	23
	2028	1.934	0	-181	1.483	0	0	1.569	254
	2029	1.966	1.255	-321	800	42	0	79	18
	2030	2.106	1.051	173	529	94	0	105	27

Source: By authors, based on national electricity sector expansion plans

Figure 6.31. Timelines for installation/decommissioning of installed capacity in the Andean Subregion



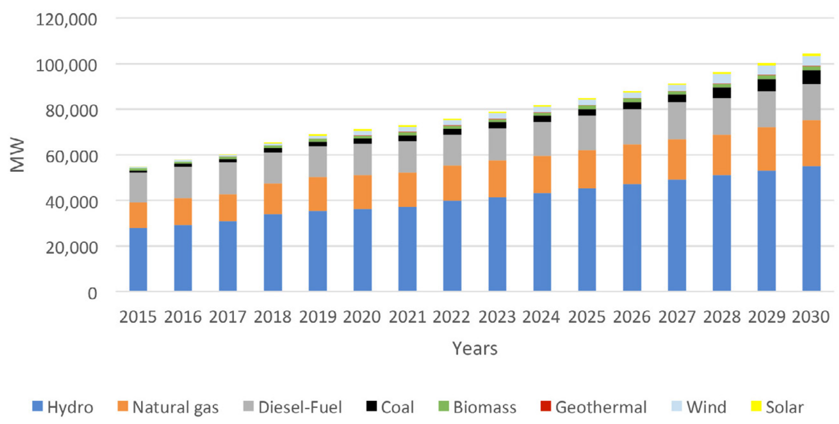
Source: By authors, based on national electricity sector expansion plans

Table 6.26. Projected Installed capacity in the Andean Subregion, CPS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	28,019	36,320	45,350	55,120
Natural gas	11,089	14,850	16,876	20,059
Diesel-Fuel Oil	13,041	13,655	14,925	15,946
Coal	992	2,330	2,983	6,021
Biomass	984	1,258	1,407	1,646
Geothermal	0	51	180	187
Wind	429	2,139	2,490	4,356
Solar	184	648	717	1,060
TOTAL	**54,738**	**71,252**	**84,926**	**104,395**

Source: Simulation results

Figure 6.32. Projected Installed capacity in the Andean Subregion, CPS



Source: Simulation results

According to the expansion plans of the countries that make up the Andean Subregion, it is observed that there is a great interest in increasing the use of water resources, of which this subregion has a high potential that has not yet been used, with the greatest increase in Bolivia being found. As a second priority, there is a great boost to the development of natural gas generation projects, with Bolivia, Peru and Venezuela being the countries that include a greater proportion of their expansion plans.

Regarding the inclusion of NCRE, it is observed that wind energy is the resource that will experience the greatest expansion, mainly in Colombia, while the exploitation of solar resources in the subregion has a greater presence in Peru, Bolivia and Venezuela.

Regarding the generation of electricity based on the use of fossil fuels, only Venezuela and Colombia plan a growth in the exploitation of mineral coal and in the case of diesel-fuel oil, net addition is observed in the 5 countries of the subregion.

In general, the total capacity of electricity generation for the subregion increases by 91% in the projection period, with an increase in the participation of NCRE sources, mainly wind power, as can be seen in Figure 6.32.

To calculate electricity generation in the Andean Subregion, the framework of dispatch priority by technology presented in Table 6.27 is used.

Table 6.27. Dispatch priority considered for the Andean Subregion, CPS (GWh)

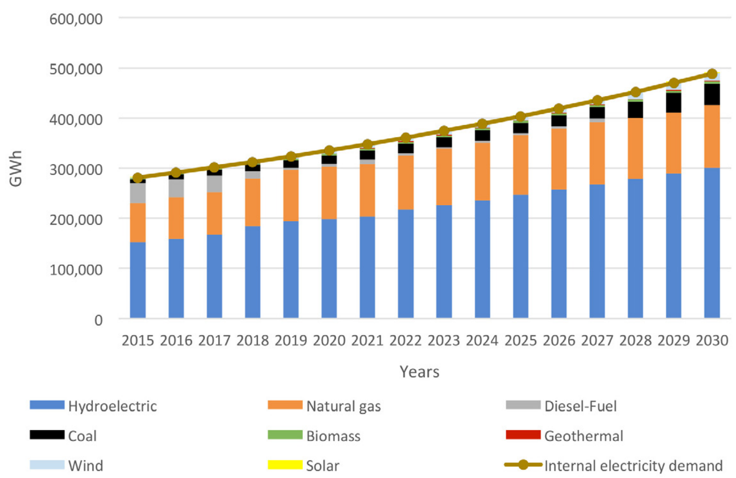
Dispatch order	Technology
1	Nuclear
2	Geothermal
3	Hydroelectric
4	Wind
5	Solar
6	Biomass
7	Coal
8	Natural gas
9	Diesel-Fuel Oil
10	Imports

Table 6.28. Projected electricity generation in the Andean Subregion, CPS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	152,886	198,181	247,449	300,761
Natural gas	77,709	104,069	118,265	125,129
Diesel-Fuel Oil	39,985	6,260	3,676	0
Coal	6,953	16,331	20,901	42,194
Biomass	2,844	3,636	4,066	4,758
Geothermal	0	404	1,418	1,474
Wind	1,503	7,493	8,723	15,265
Solar	323	1,136	1,257	1,858
TOTAL	**282,203**	**337,511**	**405,755**	**491,438**

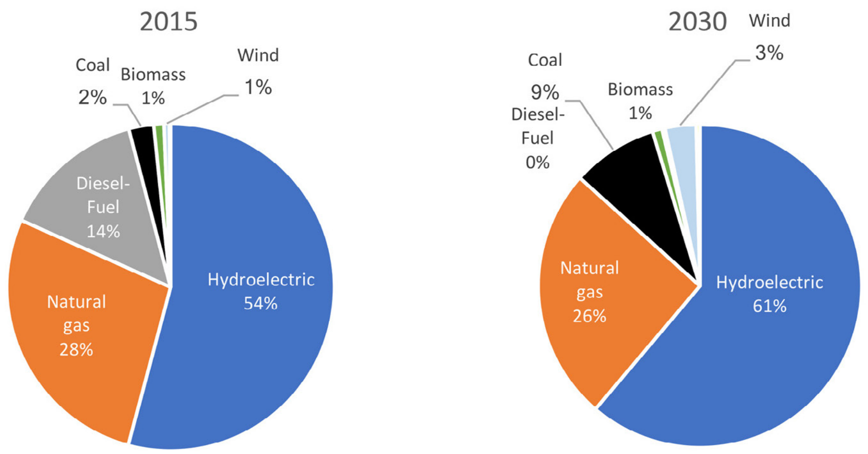
Source: Simulation results

Figure 6.33. Projected electricity generation in the Andean Subregion, CPS



Source: Simulation results

Figure 6.34. Evolution of electricity generation matrix in the Andean Subregion, CPS



Fuente: Resultados de la simulación

The Andean Subregion's significant hydroelectric potential, in addition to growing use of natural gas and NCRE, guarantees self-sufficiency in total electricity production for the region throughout the study period. It is important to note that the simulation does not consider the eventual export of electricity from Colombia to Panama via a feasible future interconnection between those two countries.

As shown in Figure 6.34, coal will become the subregional electricity matrix's third most important source by 2030, displacing the use of oil products (Diesel-fuel oil), while hydroenergy's share of the matrix increases and natural gas maintains a similar share to that of 2015.

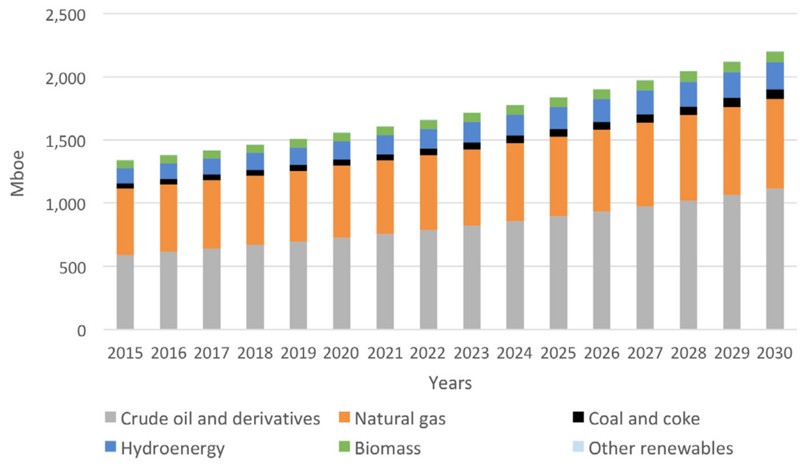
6.5.3 Projected total energy supply

Table 6.29. Projected total energy supply in the Andean Subregion, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	591	626	759	929	3.1%
Natural gas	525	591	638	679	1.7%
Coal and coke	41	66	82	134	8.3%
Hydroenergy	118	153	191	233	4.6%
Biomass	63	87	96	108	3.7%
Other renewables	1	6	9	14	18.1%
TOTAL	**1,339**	**1,529**	**1,776**	**2,097**	**3.0%**

Source: Simulation results

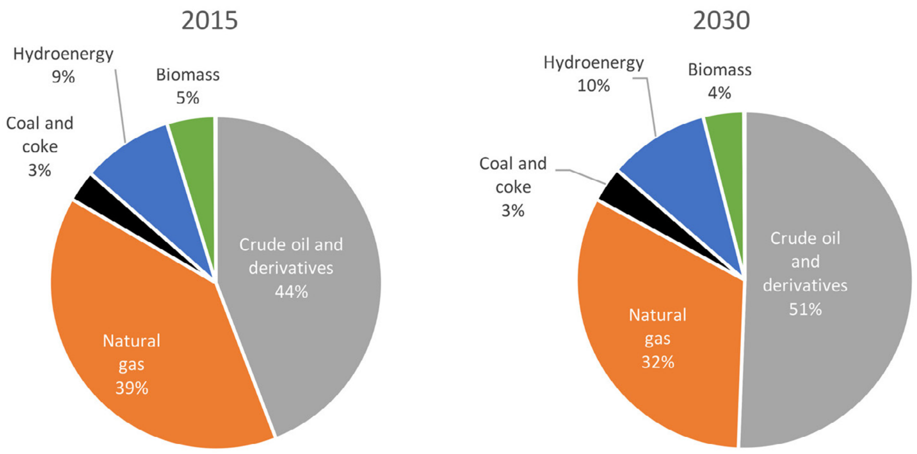
Figure 6.35. Projected total energy supply in the Andean Subregion, CPS



Source: Simulation results

With regard to total energy supply, as can be seen in Table 6.29 and Figure 6.35, both oil and its derivatives, as well as natural gas, continue to be the predominant energy sources the subregion throughout the projection period, while a gradual increase in hydroenergy and other renewable energy sources, including biomass, can be observed. Total energy supply in the Andean Subregion grows by 57% compared to 2015, at an average annual rate of 3%.

Figure 6.36. Evolution of final energy consumption matrix in the Andean Subregion, CPS



Fuente: Resultados de la simulación

As shown in figure 6.36, the share of oil products of the matrix is maintained, while hydroenergy and coal gain on natural gas.

6.6 Southern Cone

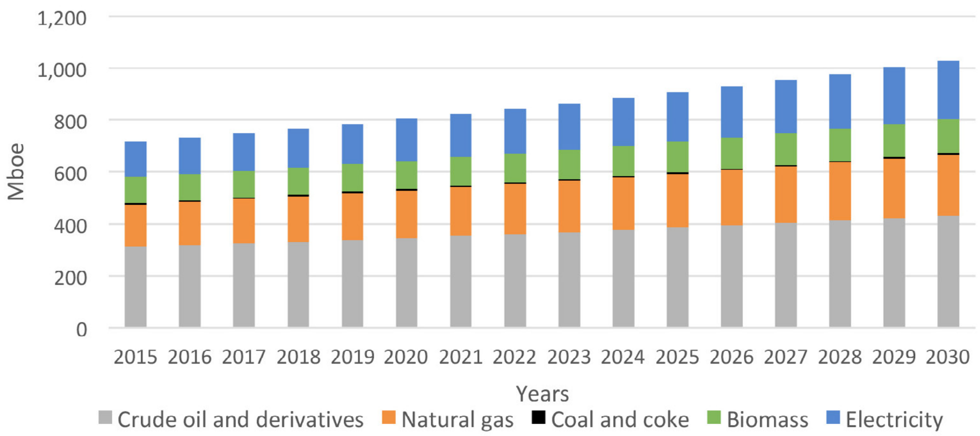
6.6.1 Projected final energy consumption

Table 6.30. Projected final energy consumption in the Southern Cone, CPS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	312	345	385	432	2.2%
Natural gas	163	184	208	236	2.5%
Coal and coke	6	6	6	6	-0.4%
Biomass	100	108	118	130	1.8%
Electricity	136	161	191	227	3.5%
TOTAL	**717**	**804**	**908**	**1,030**	**2.4%**

Source: Simulation results

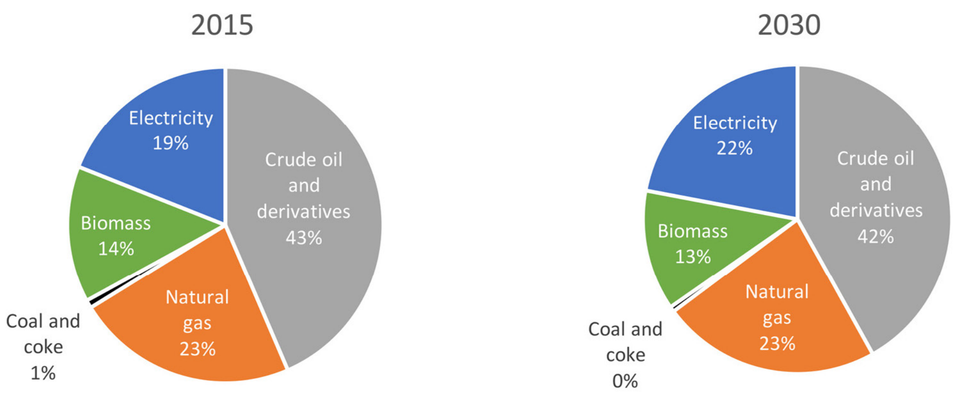
Figure 6.37. Projected final electricity consumption in the Southern Cone, CPS



Source: Simulation results

The Southern Cone's final energy consumption matrix during the study period is dominated by Crude oil and derivatives showing the highest percentages (see Figure 6.37). However, increased penetration by electricity and natural gas has slightly displaced oil products. Electricity gains in its percentage share, rising from 19% in the base year to 22% in 2030.

Figure 6.38. Evolution of final energy consumption matrix in the Southern Cone, CPS



Source: CPS simulation results

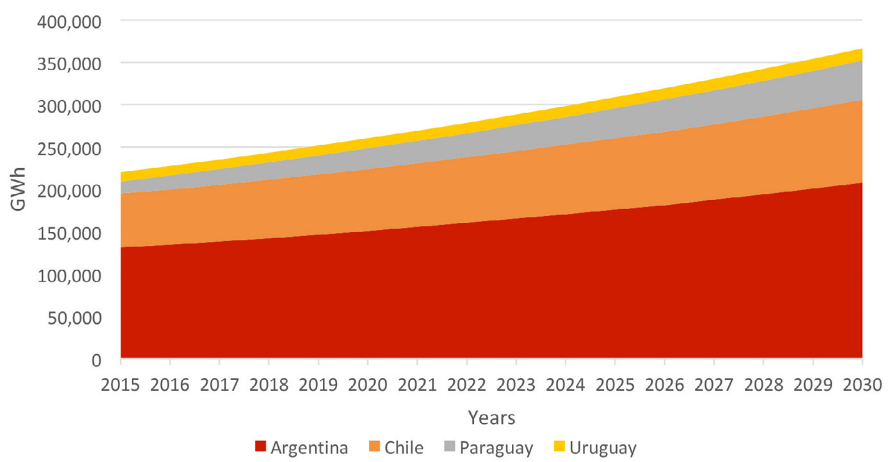
The main variation in the Southern Cone's final energy consumption matrix in the CPS is increased penetration by electricity, proportionally reducing that which corresponds to biomass, coal and oil products (see Figure 6.38).

Table 6.31. Projected final electricity consumption by country (GWh)

Country	2015	2020	2025	2030	a.a.r.
Argentina	131,400	150,987	176,167	208,012	3.1%
Chile	64,189	73,134	84,245	97,610	2.8%
Paraguay	13,433	24,282	35,188	46,337	8.6%
Uruguay	10,894	11,967	13,051	14,377	1.9%
TOTAL	**219,915**	**260,370**	**308,650**	**366,336**	**3.5%**

Source: By authors, based on national electricity sector expansion plans

Figure 6.39. Projected final energy consumption in the Southern Cone



Source: By authors, based on national electricity sector expansion plans

As can be seen in table 6.31, the fastest growth in electricity consumption in this subregion is in Paraguay (8.6%), a high number that is explained by the significant increase in the country's industrialization over recent years (ANDE, 2016). Figure 6.39 shows that Argentina and Chile are the subregion's biggest electricity consumers.

6.6.2 Projected electricity generation

Table 6.32. Timelines for installation/decommissioning of installed capacity (MW) in the Southern Cone (Expansion plans)

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
Argentina	2016	290	644		216			1066	46	
	2017	290	644		216			1066	46	745
	2018	290	644		216			1066	46	
	2019	290	644		216			1066	46	
	2020	290	644		216			1066	46	
	2021	290	644		216			1066	46	
	2022	290	644		216			1066	46	
	2023	290	644		216			1066	46	
	2024	290	644		216			1066	46	
	2025	290	644		216			1066	46	
	2026									
	2027									
	2028									
	2029									
	2030									
Chile	2016	66	521	2093	472		48	442	1499	
	2017	72	77	299				175	871	
	2018	691		250	375				284	
	2019	664								
	2020	340								
	2021									
	2022	136								
	2023									
	2024									
	2025									
	2026									
	2027									
	2028									
	2029									
	2030									
Paraguay	2016									
	2017								0.5	
	2018								0.5	
	2019	5							0.5	
	2020	76.3							0.5	
	2021	21.7								
	2022	26.7								
	2023	19								
	2024	168.6								
	2025	208							10	
	2026									
	2027									
	2028									
	2029									
	2030									

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
Uruguay	2016		-300	-205				355	24	
	2017		180			10				
	2018		180					500	205	
	2019		180							
	2020									
	2021					100				
	2022									
	2023									
	2024									
	2025									
	2026									
	2027		60						300	
	2028								200	
	2029									
	2030							100	100	
Total Southern Cone (Expansion Plans)	2016	356	865	1,888	688	0	48	1,863	1,569	0
	2017	362	901	299	216	10	0	1,241	917	745
	2018	981	824	251	591	0	0	1,566	535	0
	2019	959	824	0	216	0	0	1,066	46	0
	2020	706	644	0	216	0	0	1,066	46	0
	2021	312	644	0	216	100	0	1,066	46	0
	2022	453	644	0	216	0	0	1,066	46	0
	2023	309	644	0	216	0	0	1,066	46	0
	2024	459	644	0	216	0	0	1,066	46	0
	2025	498	644	0	216	0	0	1,066	56	0
	2026	0	0	0	0	0	0	0	0	0
	2027	0	60	0	0	0	0	0	300	0
	2028	0	0	0	0	0	0	0	200	0
	2029	0	0	0	0	0	0	0	0	0
	2030	0	0	0	0	0	0	100	100	0

Source: By authors, based on national electricity sector expansion plans

Electricity supplies will increase in the Southern Cone thanks to new power plans, which as can be seen in Table 6.32 will mostly consist in hydroelectric, wind power and natural gas implemented mainly in Argentina, Chile and Uruguay. There is also a significant addition of solar power plans in Chile during the initial years of this projection period. Argentina will also install natural gas plants until 2025. Plants generating with fossil fuels will continue to be installed throughout the study period.

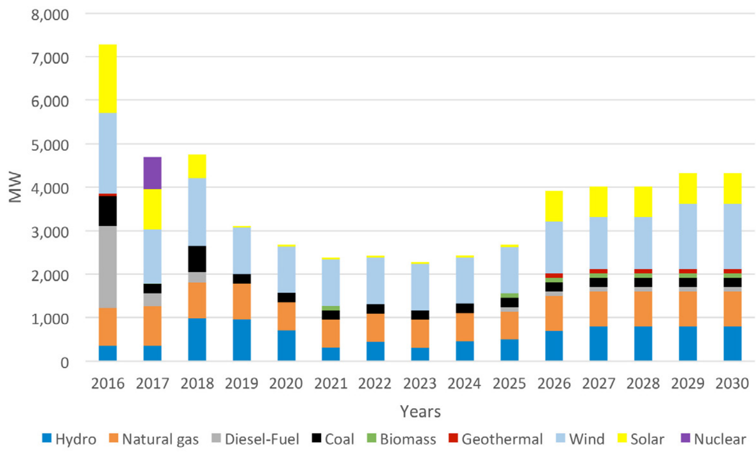
Given that some Southern Cone countries have not presented an installation/decommissioning timeline that covers this study's projection period, the consolidated regional timeline was extended according to the installation trends for each technology, as observed in Table 6.33. The case of Argentina should also be highlighted, as its expansion plan gives accumulated capacities for each technology through 2025, meaning that the total increased capacity between the base year and 2025 was evenly distributed in those 10 years of projection.

Table 6.33. Timelines for installation/decommissioning of installed capacity (MW) in the Southern Cone (extended)

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
Total Southern Cone Extended expansion plan	2016	356	865	1,888	688	0	48	1,863	1,569	0
	2017	362	901	299	216	10	0	1,241	917	745
	2018	981	824	251	591	0	0	1,566	535	0
	2019	959	824	0	216	0	0	1,066	46	0
	2020	706	644	0	216	0	0	1,066	46	0
	2021	312	644	0	216	100	0	1,066	46	0
	2022	453	644	0	216	0	0	1,066	46	0
	2023	309	644	0	216	0	0	1,066	46	0
	2024	459	644	0	216	0	0	1,066	46	0
	2025	498	644	100	216	100	0	1,066	56	0
	2026	700	800	100	216	100	100	1,200	700	0
	2027	800	800	100	216	100	100	1,200	700	0
	2028	800	800	100	216	100	100	1,200	700	0
	2029	800	800	100	216	100	100	1,500	700	0
	2030	800	800	100	216	100	100	1,500	700	0

Source: By authors, based on national electricity sector expansion plans

Figure 6.40. Timelines for installation/decommissioning of installed capacity in the Southern Cone (simulated)



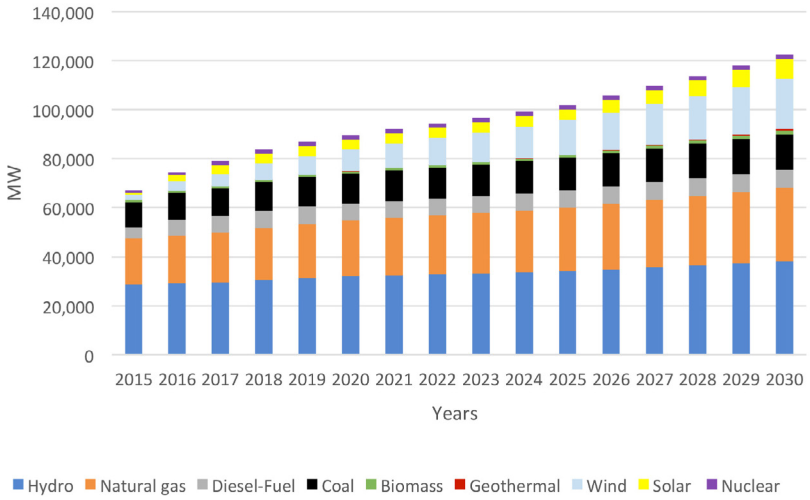
Source: By authors, based on national electricity sector expansion plans

Table 6.34. Projected Installed capacity in the Southern Cone, CPS (MW)

	2015	2020	2025	2030
Hydroelectric	28,732	32,096	34,126	38,026
Natural gas	18,647	22,706	25,928	29,928
Diesel-Fuel Oil	4,513	6,951	7,051	7,551
Coal	10,320	12,248	13,329	14,410
Biomass	829	839	1,039	1,539
Geothermal	0	48	48	548
Wind	2,054	8,855	14,183	20,783
Solar	1,000	4,113	4,351	7,851
Nuclear	1,010	1,755	1,755	1,755
TOTAL	**67,104**	**89,611**	**101,810**	**122,391**

Source: Simulation results

Figure 6.41. Projected Installed capacity in the Southern Cone, CPS



Source: Simulation results

The Southern Cone subregion's generation capacity increases by 82% between 2015 and 2030. It is worth noting that by 2030, wind power will be the third most important technology after hydroenergy and natural gas thermoelectric generation (see Figure 6.41).

The dispatch order by technology for the Southern Cone is as follows.

Table 6.35. Dispatch priority in the Southern Cone

Dispatch order	Source
1	Nuclear
2	Geothermal
3	Hydroelectric
4	Wind
5	Solar
6	Biomass
7	Coal
8	Natural gas
9	Diesel-Fuel Oil
10	Imports

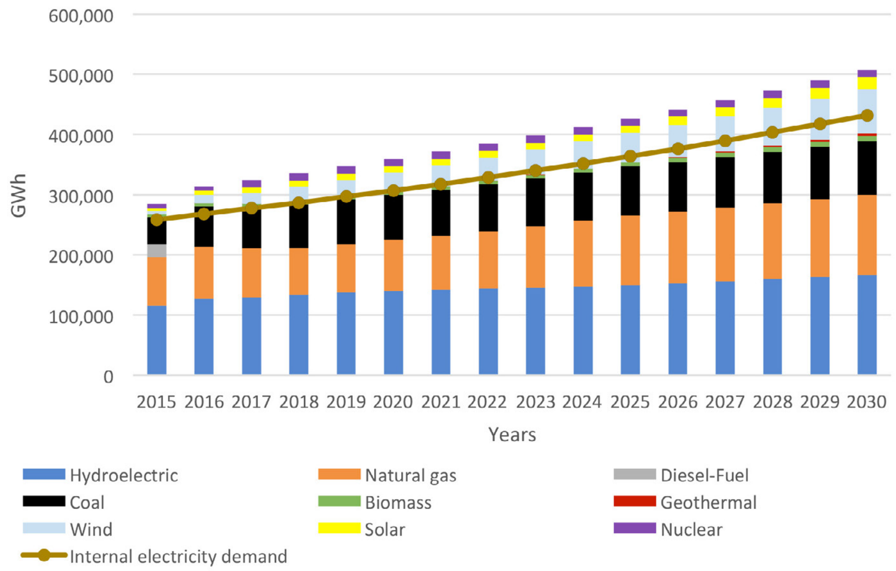
Source: Authors' compilation

Table 6.36. Projected electricity generation in the Southern Cone, CPS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	115,574	140,579	149,475	166,556
Natural gas	80,222	84,278	115,649	133,349
Diesel-Fuel Oil	21,789	0	0	0
Coal	44,972	75,096	81,719	88,341
Biomass	4,944	4,997	6,188	9,166
Geothermal	0	378	378	4,320
Wind	6,112	31,032	49,709	72,835
Solar	3,799	10,809	11,440	20,638
Nuclear	7,081	12,299	12,299	12,299
TOTAL	**284,493**	**359,469**	**426,856**	**507,505**

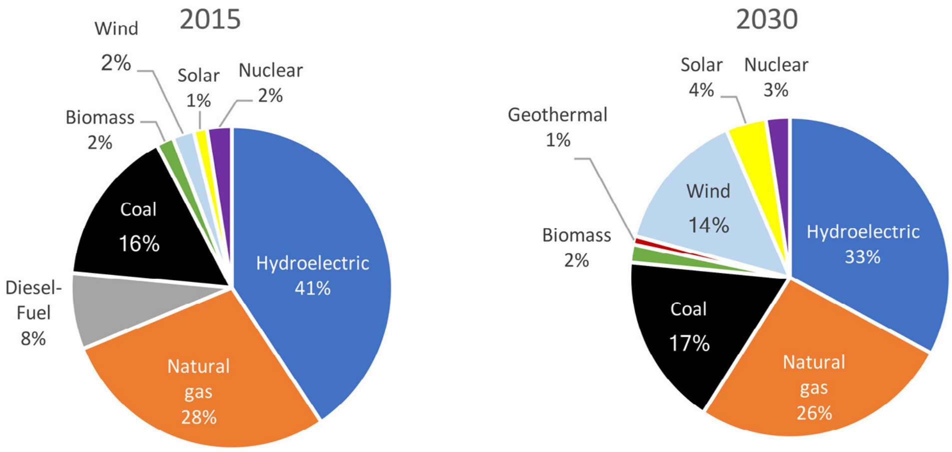
Source: Simulation results

Figure 6.42. Projected electricity generation in the Southern Cone, CPS



Source: Simulation results

Figure 6.43. Evolution of electricity generation matrix in the Southern Cone, CPS



Source: Simulation results

As can be seen in Figure 6.42, the subregion's condition as a net exporter of electricity improves, with a capacity to add more exportable energy to the subregion's natural external market, which is Brazil.

According to the simulated expansion timeline, the Southern Cone's electricity generation matrix evolves toward increased participation on the part of NCREs, such as biomass, wind, solar and geothermal power, which combined represent a significant portion of total generation at 21% in 2030, compared to 5% in the base year (Figure 6.43) Is should be noted that the geothermal energy contribution would come from Chile, the first South American country to have already begun exploitation of this renewable resource.

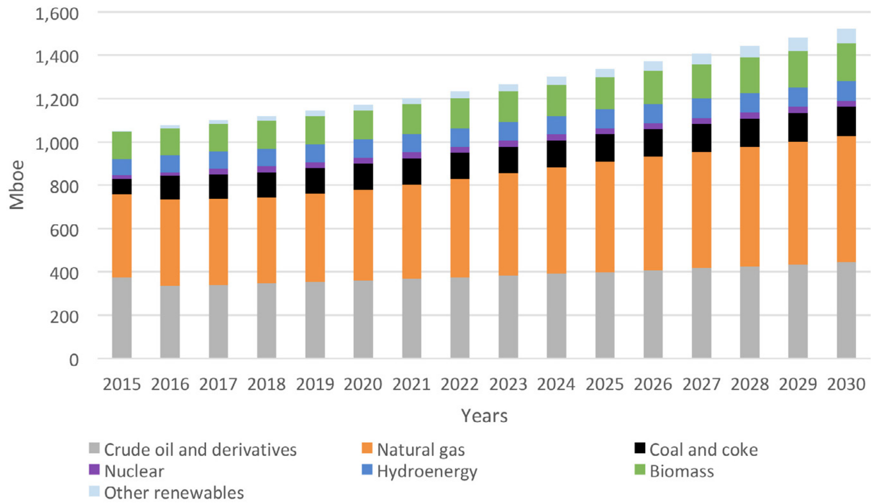
6.6.3 Projected total energy supply

Table 6.37. Projected total energy supply in the Southern Cone, CPS (Mboe)

Source	2015	2020	2025	2030	t.p.a
Crude oil and derivatives	374	360	398	445	1.2%
Natural gas	384	420	511	583	2.8%
Coal and coke	71	119	126	134	4.3%
Nuclear	16	28	28	28	3.7%
Hydroenergy	76	85	86	92	1.3%
Biomass	124	134	149	173	2.2%
Other renewables	6	27	39	67	17.3%
TOTAL	**1,052**	**1,172**	**1,337**	**1,521**	**2.5%**

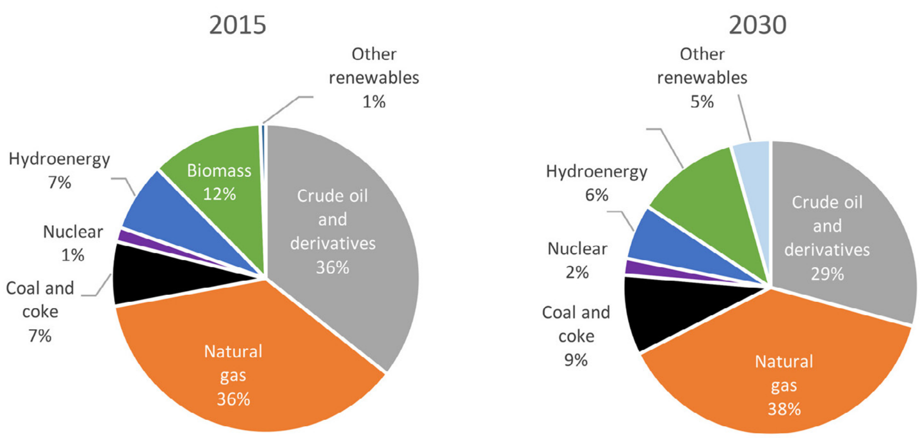
Source: Simulation results

Figure 6.44. Projected total energy supply in the Southern Cone, CPS



Source: Simulation results

Figure 6.45. Evolution of final energy consumption matrix in the Southern Cone, CPS



The evolution in total energy supply reveals the importance of natural gas to the subregion, surpassing even Crude oil and derivatives throughout the study period. The "Other renewables" series, which covers wind, geothermal and solar power, has the highest average annual growth rate (17.3%) and while it continues to represent a marginal share compared to conventional sources, it shows significant growth and increases from 1% in the base year to 5% by 2030.

6.7 The Caribbean

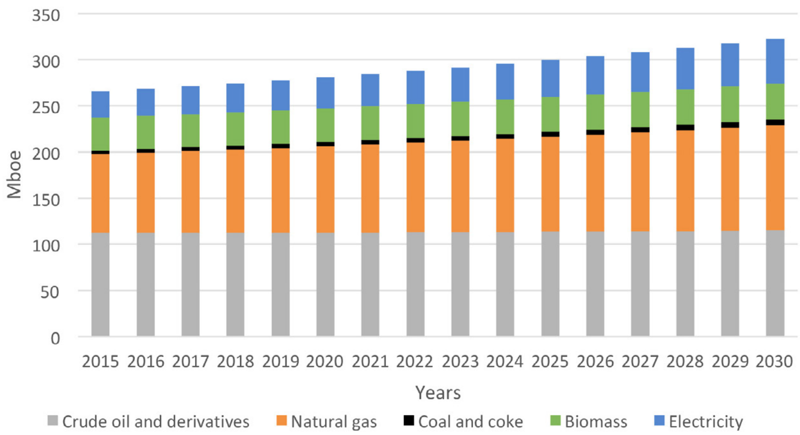
6.7.1 Projected final energy consumption

Table 6.38. Projected final energy consumption in the Caribbean, CPS (Mboe)

Sources	2015	2020	2025	2030	t.p.a
Crude oil and derivatives	113	113	113	115	0.1%
Natural gas	85	94	103	114	2.0%
Coal and coke	4	5	5	6	3.0%
Biomass	36	37	38	39	0.6%
Electricity	28	34	40	48	3.6%
TOTAL	**266**	**281**	**300**	**322**	**1.3%**

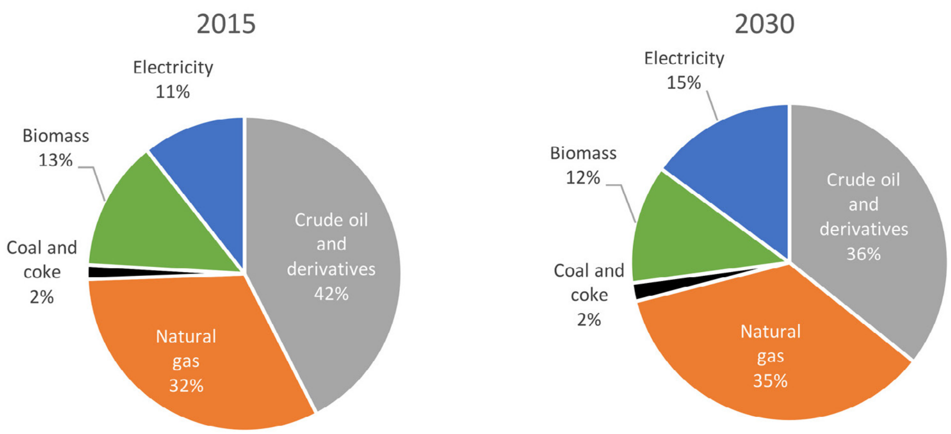
Source: Simulation results

Figure 6.46. Projected final energy consumption in the Caribbean, CPS



Source: Simulation results

Figure 6.47. Evolution of final energy consumption matrix in the Caribbean, CPS



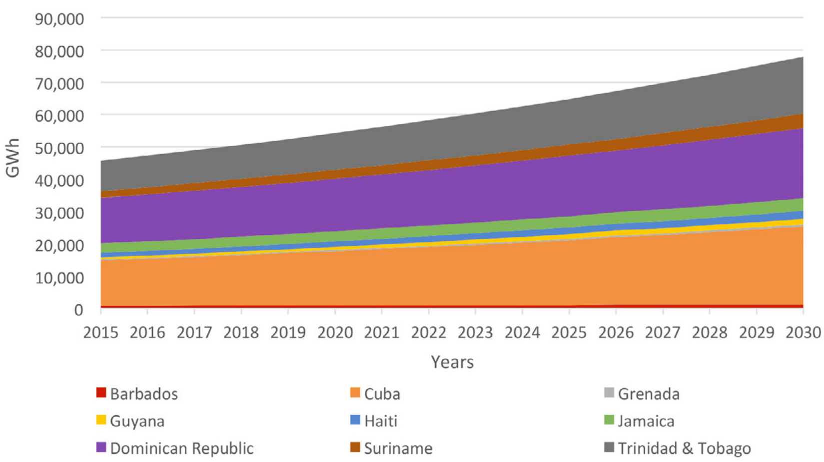
Electricity and natural gas increase their proportional share of the final consumption matrix in the Caribbean, gaining ground on oil products and biomass, as shown in Figure 6.47.

Table 6.39. Projected final electricity consumption by country (GWh)

Country	2015	2020	2025	2030	t.p.a
Barbados	970	1,025	1,104	1,200	1.4%
Cuba	13,948	16,756	20,040	24,227	3.7%
Grenada	258	330	429	566	5.4%
Guyana	688	992	1,489	1,804	6.6%
Haiti	1,356	1,682	2,027	2,402	3.9%
Jamaica	2,922	3,150	3,461	3,838	1.8%
Dominican Republic.	14,147	16,154	18,742	21,730	2.9%
Suriname	2,029	2,799	3,450	4,515	5.5%
Trinidad & Tobago	9,403	11,401	14,090	17,576	4.3%
TOTAL	**45,722**	**54,289**	**64,832**	**77,857**	**3.6%**

Source: By authors, based on national electricity sector expansion plans

Figure 6.48. Projected final energy consumption in the Caribbean



Source: By authors, based on national electricity sector expansion plans

Electricity consumption in to the Caribbean subregion grows at an approximate annual rate of 3.6%, which is mainly determined by the contribution from three countries: Cuba, the Dominican Republic and Trinidad and Tobago, which the subregion's biggest electricity consumers and maintain their relative positions during throughout the projection period (see Figure 6.48). However, it is worth noting that the fastest growth in electricity consumption is in Guyana, Suriname and Granada, as can be seen in Table 6.39.

6.7.2 Projected electricity generation

Conventional diesel-fuel oil thermoelectric projects are still important in the timelines for expansion of electricity generation capacity in the majority of Caribbean countries. However, the Dominican Republic and Trinidad and Tobago are betting on large coal and natural gas projects to sustain self-sufficiency over the course of the projection period. This is the case with the Dominican Republic, where the most important electricity generation project in the timeline is the Punta Catalina coal-fueled power plant, which adds 832 MW to generation capacity with its two stages planned to start operating in 2018 and 2019. This power plant will be supplied with coal imported from Colombia. For its part, Trinidad and Tobago plans to install an additional 1,000 MW in natural gas-fired power plants throughout the study period.

Regarding NCRE, the subregion's most significant addition in capacity corresponds to biomass, wind and solar, with Cuban standing out for its greater inclination toward these technologies (Table 6.40).

Table 6.40. Timelines for installation/decommissioning of installed capacity (MW) in the Caribbean

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
	2016			8				2	10
	2017			-14				2	
	2018			2		85		3	
	2019			-55					
	2020								
	2021							2	
	2022			-22					
Barbados	2023								
	2024			21					
	2025			-18				1	
	2026								
	2027			12					
	2028			-1					
	2029							4	
	2030			30					
	2016								
	2017	4		80					50
	2018	4		196					50
	2019	4				100		391	50
	2020	4				110		35	50
	2021	4				130		213	50
	2022	4				150			50
Cuba	2023	4				80			50
	2024	4				70			50
	2025	4				70			50
	2026	4				80			50
	2027	4				80			50
	2028	4							50
	2029	4							50
	2030	4							53

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Grenada	2016								
	2017								
	2018								
	2019								
	2020								
	2021			8					
	2022								
	2023								
	2024								
	2025								
	2026			9					
	2027								
	2028								
	2029								
	2030								
Guyana	2016								
	2017								
	2018			24					6
	2019								
	2020								
	2021	165							
	2022								
	2023								
	2024								
	2025			10					
	2026			6					
	2027								
	2028								
	2029								
	2030								
Haití	2016								
	2017								
	2018			64				11	
	2019								
	2020								
	2021								
	2022			119				21	
	2023								
	2024								
	2025								
	2026			281				50	
	2027								
	2028								
	2029								
	2030			187				33	
Jamaica	2016								
	2017								
	2018			200					
	2019								
	2020	25						50	
	2021			200					
	2022								
	2023								
	2024			200					
	2025								
	2026								
	2027	25		167				50	36
	2028								
	2029								
	2030								

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
Dominican Republic	2016		114					50	30
	2017							50	
	2018		300	-300	447	30		184	50
	2019				385			100	50
	2020							50	52
	2021								
	2022								
	2023								
	2024								
	2025								
	2026								
	2027								
	2028								
	2029								
	2030			500					
Suriname	2016								
	2017								
	2018								
	2019								
	2020								
	2021								
	2022								
	2023								
	2024								
	2025								
	2026								
	2027	225		237					
	2028								
	2029								
	2030								
Trinidad & Tobago	2016								
	2017		300						
	2018								
	2019								
	2020								
	2021		400						
	2022								
	2023								
	2024								
	2025								
	2026								
	2027		300						
	2028								
	2029								
	2030								

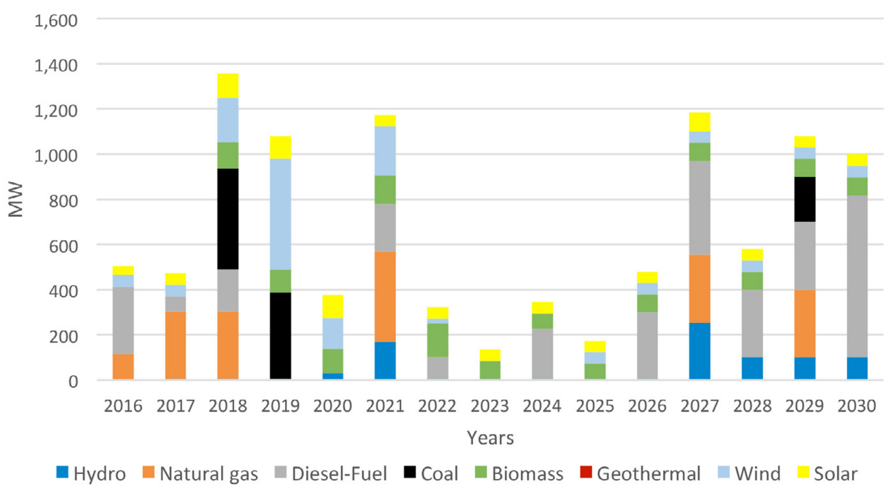
Given that not all countries contributed with enough information on their electricity sector expansion plans to cover growth of subregional demand throughout the entire study period, the timeline for the installation of capacity for the subregion was adjusted in the way shown in Table 6.41.

Table 6.41. Adjusted timelines for installation/decommissioning of installed capacity in the Caribbean (MW)

Country	Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
The Caribbean	2016	0	114	300	0	0	0	52	40
	2017	4	300	66	0	0	0	52	50
	2018	4	300	186	447	115	0	198	106
	2019	4	0	0	385	100	0	491	100
	2020	29	0	0	0	110	0	135	102
	2021	169	400	208	0	130	0	215	50
	2022	4	0	97	0	150	0	21	50
	2023	4	0	0	0	80	0	0	50
	2024	4	0	221	0	70	0	0	50
	2025	4	0	0	0	70	0	50	50
	2026	4	0	296	0	80	0	50	50
	2027	254	300	416	0	80	0	50	86
	2028	100	0	300	0	80	0	50	50
	2029	100	300	300	200	80	0	50	50
	2030	100	0	717	0	80	0	50	53

Source: By authors, based on national electricity sector expansion plans

Figure 6.49. Timelines for installation/decommissioning of installed capacity in the Caribbean



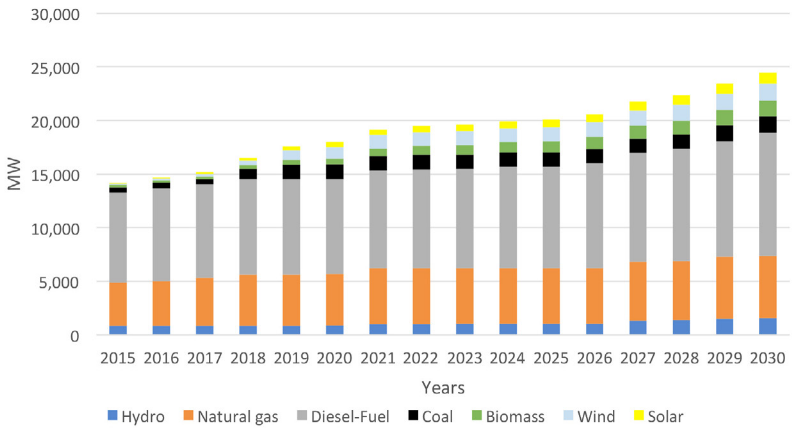
Source: By authors, based on national electricity sector expansion plans

Table 6.42. Projected Installed capacity in The Caribbean, CPS (MW)

Source	2015	2020	2025	2030
Hydroelectric	800	841	1,026	1,584
Natural gas	4,088	4,802	5,202	5,802
Diesel-Fuel Oil	8,374	8,926	9,452	11,481
Coal	500	1,332	1,332	1,532
Biomass	233	558	1,058	1,458
Wind	114	1,042	1,328	1,578
Solar	60	458	708	997
TOTAL	**14,170**	**17,960**	**20,107**	**24,433**

Source: Simulation results based on installation/decommissioning timelines.

Figure 6.50. Projected Installed capacity in The Caribbean, CPS



Source: Simulation results based on installation/decommissioning timelines.

According to the schedules for installation/decommissioning of power plants as proposed by Caribbean countries, the subregion's electricity generation would increase by 72% over the base year through 2030, which represents an additional capacity of about 10,263 MW. It is also worth mentioning that while NCRE represented a modest 3% share of total capacity in the base year, that share increases to 17% in 2030.

To calculate electricity generation for each technology available, the dispatch priority indicated in Table 6.43 was used. Though the possibility of electrical interconnection projects between insular and continental countries via underwater cables is often mentioned, the projection does not consider electricity import or export capacities for the subregion.

Table 6.43. Dispatch priority of electricity generation technologies in the Caribbean

Dispatch order	Technology
1	Hydroelectric
2	Wind
3	Solar
4	Biomass
5	Coal
6	Natural gas
7	Diesel-Fuel Oil

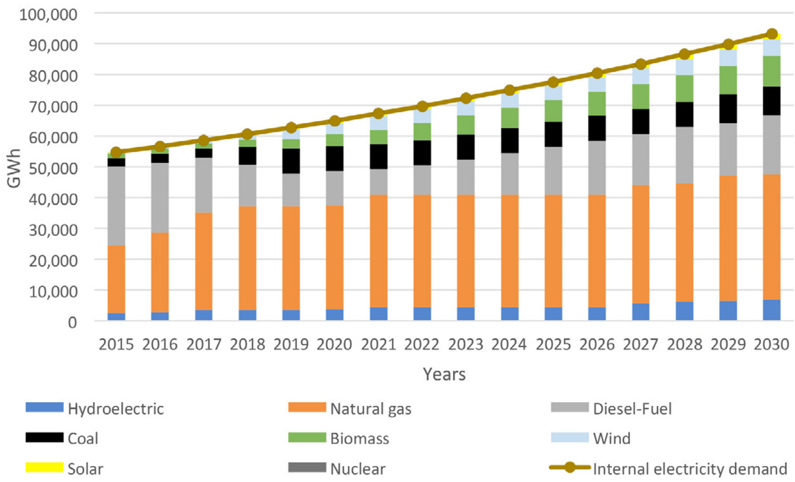
Source: Authors' compilation

Table 6.44. Projected electricity generation in the Caribbean, CPS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	2,398	3,684	4,494	6,938
Natural gas	22,039	33,655	36,458	40,663
Diesel-Fuel Oil	25,674	11,307	15,514	19,163
Coal	2,696	8,169	8,169	9,395
Biomass	1,573	3,763	7,132	9,828
Wind	308	3,652	4,655	5,531
Solar	81	802	1,240	1,747
TOTAL	**54,769**	**65,032**	**77,662**	**93,264**

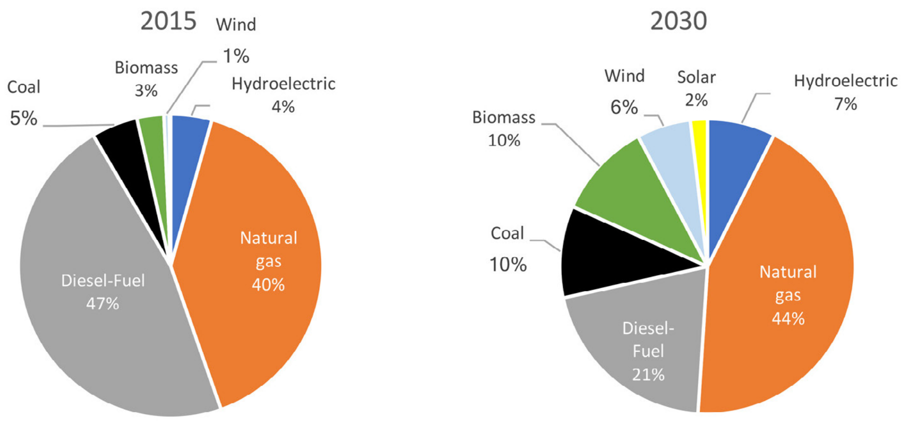
Source: Simulation results

Figure 6.51. Projected electricity generation in the Caribbean, CPS



Source: Simulation results

Figure 6.52. Evolution of electricity generation matrix in the Caribbean, CPS



Source: Simulation results

The simulation performed for the study period based on projected electricity demand and the availability of installed capacity for each year allows the evolution of electricity generation as illustrated in Figure 6.52 to be obtained. As can be seen, natural gas gains importance in the generation matrix, displacing oil products. Coal also gains a greater share due to the Punta Catalina project in the Dominican Republic and when it comes to renewable energies (including hydroenergy), their share evolves from 8% in the base year to a significant 25% in 2030, thanks to contributions from new biomass, wind, solar, and hydroelectric power plants.

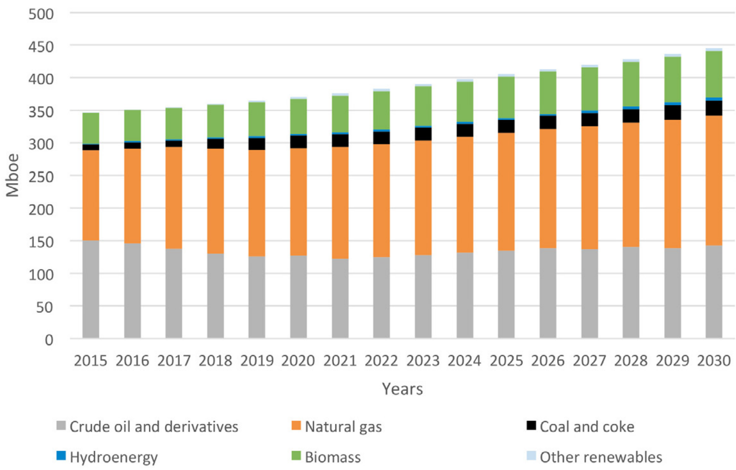
6.7.3 Projected total energy supply

Table 6.45. Projected total energy supply in the Caribbean, CPS (Mboe)

Sources	2015	2020	2025	2030	t.p.a
Crude oil and derivatives	150	127	135	143	-0.3%
Natural gas	138	165	181	199	2.5%
Coal and coke	9	19	20	23	6.7%
Hydroenergy	2	3	3	5	7.3%
Biomass	47	54	63	71	2.8%
Other renewables	0.2	2.8	3.7	4.5	21.6%
TOTAL	**347**	**371**	**405**	**445**	**1.7%**

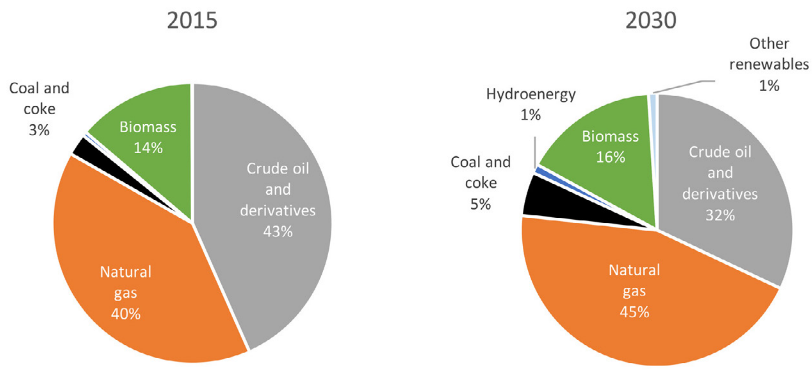
Source: Simulation results

Figure 6.53. Projected total energy supply in the Caribbean, CPS



Source: Simulation results

Figure 6.54. Evolution of total energy supply matrix in the Caribbean, CPS



Source: Simulation results

In a very similar way to the situation with the electricity generation matrix, the evolution of total energy supply for the Caribbean subregion reflects the partial replacement of oil and its derivatives with the use of natural gas, coal and renewable sources, predominated by an increased supply of biomass. As far as hydroenergy is concerned, this source's share of the energy supply matrix remains marginal throughout the study period.

6.8 Latin America and the Caribbean (LAC)

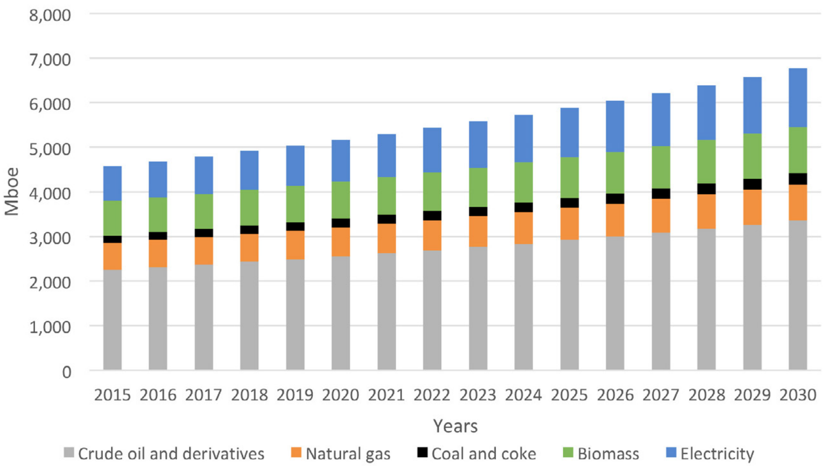
6.8.1 Projected final energy consumption

Table 6.46. Projected final energy consumption in LAC, CPS (Mboe)

Source	2015	2020	2025	2030	t.p.a
Crude oil and derivatives	2,261	2,554	2,916	3,360	2.7%
Natural gas	590	649	721	808	2.1%
Coal and coke	174	196	223	255	2.6%
Biomass	767	832	916	1,022	1.9%
Electricity	784	932	1,110	1,324	3.6%
TOTAL	**4,576**	**5,163**	**5,886**	**6,769**	**2.6%**

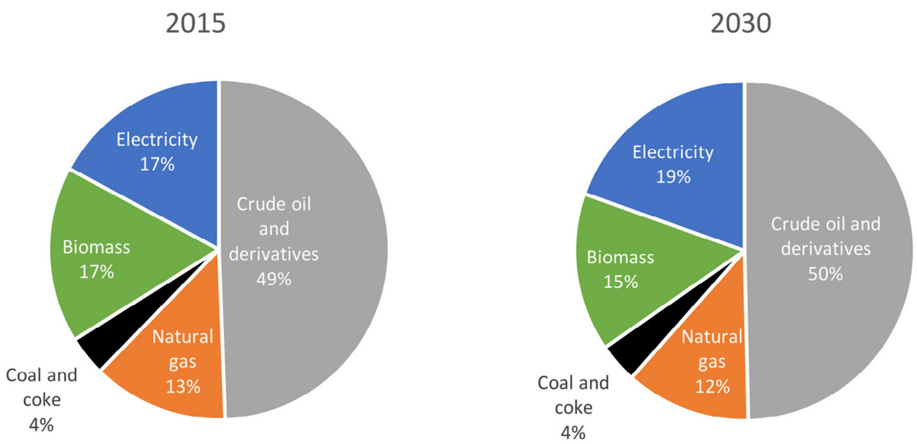
Source: Simulation results

Figure 6.55. Projected final energy consumption in LAC, CPS



Source: Simulation results with SAME, BAU scenario

Figure 6.56. Evolution of final energy consumption matrix in LAC, CPS



Source: Simulation results with SAME, BAU scenario

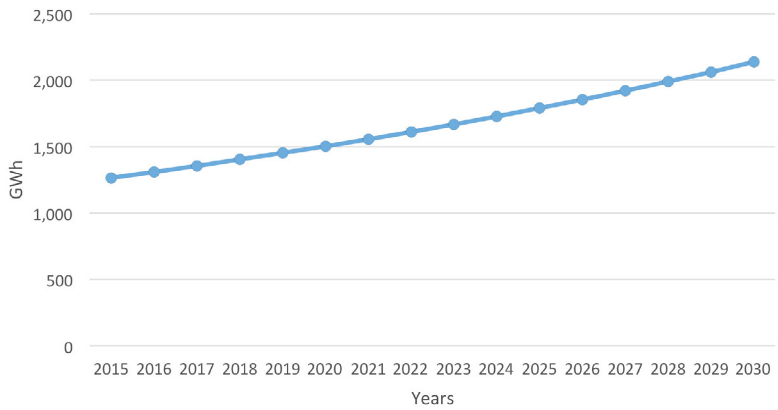
The evolution in the final consumption matrix of ALC in the CPS is very similar to what was observed in the BAU scenario, but with a lower penetration by electricity (Figure 6.56).

Table 6.47. Projected final electricity consumption in LAC, CPS (GWh)

Source	2015	2020	2025	2030	t.p.a
Electricity	1,265	1,504	1,791	2,137	3.6%

Source: Simulation results

Figure 6.57. Projected final electricity consumption in LAC, BAU scenario



Source: Simulation results

The average annual growth rate for electricity consumption in LAC under the CPS is two-tenths of a percentage point less than in the BAU scenario.

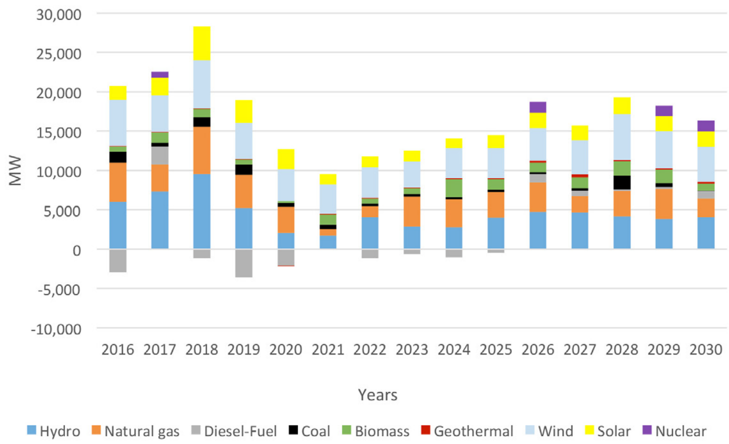
6.8.2 Projected electricity generation

Table 6.48. Timelines for installation/decommissioning of installed capacity (MW) in LAC, CPS (MW)

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	5,996	5,025	-2,938	1,394	676	48	5,862	1,715	0
2017	7,337	3,449	2,289	414	1,359	51	4,679	2,226	745
2018	9,576	6,015	-1,169	1,212	1,056	45	6,104	4,286	0
2019	5,250	4,227	-3,586	1,298	607	55	4,602	2,909	0
2020	2,072	3,355	-2,121	481	206	-30	4,053	2,549	0
2021	1,721	856	-10	543	1,282	133	3,723	1,306	0
2022	4,076	1,397	-1,158	290	683	71	3,872	1,405	0
2023	2,886	3,815	-593	316	697	120	3,276	1,375	0
2024	2,769	3,551	-1,067	320	2,246	119	3,832	1,236	0
2025	4,022	3,293	-427	263	1,303	134	3,834	1,659	0
2026	4,729	3,769	1,069	237	1,194	233	4,176	1,918	1,405
2027	4,653	2,092	684	331	1,370	359	4,346	1,921	0
2028	4,185	3,203	261	1,699	1,820	182	5,800	2,124	0
2029	3,873	3,829	197	516	1,727	155	4,730	1,868	1,360
2030	4,086	2,351	990	46	872	210	4,441	1,974	1,361

Source: By authors, based on national electricity sector expansion plans

Figure 6.58. Timelines for installation/decommissioning of installed capacity (MW) in LAC, CPS



Source: By authors, based on national electricity sector expansion plans

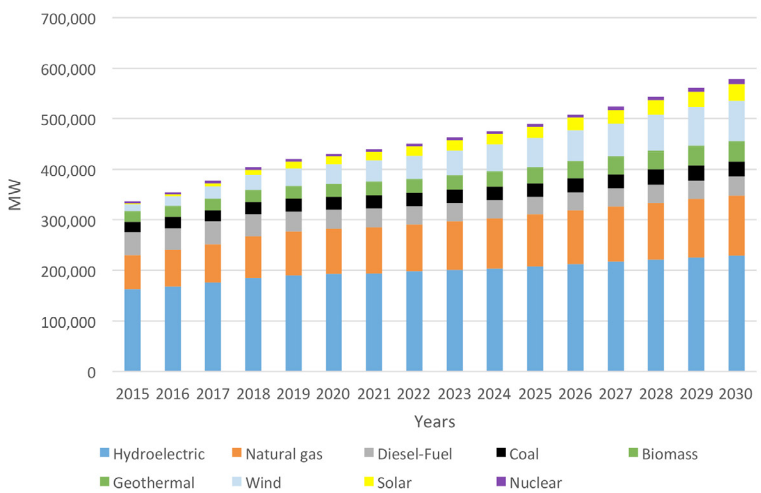
As can be seen in Table 6.48 and Figure 6.58, electricity generation technologies that predominate the timeline for the installation of new capacity during the study period for LAC will be the hydroenergy, natural gas-fired power plants and the wind power.

Table 6.49. Projected Installed capacity in LAC, CPS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	162,241	192,471	207,945	229,471
Natural gas	67,798	89,869	102,781	118,026
Diesel-Fuel Oil	45,260	37,734	34,479	37,680
Coal	20,736	25,535	27,268	30,097
Biomass	19,834	23,738	29,948	36,930
Geothermal	1,484	1,653	2,231	3,370
Wind	13,099	38,399	56,936	80,429
Solar	2,091	15,776	22,757	32,561
Nuclear	4,510	5,255	5,255	9,381
TOTAL	**337,052**	**430,430**	**489,599**	**577,946**

Source: By authors, based on national electricity sector expansion plans

Figure 6.59. Projected Installed capacity in LAC, CPS



Source: Simulation results

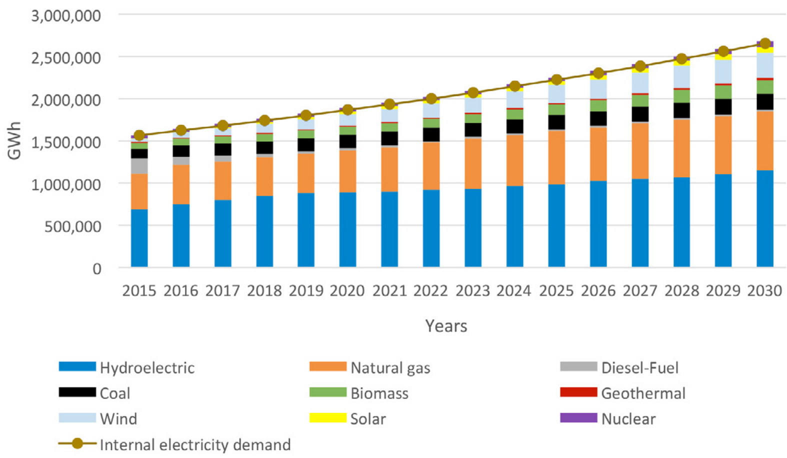
As shown in Table 6.49 and Figure 6.59, the installed electricity generation capacity in LAC will maintain a higher proportion of hydroenergy throughout the study period. However, there is a clear increase in the importance of natural gas and NCRE like wind, biomass and solar power.

Table 6.50. Projected electricity generation in LAC, CPS (GWh)

Technology	2015	2020	2025	2030
Hydroelectric	686,983	889,565	985,191	1,149,101
Natural gas	427,355	500,734	632,842	699,272
Diesel-Fuel Oil	178,285	25,825	19,189	19,163
Coal	112,917	160,462	171,655	191,335
Biomass	69,732	92,495	124,354	160,159
Geothermal	11,861	12,361	16,656	25,240
Wind	39,521	134,556	211,808	298,421
Solar	5,763	32,530	46,726	68,720
Nuclear	33,277	38,551	38,551	69,697
TOTAL	**1,565,695**	**1,887,079**	**2,246,971**	**2,681,108**

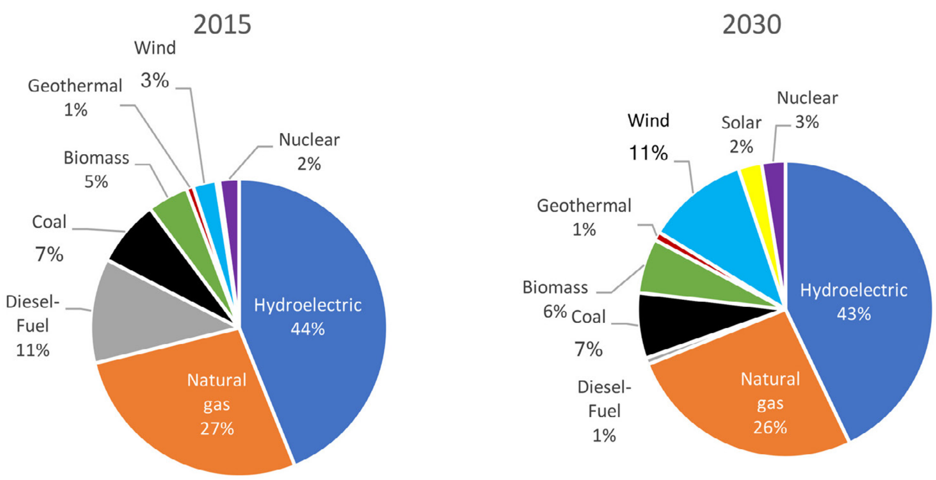
Source: Simulation results

Figure 6.60. Projected electricity generation in LAC, CPS



Source: Simulation results

Figure 6.61. Evolution of electricity generation matrix in LAC, CPS



Source: Simulation results

Electricity generation in LAC will continue to depend mainly on hydroelectricity and natural gas, though the most relevant aspect in the matrix's evolution is the clear increase in participation by NCRE, which contribute toward increasing the renewability index from 53% in the base year to 63% in 2030 (see Figure 6.61).

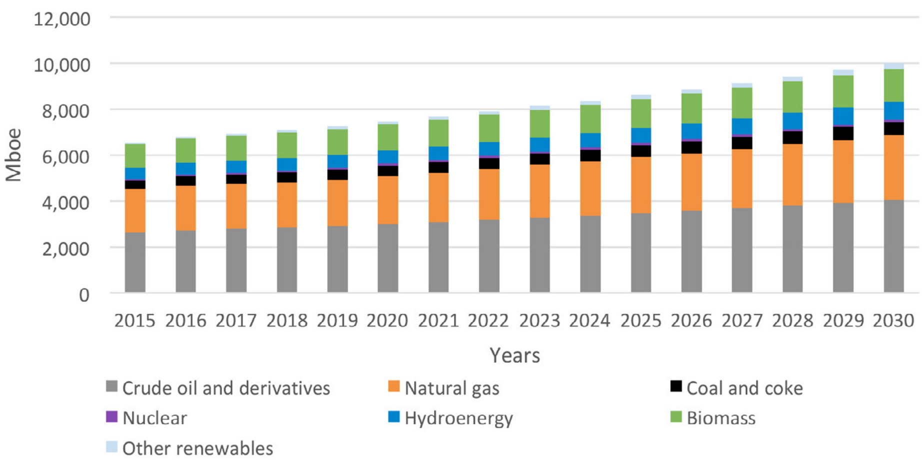
6.8.3 Projected total energy supply

Table 6.51. Projected total energy supply in LAC, CPS (Mboe)

Fuente	2015	2020	2025	2030	t.p.a
Petróleo y derivados	2,634	3,006	3,462	4,050	2.9%
Gas natural	1,895	2,080	2,465	2,811	2.7%
Carbón mineral y coque	369	463	517	582	3.1%
Nuclear	64	80	85	111	3.7%
Hidroenergía	471	587	649	763	3.3%
Biomasa	1,041	1,131	1,264	1,430	2.1%
Otras renovables	57	127	183	254	10.4%
TOTAL	**6,532**	**7,474**	**8,626**	**10,000**	**2.9%**

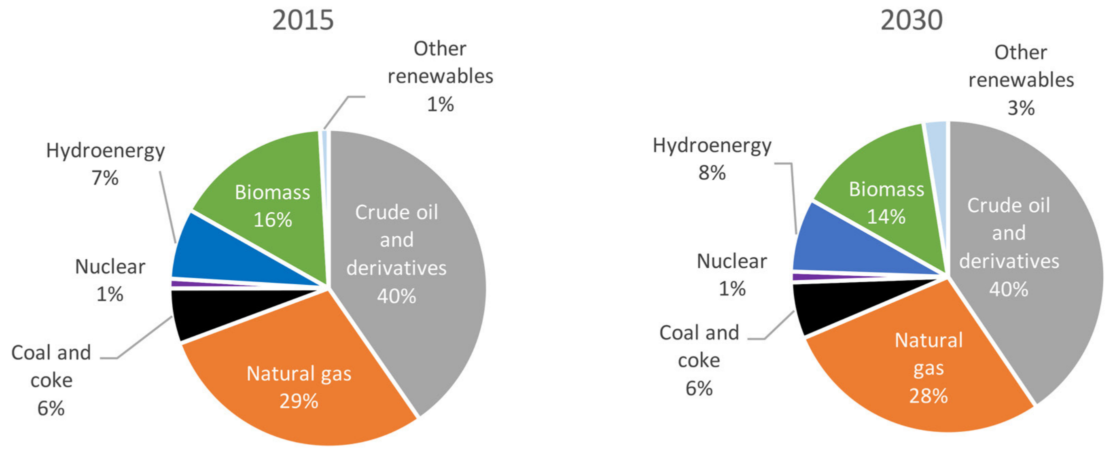
Source: Simulation results

Figure 6.62. Projected total energy supply in LAC, CPS



Source: Simulation results

Figure 6.63. Evolution of total energy supply matrix in LAC, CPS



Source: Simulation results

The total energy supply matrix for LAC is predominated by hydrocarbons throughout the projection period. Though the renewability index remains unchanged, hydroenergy and other renewable sources (wind, solar and geothermal) gain ground against biomass (Figure 6.63).

7. Comparative analysis of CO_2e emissions under CPS and BAU scenario, in relation to the reduction goals implicit in the NDCs

7. Comparative analysis of CO2e emissions under CPS and BAU scenario, in relation to the reduction goals implicit in the NDCs

7.1 Introduction

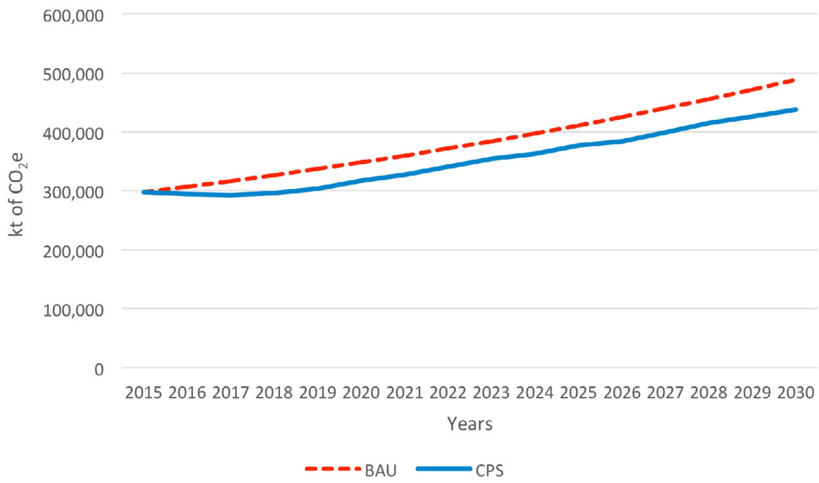
The purpose of this chapter is to obtain the percentage reduction in CO2e emissions for the energy matrixes of the different subregions analyzed by applying current energy development policies (CPS) when compared to those produced under the BAU baseline scenario, and the difference of these, with the referential goals of reduction implicit in the NDCs.

The magnitude of the GHG emissions valued in thousands of tons (kt) of CO2e, is calculated by multiplying each flow of the energy matrix, both supply and consumption, measured in Thousands of barrels of oil equivalent (kboe), by its corresponding emission factor. The emission factors used are those proposed by the IPCC and are compiled in the OLADE's SieLAC database, which can be seen in Annex V of this document.

In the case of electricity generation, the GHG emission factors correspond exclusively to the use of fossil fuels, since for nuclear energy and renewable energy sources, including biomass, the emission factors are considered null. Similarly, in the final consumption, both for primary and secondary biomass, zero factors of CO2e emission are considered.

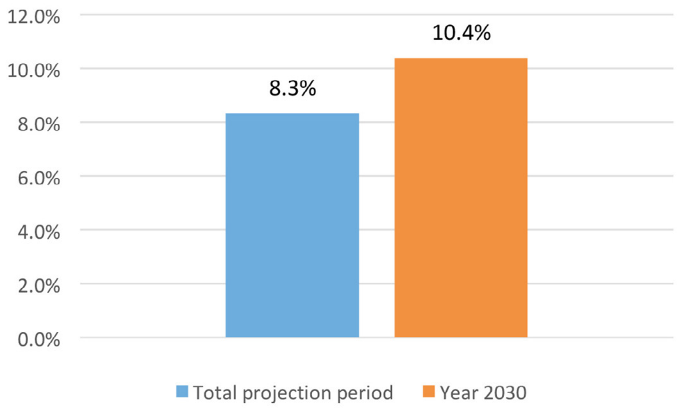
7.2 Brazil

Figure 7.1. Total CO2e emissions for Brazil's energy matrix



Source: Simulation results

Figure 7.2. Percentage reduction in CO2e emissions for Brazil's energy matrix compared to BAU scenario



Source: Simulation results

As can be seen in figure 7.2, the application of the current policy scenario (CPS) in Brazil, would produce a percentage of CO2e emissions reduction, compared to the BAU scenario of only 8.3% during the entire projection period and 10.4%. % in annual values of the year 2030. Although Brazil does not propose a reference to a BAU scenario in its NDCs, nor a specific one for the energy sector, these percentages are much lower than those that appear in the NDCs, for most of the countries and the one taken as reference for the region (25-30%). Brazil proposes an overall reduction of 43% by 2030 compared to 2005 (see Annex II). However, no specific goal is mentioned for the energy sector.

A recent exercise in the Ministry of Mines and Energy of Brazil (MME), establishes some average annual rates of variation of GHG emissions with respect to 2015, for different sectors, with which this country could meet the goals defined in your NDCs. These rates are shown in Table 7.1.

Table 7.1. Variation of GHG emissions until the year 2030, for Brazil

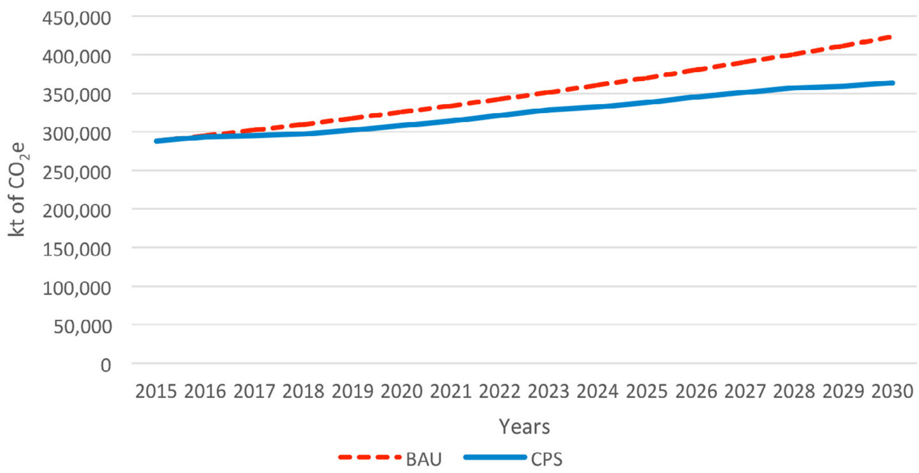
Sector de emisiones de GEIs	%2020 / 2005	%2030 / 2005	%t.p.a. 2015 /2005	%t.p.a 2020 /2015	%t.p.a 2030 /2015
Total	-37.0	-43.0	-6.7	4.7	0.9
Cambio en el uso del suelo y bosques	-67.9	-84.7	-16.1	13.3	-0.8
Agropecuario	11.4	16.5	0.8	0.6	0.5
Energético	57.8	88.7	3.7	1.8	1.8
Tratamiento de residuos y procesos industriales	43.8	75.3	2.7	2.0	2.0

Source: MME/DIE/SPE/Patusco, 2018

As a result of the simulation, emissions from the BAU scenario grow during the projection period at an average annual rate of 3.4%, while in the CPS this rate is reduced to 2.6%, a value higher than the percentage presented in the Table 7.1 (1.8%). With this comparison, it is concluded that the CPS is insufficient for the fulfillment of the general goal of emission reduction established by Brazil in its NDCs.

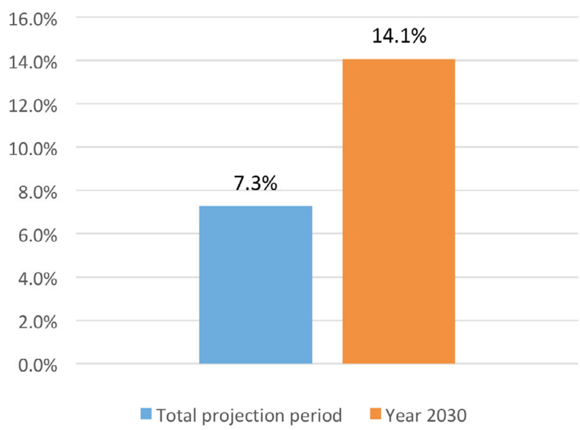
7.3 Mexico

Figure 7.3. Total CO2e emissions for Mexico's energy matrix



Source: Simulation results

Figure 7.4. Percentage reduction in CO2e emissions for Mexico's energy matrix compared to BAU scenario

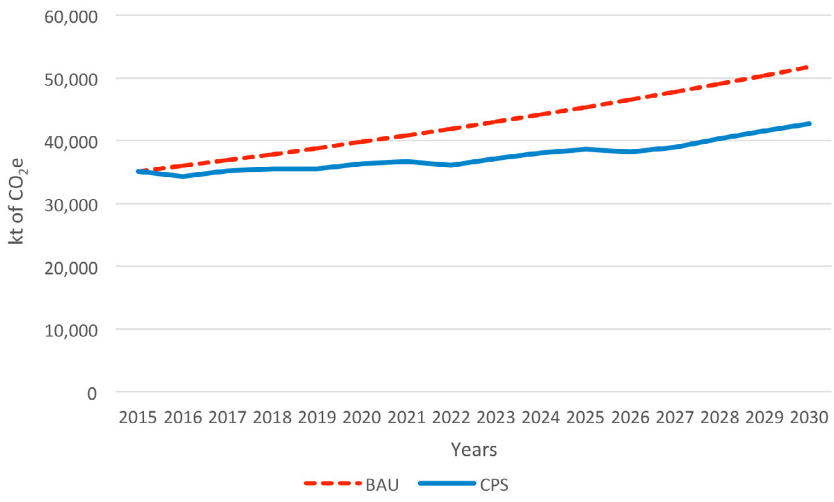


Source: Simulation results

In Mexico, the percentage of CO2e emissions reduction for annual values in the year 2030 is approximately double the percentage of reduction accumulated throughout the projection period, as shown in Figure 7.4. However, this percentage is much lower than the 25% established by Mexico in its NDCs as a general goal of reducing emissions with respect to the BAU scenario (see Annex II). This means that, under the CPS, Mexico's energy sector would not be making a sufficient contribution to achieve this goal despite the fact that the sector is responsible for 67.3% of total emissions (see Annex VI).

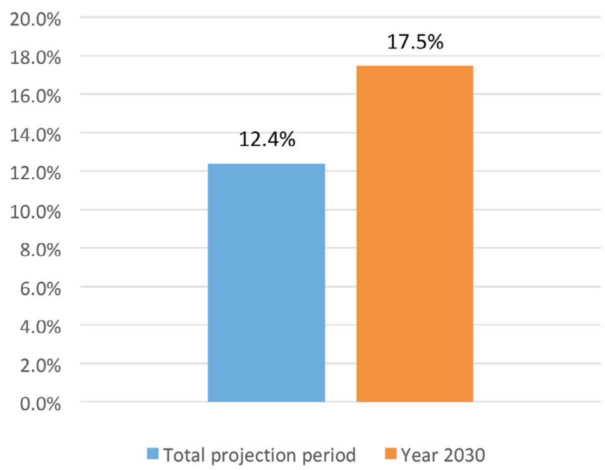
7.4 Central America

Figure 7.5. Total CO2e emissions for Central America's energy matrix



Source: Simulation results

Figure 7.6. Percentage reduction in CO2e emissions for Central America's energy matrix compared to BAU scenario



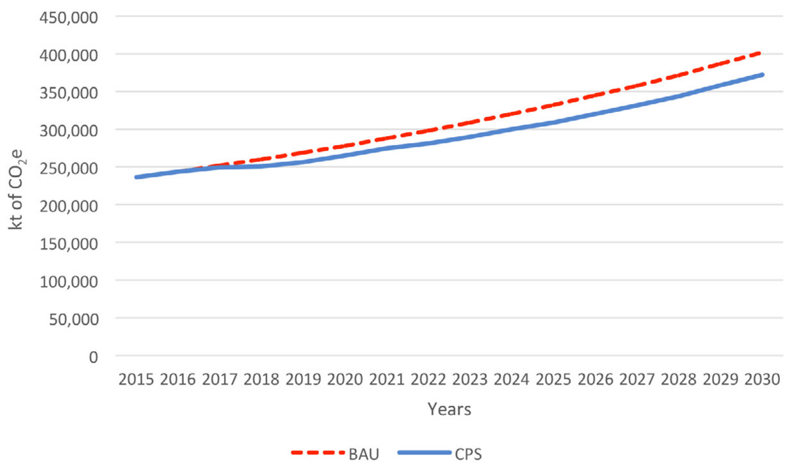
Source: Simulation results

The Central American subregion is the one to achieve the largest percentage reduction in CO2e emissions by the energy sector, thanks to the application of current energy policy development policies (CPS). This is due to a significant renewable component in the timelines for the electricity sector's expansion in the majority of countries that belong to it.

Unfortunately, the values available in the NDCs of the countries of this region are not sufficient to draw conclusions as to whether current policies are sufficient to achieve the goals. Guatemala presents an objective between 11.2% and 22.5% and Honduras a maximum of 15.0%.

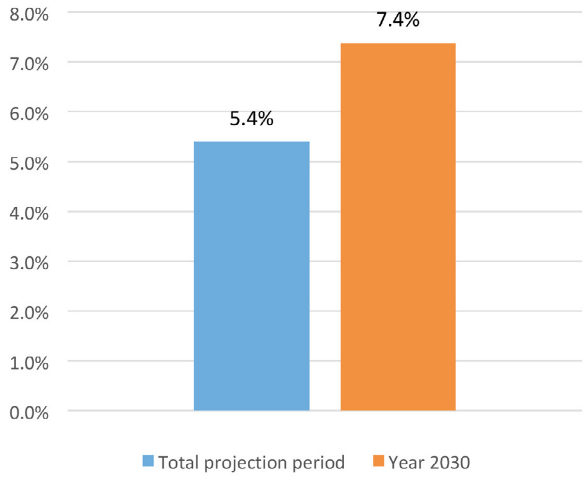
7.5 Andean Subregion

Figure 7.7. Total CO2e emissions for the Andean subregion's energy matrix



Source: Simulation results

Figure 7.8. Percentage reduction in CO2e emissions for the Andean Subregion's energy matrix compared to BAU scenario



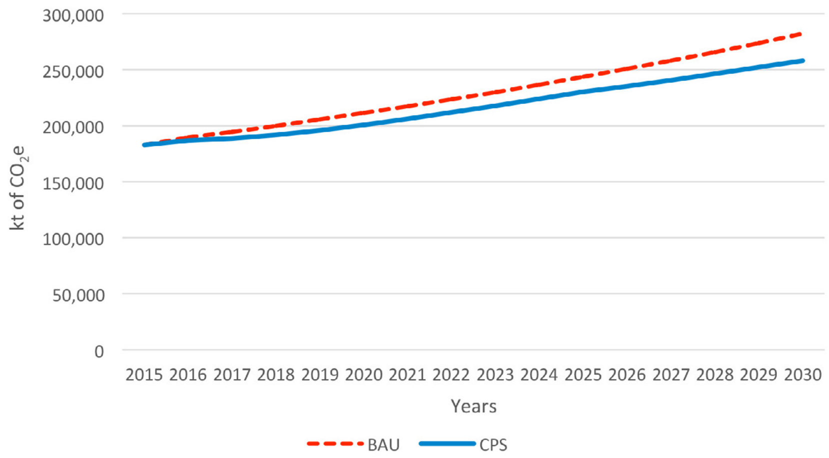
Source: Simulation results

The difference between CO2e emissions under CPS and the BAU scenario in the Andean subregion is relatively low, because in both cases electricity generation matrixes are predominated by hydroenergy, and given this resource's abundant potential in the subregion it is the one to dominate expansion timelines in the majority of countries that belong to it.

According to the NDCs of the Andean countries (Annex II), an emission reduction goal of between 20 and 25% at the subregional level could be used as a reference, so it would be necessary to deepen the measures of clean energy development to reach this referential goal.

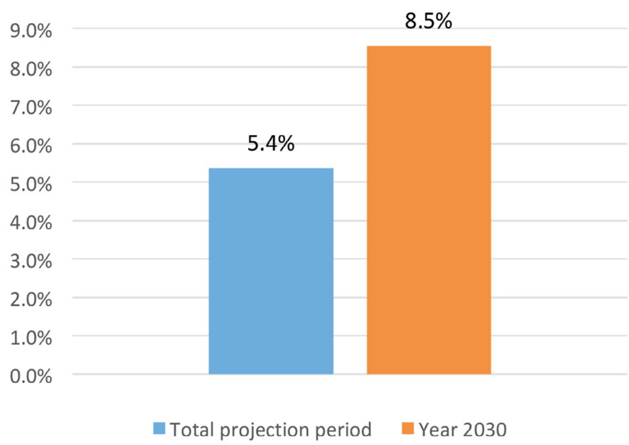
7.6 Southern Cone

Figure 7.9. Total CO2e emissions for the Southern Cone's energy matrix



Source: Simulation results

Figure 7.10. Percentage reduction in CO2e emissions for the Southern Cone's energy matrix compared to BAU scenario



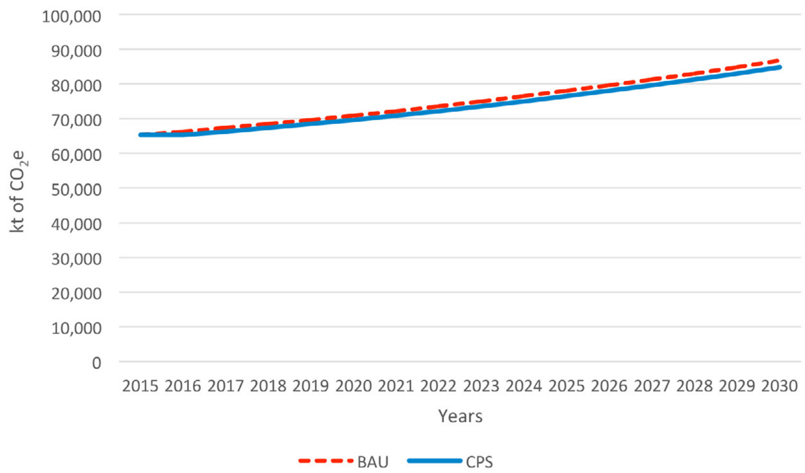
Source: Simulation results

As illustrated in figure 7.10, in a similar way to the situation with the Andean Subregion, the current policy scenario, CPS, produces a relatively low percentage reduction in CO2e emissions compared to the BAU scenario, since the electricity generation matrix continues to rely mainly on hydroelectricity and natural gas in both scenarios.

Considering for this sub-region a referential goal to reduce GHG emissions to the year 2030, of 20%, according to the NDCs proposed by the countries that comprise it (see Annex II), the proposal of new premises aimed at the fulfillment of said goal is justified.

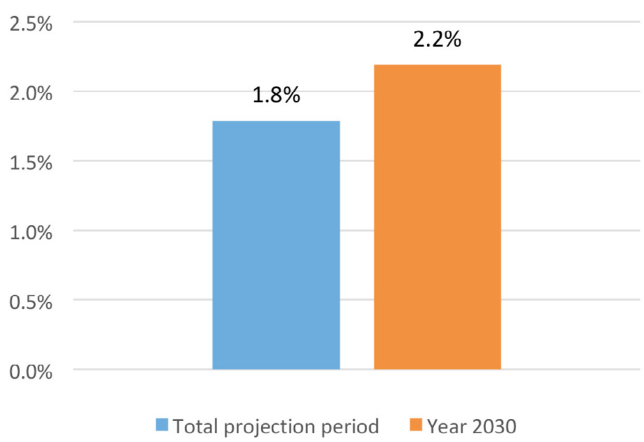
7.7 The Caribbean

Figure 7.11. Total CO2e emissions for the Caribbean's energy matrix



Source: Simulation results

Figure 7.12. Percentage reduction in CO2e emissions for the Caribbean's energy matrix compared to BAU scenario



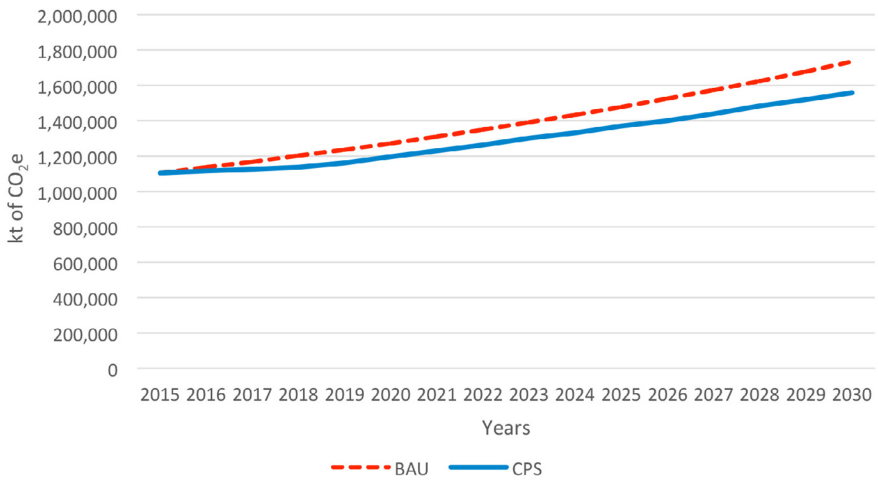
Source: Simulation results

In the case of the Caribbean, a subregion that is highly dependent on fossil fuel sources like natural gas and oil products; and with limited hydroenergy and NCRE potential, the CO2e emissions reduction percentages obtained under CPS when compared to the BAU scenario are the lowest of all the subregions analyzed, as shown in figure 7.12.

Due to the low percentages of GHG emissions reduction achieved with the CPS in this sub-region and considering a 15% benchmark goal, according to the NDCs of the countries that make up the sub-region, the proposal for an alternative energy scenario is very justified, which would allow the achievement of this goal.

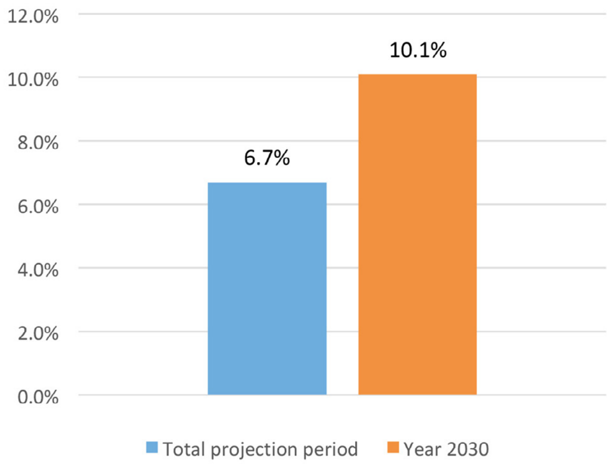
7.8 Latin America and the Caribbean (LAC)

Figure 7.13. Total CO_2e emissions for LAC's energy matrix



Source: Simulation results

Figure 7.14. Percentage reduction in CO_2e emissions for LAC's energy matrix compared to BAU scenario



Source: Simulation results

In the regional outlook of LAC, the aggregation of CO2e emissions from the different sub-regions shows that with the CPS, relatively modest values could be obtained in the reduction percentages, as can be seen in Figure 7.14. As already mentioned in chapter 4, due to the heterogeneity of the region and the lack of well-defined emission reduction targets by many countries, it is not possible to draw a precise conclusion at the regional level. However, taking into account the reductions proposed by the four countries with the greatest economic weight in the region: Brazil (43%), Mexico (25%), Argentina (20-40%) and Colombia (20-30%), has set a benchmark goal for the LAC region of between 25 and 30% with respect to the BAU scenario. With this range, everything seems to indicate that the reductions that would be achieved by the CPS at the regional level would be insufficient.

8. Construction of the scenario aimed at fulfillment of NDCs (NFS)

8. Construction of the scenario aimed at fulfillment of NDCs (NFS)

8.1 General Considerations

As seen in the previous chapter, the percentage reductions in CO2e emissions obtained from the current policy scenario (CPS) simulation, when compared to the baseline scenario (BAU), are significantly lower than the benchmark goals for the energy sector, defined in relation to the NDCs. For this reason, a third scenario is presented in which a far more aggressive sustainable energy development policy is simulated, one that considers more vigorous energy efficiency measures in the main consumer sectors and a swifter transition toward an electricity generation matrix using renewable energy sources. Thus, an attempt is made to achieve percentage reductions in GHG emissions, that contribute in a better way to the commitments assumed by the countries on the matter. The assumptions made in the NFS are as follows:

• The NFS is configured in the SAME Model as an offshoot of the CPS, with roots in 2016. In other words, starting in 2017, the premises of this new energy scenario begin to emerge.

• The NFS is one of anticipation, or a "roadmap" that defines a desirable future for the energy matrix in the study horizon and then the evolution from its current state (base year) to said future state is determined. Annex IV specifies the simulated energy efficiency measures for each subregion and consumption sector for 2030.

• In Annex IV, the measures for the promotion of sustainable sources of energy and energy efficiency, proposed for each sub-region and consumer sector, are specified for the year 2030. These measures are intended to reduce GHG emissions in final consumption, with base on: 1) reduce the total final energy consumption, in the NFS, maintaining the same levels of useful energy corresponding to the CPS; and 2) increase the use of non-polluting sources, such as electricity from renewable sources and biofuels. Specific characteristics of these measures are detailed below:

a) In some cases, energy efficiency measures in the main consumption sectors (transportation, industry, residential and commercial) correspond to the substitution of energy sources, while in others to the substitution of conventional technologies for more efficient ones.

b) Increased penetration by electricity is promoted in related final uses, such as transportation, cooking, driving forces, direct heat, etc.

c) An increase in the consumption of biofuels in road transport is sought, in order to partially displace the use of fossil fuels, especially gasoline and diesel oil.

d) It is proposed to make the most use of solar thermal energy for water heating, in the residential sector, in order to reduce the expenditure of fossil fuels and electricity. Although the consumption of this source may be implicit in the BAU and CPS, since it is considered a substitute source, in the NFS, its differential use is explicit in this scenario.

e) Due to the level of aggregation of the available consumption data, it is not possible to know precisely the values of transformation efficiencies and useful energy in the different end uses. For this reason, the relative values of consumption efficiencies shown in Annex III were used, with which a useful benchmark energy can be calculated and the effect of substitution between sources and consumption technologies on final energy expenditure can be evaluated.

- In the timelines for installation of electricity generation capacity (see Chapter 6), the expansion of coal and oil-based (diesel-fuel oil technologies is eliminated as of 2017 and a NCRE are favored significantly in an attempt to replace the use of fossil fuel sources with increased proportions of renewable resources, according to the potential available in each region .

- The same dispatch order priority for electricity generation technologies is maintained as in the CPS.

- A gradual decline in the percentage of electricity transmission and distribution losses is considered for the study period, both technical and non-technical, reaching 2030 with maximum total losses of 10% in all of the subregions analyzed.

Strictly speaking, the set of measures included in Annex IV should only be baseline values of the NFS, which should be adjusted for each subregion through an iterative process. Each iteration would establish new combinations of measures until the convergence of the emission values obtained for each new combination with the values of the goals established in the NDCs is reached. In practice, as explained in previous chapters, the lack of precise quantitative targets prevents such analysis. Therefore, the NFS used here is a work scenario defined from the measures proposed in Annex IV, which are assumed as a useful first approximation to achieve the main objective of this study (see Introduction). These measures have been defined based on the experience and knowledge of OLADE according to values that the Organization estimates as feasible for the capacities of the LAC region by the 2030 horizon, and, as will be seen in Chapter 10, they give an idea of the type of measures that could be adopted in the region to achieve the commitments established in the NDCs.

The most significant results of the NFS and their comparison with the BAU scenario and CPS are presented below.

[5] Useful energy is the energy available after the system of use for the production of a good or service, once all the transformation and transport losses associated with it have been deducted [70]

8.2 Brazil

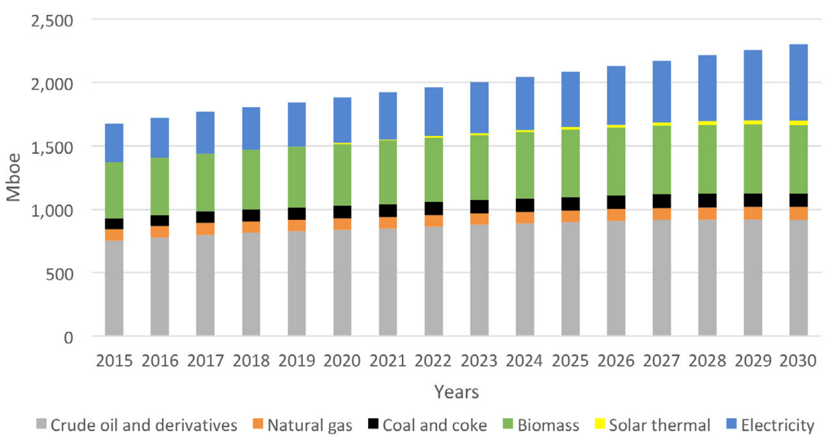
8.2.1 Projected final energy consumption

Table 8.1. Projected final energy consumption in Brazil, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	753	839	898	917	1.3%
Natural gas	91	91	92	100	0.6%
Coal and coke	84	100	108	108	1.7%
Biomass	443	488	530	541	1.3%
Solar thermal	0	6	20	34	18.4%
Electricity	304	360	438	601	4.6%
TOTAL	**1,676**	**1,883**	**2,086**	**2,301**	**2.1%**

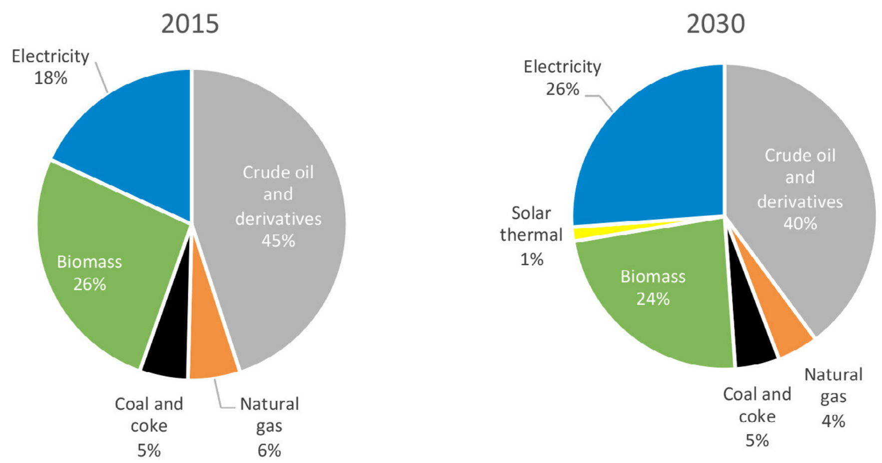
Source: Simulation results

Figure 8.1. Projected final energy consumption in Brazil, NFS



Source: Simulation results

Figure 8.2. Evolution of final energy consumption matrix in Brazil, NFS



Source: Simulation results

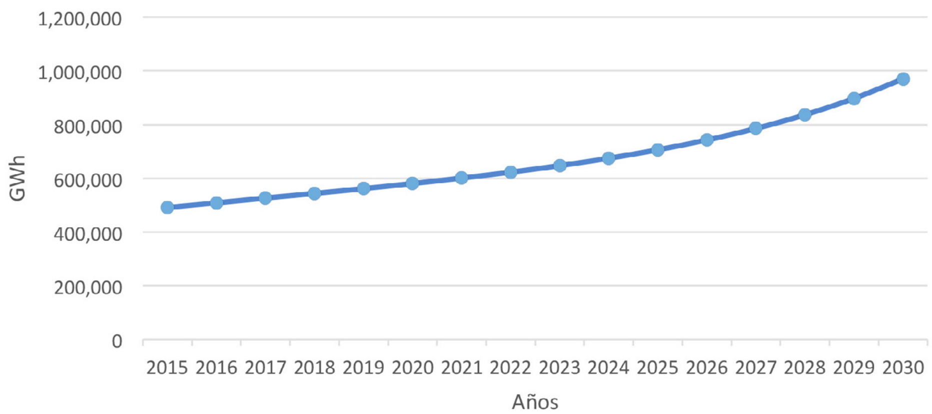
In the NFS the evolution of Brazil's final consumption matrix is characterized by a significant increase in the share represented by electricity, increased use of solar collectors for heating water and a significant reduction in the use of oil products.

Table 8.2. Projected final electricity consumption in Brazil, NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	491,241	580,484	706,127	969,971	4.6%

Source: Simulation results

Figure 8.3. Total electricity consumption in Brazil', NFS.



Source: Simulation results

A sharp increase in the annual growth of electricity consumption can be seen in the NFS for the last five years of the projection period (figure 8.3), due to simulated measures to expand electrification of end uses in the transportation, industrial, residential and commercial sectors.

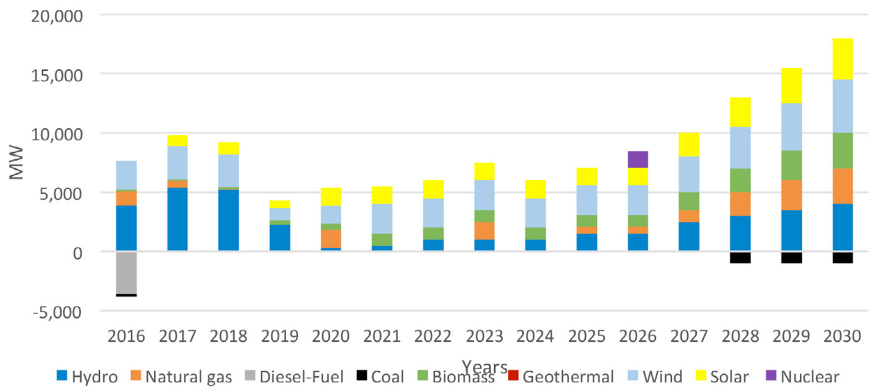
8.2.2 Projected electricity generation

Table 8.3. Timelines for installation/decommissioning of installed capacity (MW) in Brazil, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	3,868	1,215	-3,577	-215	137		2,392		
2017	5,380	591			129		2,818	939	
2018	5,218	28			172		2,755	1,030	
2019	2,285				324		1,047	670	
2020	265	1,521			571		1,500	1,500	
2021	500				1,000		2,500	1,500	
2022	1,000				1,000		2,500	1,500	
2023	1,000	1,500			1,000		2,500	1,500	
2024	1,000				1,000		2,500	1,500	
2025	1,500	584			1,000		2,500	1,500	
2026	1,500	583			1,000		2,500	1,500	1,405
2027	2,500	1,000			1,500		3,000	2,000	
2028	3,000	2,000		-1,000	2,000		3,500	2,500	
2029	3,500	2,500		-1,000	2,500		4,000	3,000	
2030	4,000	3,000		-1,000	3,000		4,500	3,500	

Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2026)

Figure 8.4. Timelines for installation/decommissioning of installed electricity generation capacity in Brazil, NFS



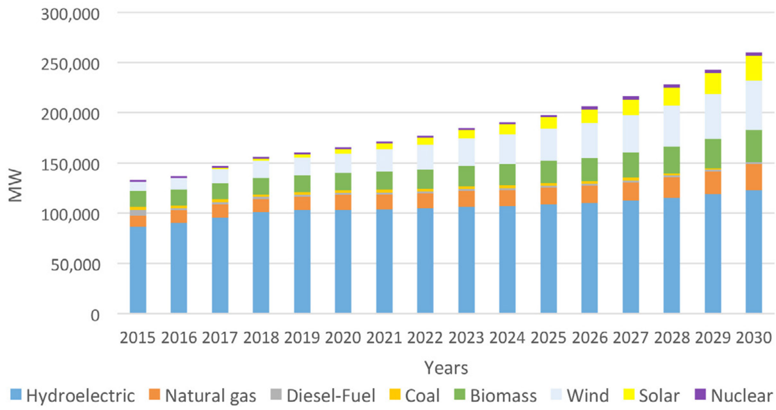
Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2017)

Table 8.4. Projected installed capacity in Brazil, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	86,540	103,556	108,556	123,056
Natural gas	11,317	14,672	16,756	25,839
Diesel-Fuel Oil	5,542	1,965	1,965	1,965
Coal	3,064	2,849	2,849	0
Biomass	15,773	17,106	22,106	32,106
Wind	9,029	19,541	32,041	49,541
Solar	37	4,176	11,676	24,176
Nuclear	1,990	1,990	1,990	3,395
TOTAL	**133,292**	**165,855**	**197,939**	**260,078**

Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2017)

Figure 8.5. Installed electricity generation capacity in Brazil, NFS



Source: By authors, based on Brazil's Ten-Year Energy Plan (2016-2017)

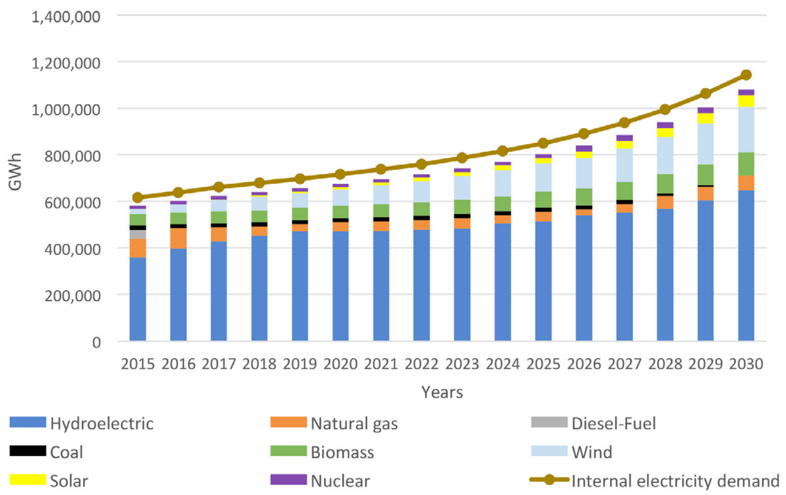
As can be seen in both the installation/decommissioning timeline, as well as in the graph on total installed capacity, installation of NCRE becomes very important in Brazil, especially in the last 5 years of the projection period, thanks to which wind power rises to second place in terms of importance in 2030, after hydroenergy.

Table 8.5. Projected electricity generation in Brazil, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	359,975	471,718	513,513	646,782
Natural gas	79,541	38,758	41,699	63,228
Diesel-Fuel Oil	37,735	0	0	0
Coal	19,108	17,767	17,767	0
Biomass	49,059	53,205	68,756	99,858
Wind	21,640	70,360	120,713	195,292
Solar	59	8,780	24,548	50,828
Nuclear	14,744	14,744	14,744	25,153
TOTAL	**581,861**	**675,332**	**801,740**	**1,081,141**

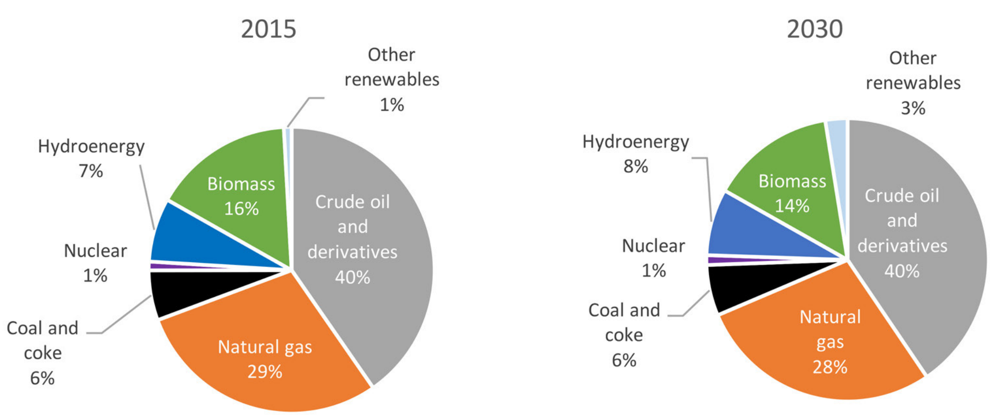
Source: CPS simulation results

Figure 8.6. Projected electricity generation in Brazil, NFS



Source: Simulation results

Figure 8.7. Evolution of electricity generation matrix in Brazil, NFS



Source: Simulation results

Regarding the evolution of Brazil's electricity generation matrix in the NFS, it is worth noting that the only nonrenewable sources still used in 2030 are natural gas and nuclear power, with a minority share, while renewable sources represent 92% of said matrix, with a considerable increase in the share of wind energy and solar power.

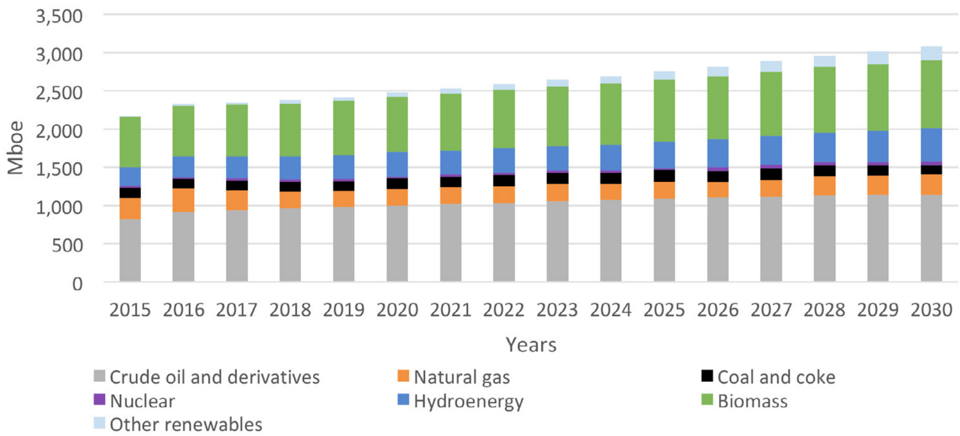
8.2.3 Projected total energy supply

Table 8.6. Projected total energy supply in Brazil, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	821	999	1,088	1,132	2.2%
Natural gas	281	213	224	271	-0.2%
Coal and coke	127	139	149	120	-0.4%
Nuclear	28	28	28	47	3.6%
Hydroenergy	244	316	347	438	4.0%
Biomass	655	724	815	893	2.1%
Other renewables	13	55	110	187	16.6%
TOTAL	**2,169**	**2,476**	**2,760**	**3,088**	**2.4%**

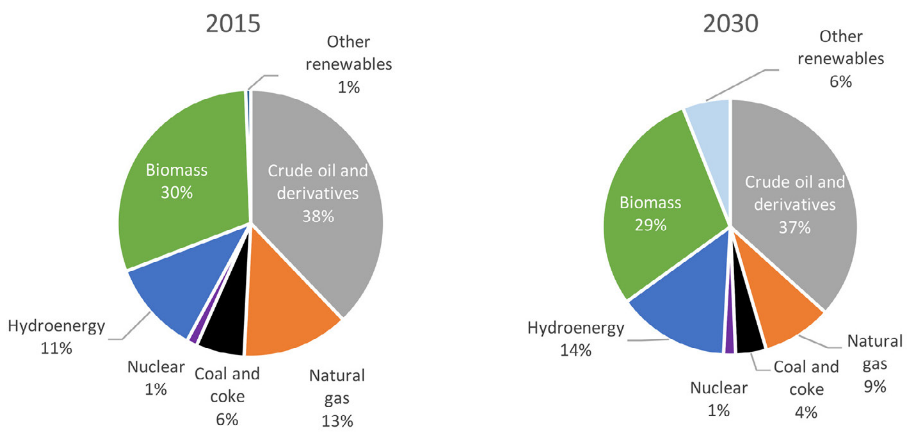
Source: CPS simulation results

Figure 8.8. Projected total energy supply in Brazil, NFS



Source: CPS simulation results

Figure 8.9. Evolution of total energy supply matrix in Brazil, NFS



Source: Simulation results

In a similar way to the situation with the electricity generation matrix, under the NFS simulation a significant increase in the renewability of the total energy supply matrix is achieved, rising from 42% in the base year to 49% in 2030.

8.3 Mexico

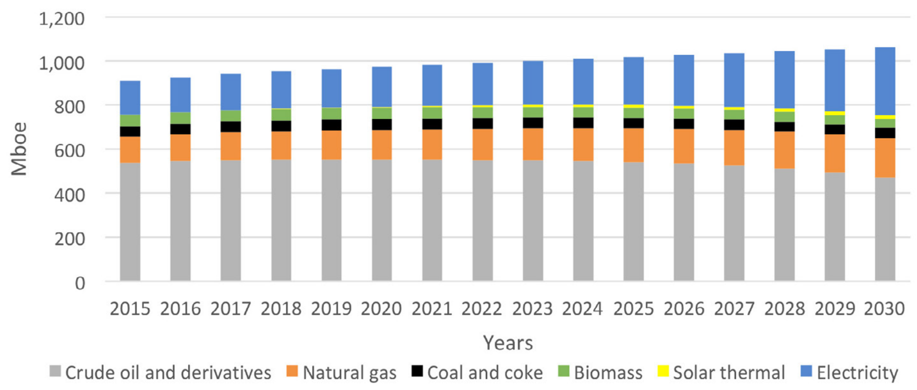
8.3.1 Projected final energy consumption

Table 8.7. Projected final energy consumption in Mexico, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	539	553	541	471	-0.9%
Natural gas	118	134	153	179	2.8%
Coal and coke	47	51	48	45	-0.4%
Biomass	52	51	46	41	-1.5%
Solar thermal	0	4	11	17	15.7%
Electricity	154	181	218	307	4.7%
TOTAL	**910**	**973**	**1,018**	**1,061**	**1.0%**

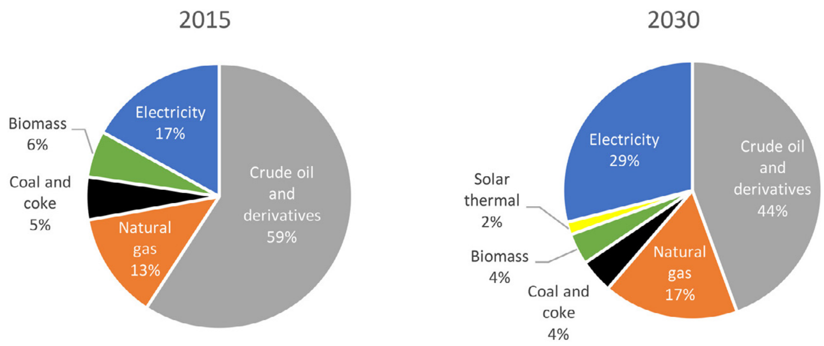
Source: Simulation results

Figure 8.10. Projected final energy consumption in Mexico, NFS



Source: Simulation results

Figure 8.11. Evolution of final energy consumption matrix in Mexico, NFS



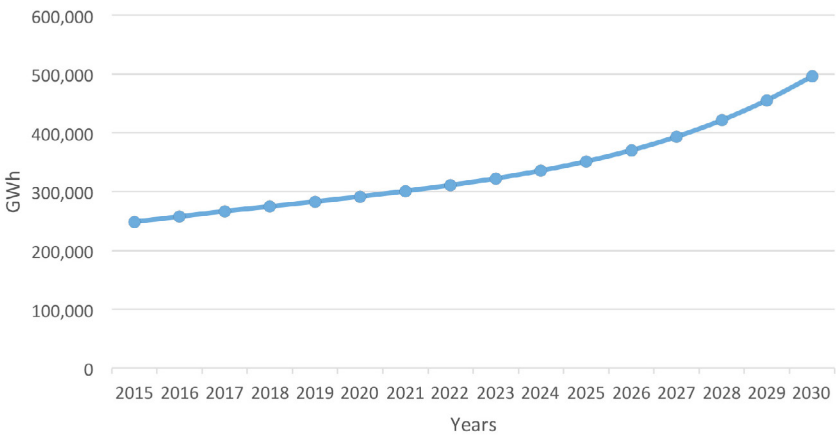
Source: Simulation results

The evolution of Mexico's final energy consumption matrix under the NFS shows a significant increase in the share represented by electricity and natural gas and a drastic cut in the use of oil products. The penetration by solar thermal power, corresponding to increased use of solar collectors to heat water, also stands out.

Table 8.8. Projected final electricity consumption in Mexico, NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	248,895	291,779	351,473	496,019	4.7%

Figure 8.12. Total electricity consumption in Mexico, NFS



Source: Simulation results

Annual electricity consumption in Mexico in the NFS shows a clear acceleration in the last five years of the projection period, as can be seen in Figure 8.12, doubling by 2030 compared to the base year. This is due to measures for the electrification of end uses in the main consumer sectors, including transportation.

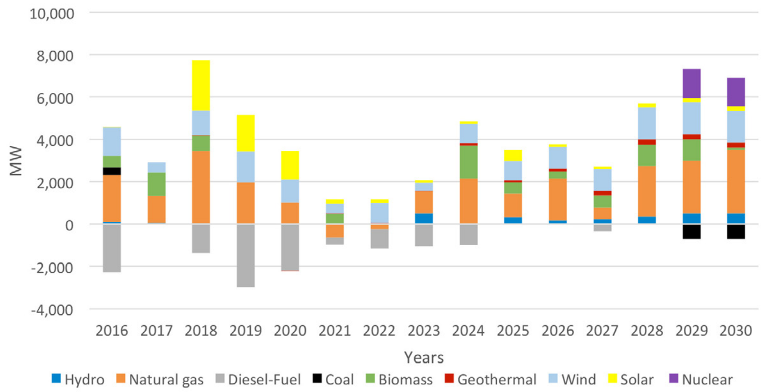
8.3.2 Projected electricity generation

Table 8.9. Timelines for installation/decommissioning of installed capacity (MW) in Mexico, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	101	2,211	-2,280	378	527		1,361	14	
2017	53	1,284			1,096		468		
2018	29	3,404	-1,355		750	10	1,176	2,364	
2019		1,965	-2,974				1,452	1,727	
2020		1,017	-2,189			-30	1,093	1,335	
2021	27	-640	-320		452	25	450	205	
2022		-245	-899			50	944	162	
2023	516	1,034	-1,058			30	356	130	
2024		2,143	-992		1,574	116	910	120	
2025	327	1,109			533	108	891	537	
2026	186	1,963			336	130	1,026	120	
2027	230	539	-341		580	230	1,013	102	
2028	351	2,403			1,000	250	1,500	200	
2029	500	2,500		-700	1,000	250	1,500	200	1,360
2030	500	3,000		-700	100	250	1,500	200	1,361

Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 8.13. Timelines for installation/decommissioning of installed electricity generation capacity in Mexico, NFS



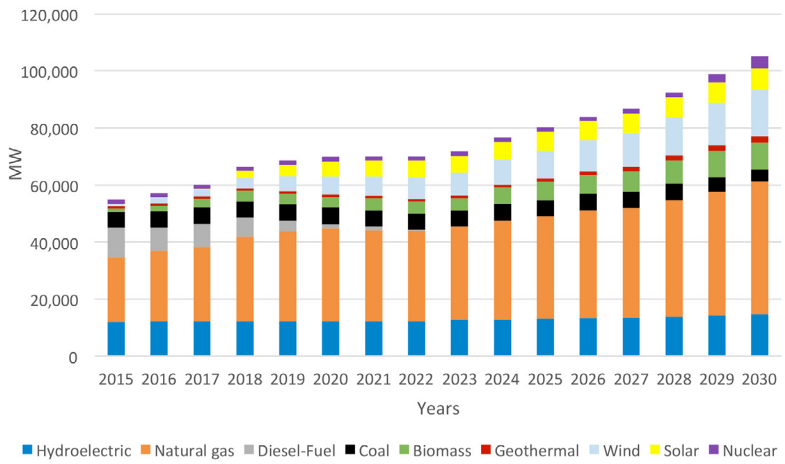
Fuente: Elaboración propia en base al documento "Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles Más Limpios" (SENER, 2016)

Table 8.10. Projected installed capacity in Mexico, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	12,028	12,211	13,081	14,848
Natural gas	22,658	32,539	35,940	46,345
Diesel-Fuel Oil	10,353	1,555	0	0
Coal	5,378	5,756	5,756	4,356
Biomass	1,347	3,720	6,279	9,295
Geothermal	874	854	1,183	2,293
Wind	699	6,249	9,800	16,339
Solar	6	5,446	6,600	7,422
Nuclear	1,510	1,510	1,510	4,231
TOTAL	**54,853**	**69,840**	**80,149**	**105,129**

Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

Figure 8.14. Installed electricity generation capacity in Mexico, NFS



Source: By authors, based on the document "Transition Strategy for Promoting the Use of Cleaner Technologies and Fuels" (SENER, 2016)

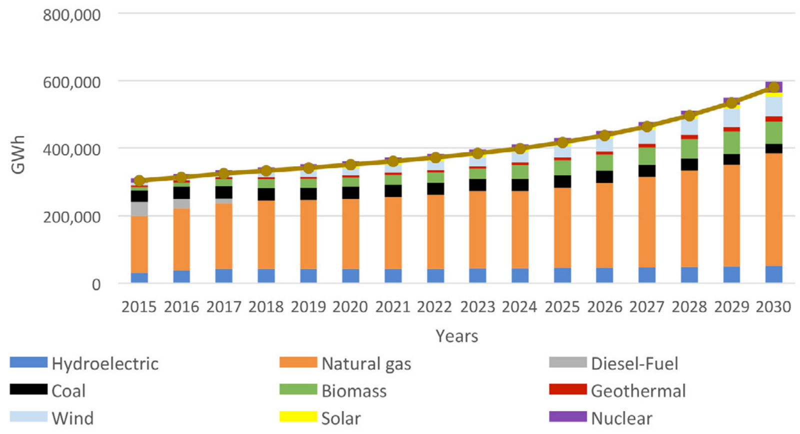
Under NFS assumptions, Mexico's installed capacity is characterized by highly representative implementation of natural gas power plants and NCRE like wind, solar, geothermal and biomass, completely removing thermoelectric capacity fueled by oil products. This scenario maintains the expansion in nuclear power capacity in the last two years in the projection period.

Table 8.11. Projected electricity generation in Mexico, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	30,955	42,787	45,836	52,027
Natural gas	167,842	207,617	237,062	333,749
Diesel-Fuel Oil	42,099	0	0	0
Coal	33,741	36,304	36,304	27,474
Biomass	9,503	26,396	44,553	65,954
Geothermal	6,191	6,060	8,394	16,270
Wind	8,667	21,897	34,340	57,252
Solar	93	9,541	11,563	13,003
Nuclear	11,453	11,508	11,508	32,245
TOTAL	**310,544**	**362,110**	**429,560**	**597,975**

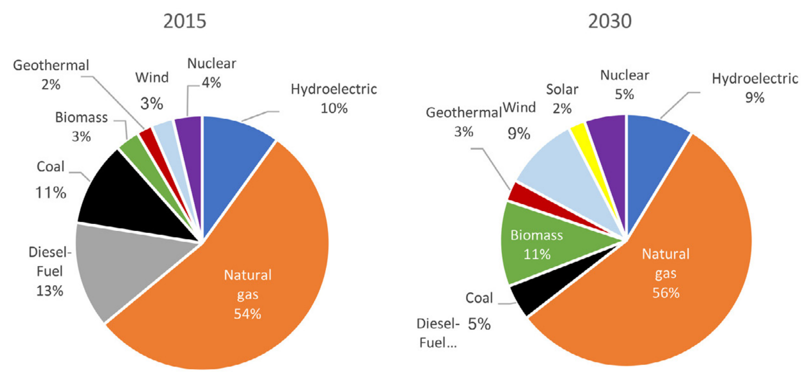
Source: Simulation results

Figure 8.15. Projected electricity generation in Mexico, NFS



Source: Simulation results

Figure 8.16. Evolution of electricity generation matrix in Mexico, NFS



Source: Simulation results

The NFS shows clear penetration by NCRE in Mexico's electricity generation matrix, such as wind, solar, biomass and geothermal power, which together go from representing a modest 8% in the base year to a significant 25% in 2030. The share of natural gas also increases, while dispensing with the use of oil products completely.

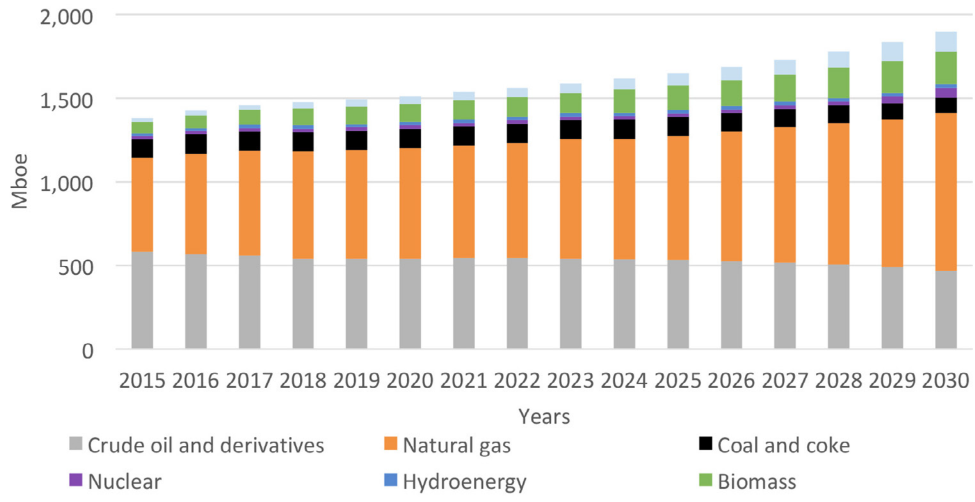
8.3.3 Projected total energy supply

Table 8.12. Projected total energy supply in Mexico, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	580	542	534	469	-1.4%
Natural gas	566	660	741	945	3.5%
Coal and coke	109	116	112	90	-1.3%
Nuclear	21	21	21	58	7.1%
Hydroenergy	15	20	21	22	2.6%
Biomass	69	107	150	194	7.1%
Other renewables	23	46	71	121	11.7%
TOTAL	**1,382**	**1,511**	**1,649**	**1,898**	**2.1%**

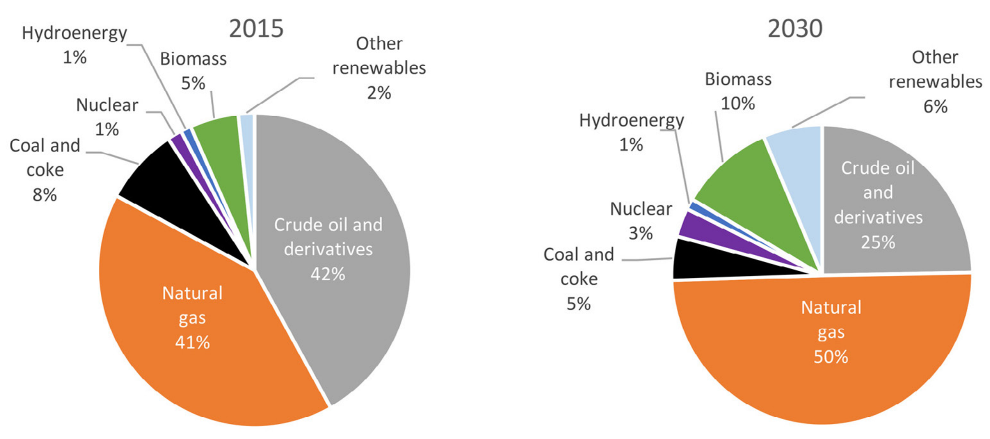
Source: Simulation results

Figure 8.17. Projected total energy supply in Mexico, NFS



Source: Simulation results

Figure 8.18. Evolution of total energy supply matrix in the Andean sub-region, NFS



Source: Simulation results

Mexico's total energy supply matrix in the NFS shows the participation by natural gas rise to 50% of the matrix, while oil products suffer a drastic reduction Biomass and other renewable sources such as wind, solar and geothermal power gain a significant share during the projection period.

8.4 Central America

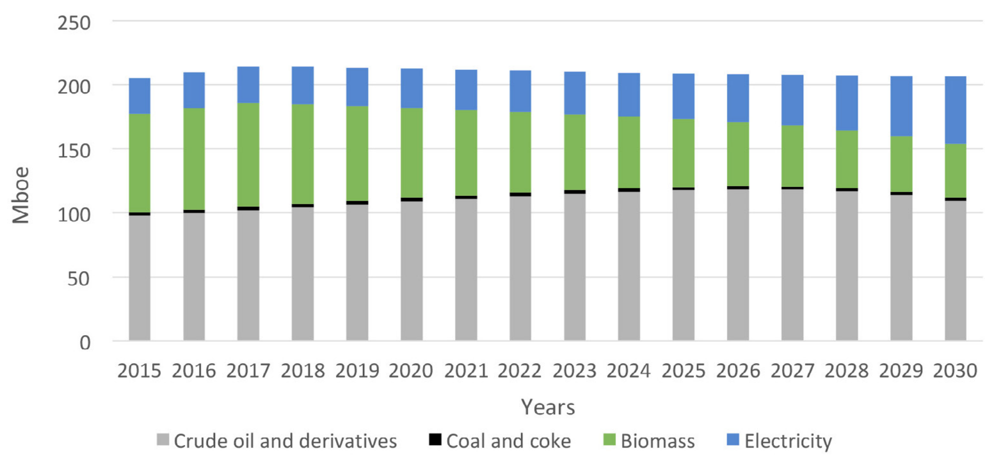
8.4.1 Projected final energy consumption

Table 8.13. Projected final energy consumption in Central America, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	98	109	118	109	0.7%
Coal and coke	3	3	3	2	-0.9%
Biomass	77	70	53	42	-4.0%
Solar thermal	0	1	3	6	17.9%
Electricity	27	31	36	53	4.5%
TOTAL	**205**	**214**	**212**	**212**	**0.2%**

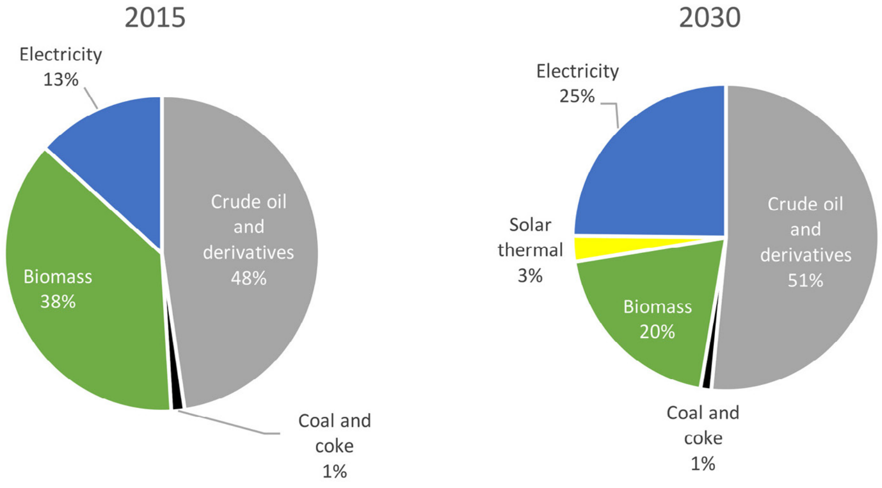
Source: Simulation results

Figure 8.19. Projected final energy consumption in Central America, NFS



Source: Simulation results

Figure 8.20. Evolution of final energy consumption matrix in Central America, NFS



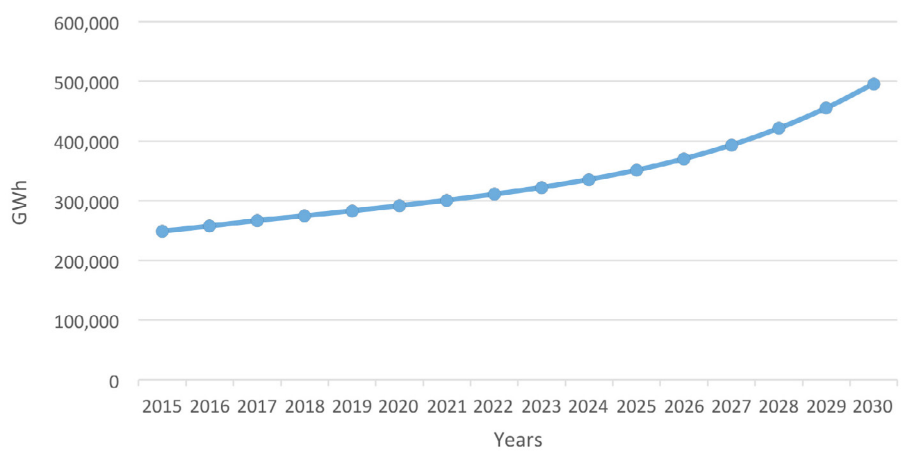
Source: Simulation results

Evolution in the final consumption matrix in Central America under NFS assumptions is characterized by a reversal in the growth of total consumption, thanks to energy efficiency measures, so that the value for 2030, it is almost equal to that of the base year. In addition, there is a clear substitution of firewood with LPG and electricity, allowing this source and oil products to gain in their share of the matrix.

Table 8.14. Projected final electricity consumption in Central America, NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	44,082	49,679	57,622	84,959	4.5%

Figure 8.21. Total electricity consumption in Central America, NFS



Source: Simulation results

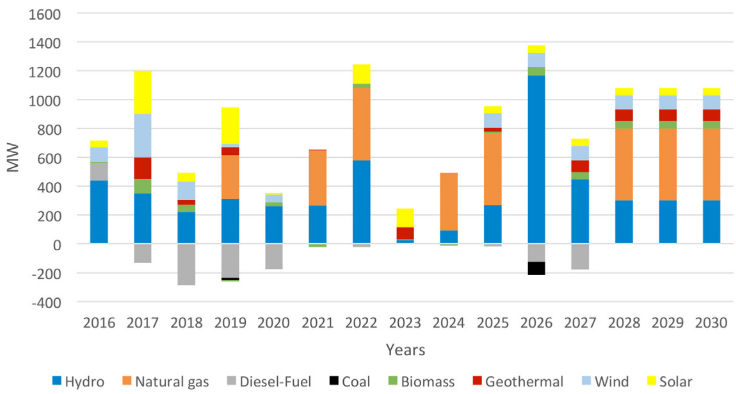
8.4.2 Projected electricity generation

Table 8.15. Timelines for installation/decommissioning of installed capacity (MW) in Central America, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
2016	437		120		10		100	50
2017	350		-132		100	150	300	300
2018	220		-286		50	35	127	61
2019	314	300	-237	-16	-8	55	23	253
2020	263		-177		25		50	12
2021	266	380			-22	8		
2022	579	500	-22		32			133
2023	26				3	87		130
2024	92	400			-14			
2025	267	500	-20		13	25	100	50
2026	1,166		-125	-90	60		100	50
2027	448		-180		50	80	100	50
2028	300	500			50	80	100	50
2029	300	500			50	80	100	50
2030	300	500			50	80	100	50

Source: By authors, based on national electricity sector expansion plans

Figure 8.22. Timelines for installation/decommissioning of installed electricity generation capacity in Central America, NFS



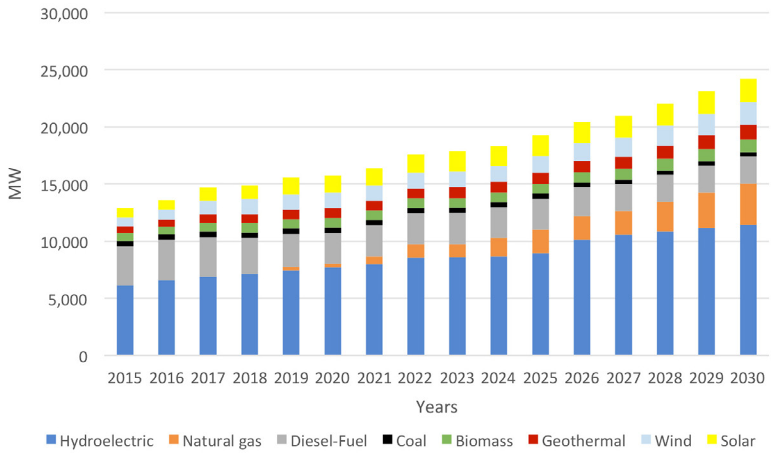
Source: By authors, based on national electricity sector expansion plans

Table 8.16. Projected Installed capacity in Central America, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	6,122	7,706	8,936	11,450
Natural gas	0	300	2,080	3,580
Diesel-Fuel Oil	3,436	2,724	2,682	2,377
Coal	482	466	466	376
Biomass	667	845	856	1,116
Geothermal	610	850	970	1,290
Wind	773	1,373	1,473	1,973
Solar	804	1,479	1,792	2,042
TOTAL	**12,894**	**15,742**	**19,254**	**24,204**

Source: By authors, based on national electricity sector expansion plans

Figure 8.23. Installed electricity generation capacity in Central America, NFS



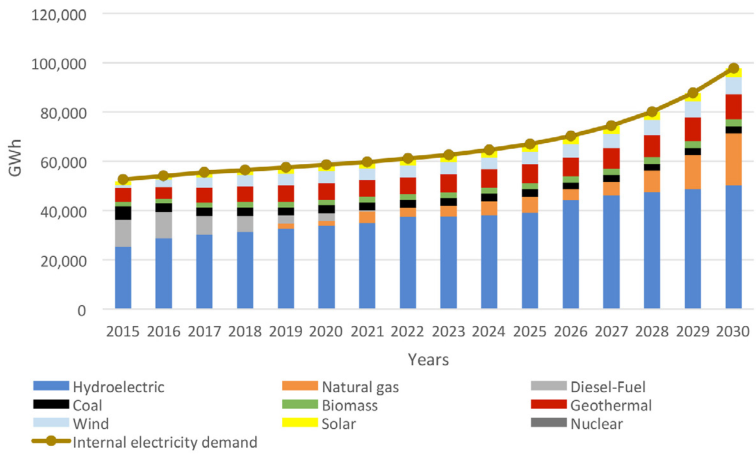
Source: By authors, based on national electricity sector expansion plans

Table 8.17. Projected electricity generation in Central America, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	25,195	33,751	39,141	50,153
Natural gas	0	2,102	6,350	21,187
Diesel-Fuel Oil	11,004	3,039	0	0
Coal	5,446	3,264	3,264	2,633
Biomass	1,810	2,294	2,324	3,030
Geothermal	5,670	6,701	7,647	10,170
Wind	1,291	4,811	5,161	6,913
Solar	1,408	2,592	3,139	3,577
TOTAL	**51,824**	**58,555**	**67,027**	**97,665**

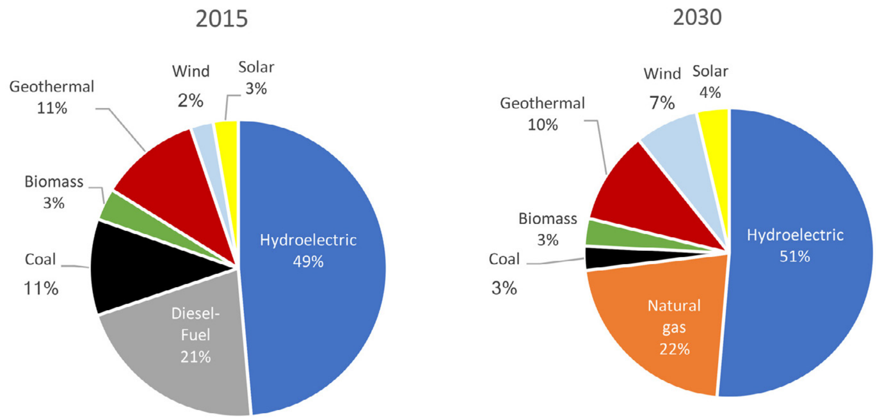
Source: Simulation results

Figure 8.24. Projected electricity generation in Central America, NFS



Source: Simulation results

Figure 8.25. Evolution of electricity generation matrix in Central America, NFS



Source: Simulation results

Under NFS assumptions, the proportion of renewable energy sources will increase significantly in Central America by 2030 and, together with natural gas, will completely displace oil productgs and considerably reduce the share represented by coal.

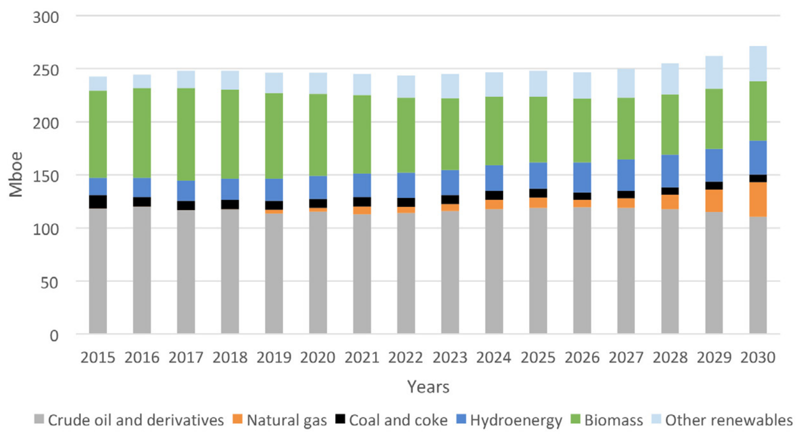
8.4.3 Projected total energy supply

Table 8.18. Projected total energy supply in Central America, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	118	116	119	110	-0.5%
Natural gas	0.01	3	10	33	76.9%
Coal and coke	12	9	8	7	-3.7%
Hydroenergy	17	22	25	32	4.5%
Biomass	82	78	62	56	-2.5%
Other renewables	13	19	24	33	6.2%
TOTAL	**243**	**246**	**248**	**272**	**0.7%**

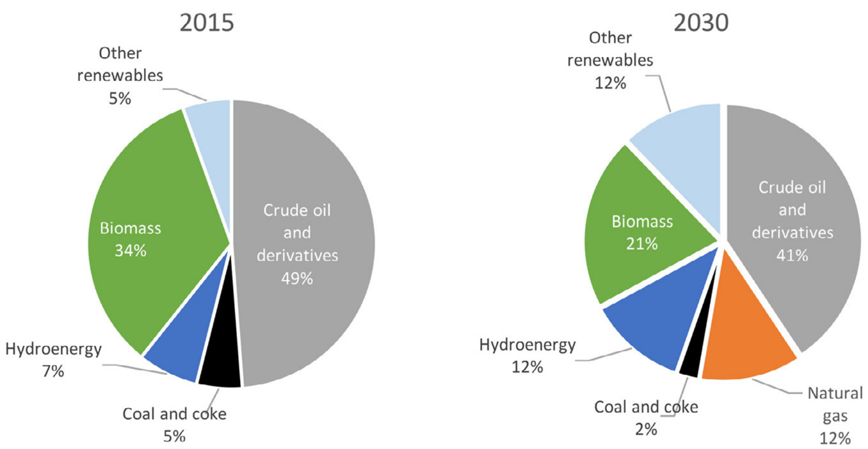
Source: Simulation results

Figure 8.26. Projected total energy supply in Central America, NFS



Source: Simulation results

Figure 8.27. Evolution in total energy supply matrix in Central America, NFS



Source: Simulation results

Under NFS assumptions, the decline in the share of biomass and oil products stands out in Central America's total energy supply matrix, as does the significant increase in renewable energies and natural gas.

8.5 Andean Subregion

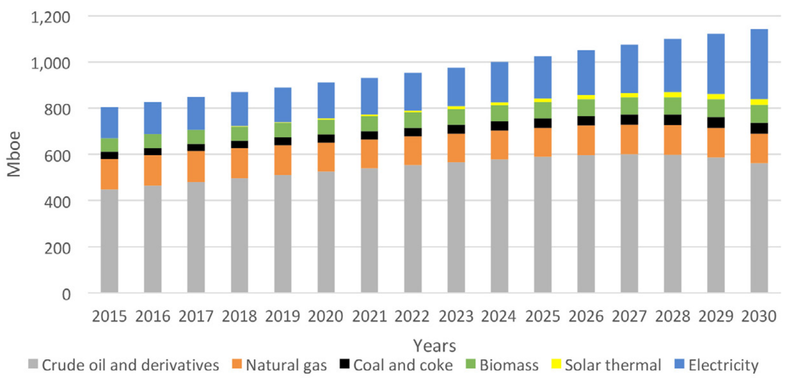
8.5.1 Projected final energy consumption

Table 8.19. Projected final energy consumption in the Andean Subregion, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	447	525	589	561	1.5%
Natural gas	134	126	126	129	-0.2%
Coal and coke	29	36	41	46	3.1%
Biomass	60	64	71	78	1.8%
Solar thermal	0	5	15	25	17.9%
Electricity	133	154	182	303	5.6%
TOTAL	**803**	**910**	**1,024**	**1,142**	**2.4%**

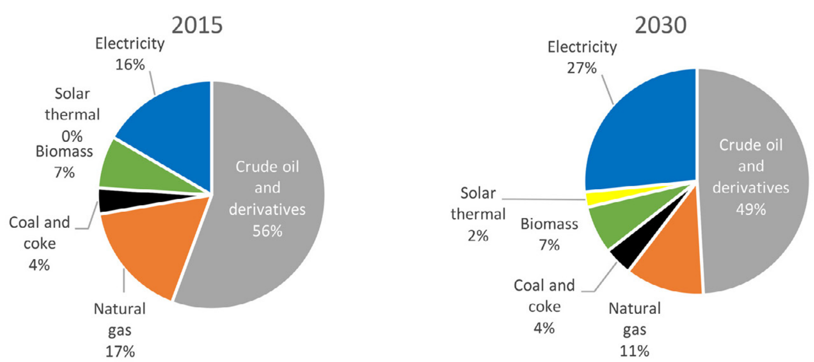
Source: Simulation results

Figure 8.28. Projected final energy consumption in the Andean Subregion, NFS



Source: Simulation results

Figure 8.29. Evolution of final energy consumption matrix in the Andean Subregion, NFS



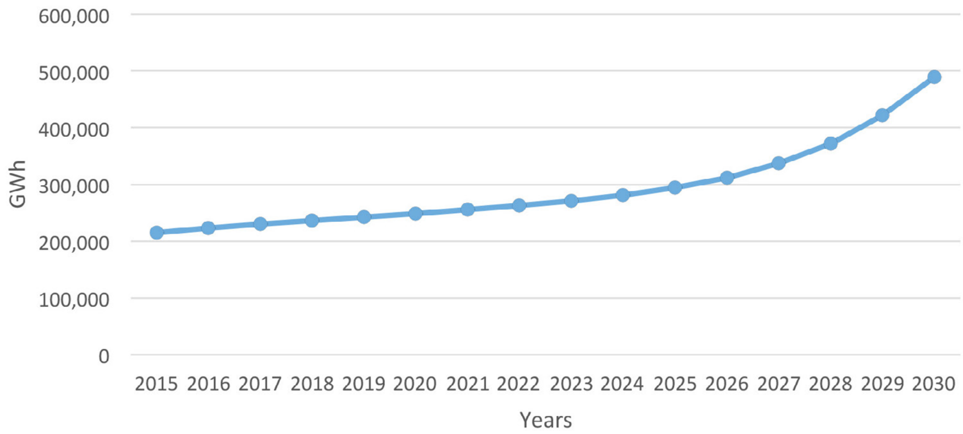
Source: Simulation results

Thanks to increased electrification of the main consumption sectors, one of the assumptions in the NFS, electricity gains a significant share in the Andean Subregion's final consumption matrix, displacing hydrocarbons.

Table 8.20. Projected final electricity consumption in the Andean Subregion, NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	215,097	248,928	294,494	488,880	5.6%

Figure 8.30. Total electricity consumption in the Andean Subregion, NFS



Source: Simulation results

The assumption of expanded electrification of the main consumption sectors causes a clear acceleration in electricity consumption in the final years of the projection period.

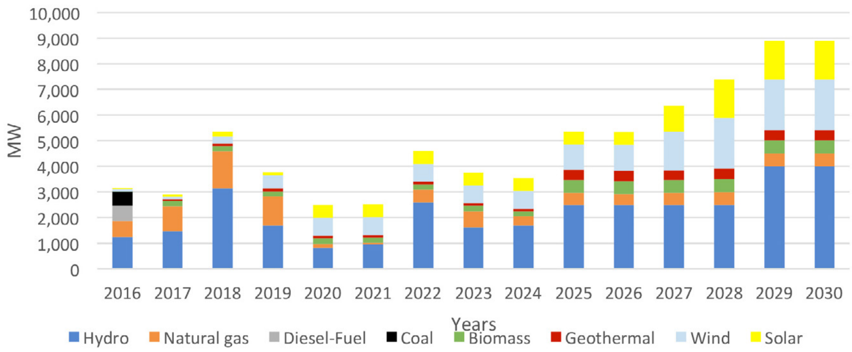
8.5.2 Projected electricity generation

Table 8.21. Timelines for installation/decommissioning of installed capacity (MW) in the Andean Subregion, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
2016	1.234	620	610	543	2	0	95	42
2017	1,447	1,000			200	51	100	100
2018	3,124	1,458			200	100	282	190
2019	1,688	1,138			200	100	523	113
2020	808	173			200	100	709	500
2021	947	72			200	100	700	500
2022	2,598	497			200	100	700	500
2023	1,613	637			200	100	700	500
2024	1,681	363			200	100	700	500
2025	2,500	456			500	400	1,000	500
2026	2,500	423			500	400	1,000	500
2027	2,500	453			500	400	1,500	1,000
2028	2,500	500			500	400	2,000	1,500
2029	4,000	500			500	400	2,000	1,500
2030	4,000	500			500	400	2,000	1,500

Source: By authors, based on national electricity sector expansion plans

Figure 8.31. Timelines for installation/decommissioning of installed electricity generation capacity in the Andean Subregion, NFS



Source: By authors, based on national electricity sector expansion plans

Table 8.22. Projected Installed capacity in the Andean Subregion NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	28,019	36,320	45,660	61,160
Natural gas	11,089	15,477	17,503	19,879
Diesel-Fuel Oil	13,041	13,652	13,652	13,652
Coal	992	1,535	1,535	1,535
Biomass	984	1,786	3,086	5,586
Geothermal	0	351	1,151	3,151
Wind	429	2,139	5,939	14,439
Solar	184	1,129	3,629	9,629
TOTAL	**54,738**	**72,390**	**92,155**	**129,031**

Source: By authors, based on national electricity sector expansion plans

Figure 8.32. Installed electricity generation capacity in the Andean Subregion, NFS

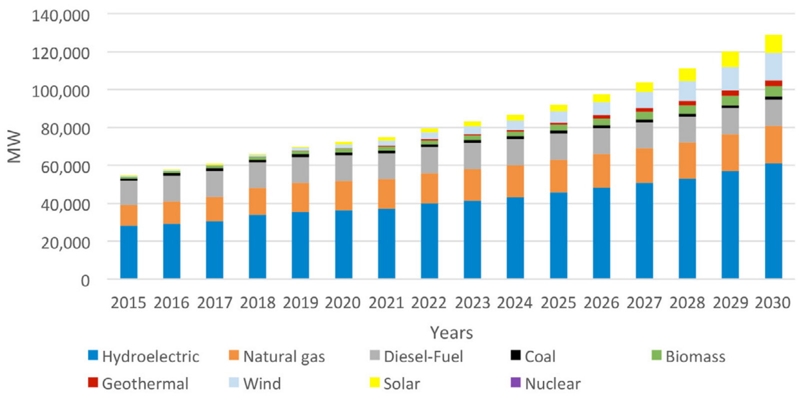


Table 8.22. Projected Installed capacity in the Andean Subregion NFS (MW)

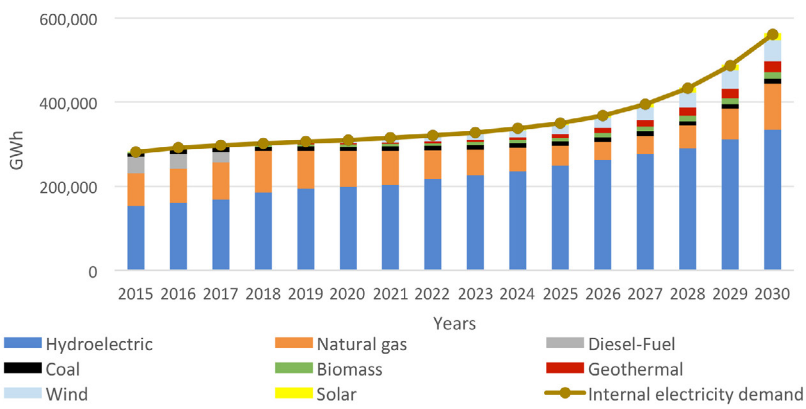
Expansion in the installed capacity based on renewable energies covers the accelerated growth in electricity under the NFS.

Table 8.23. Projected electricity generation in the Andean Subregion, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	152,886	198,181	249,141	333,716
Natural gas	77,709	85,287	46,673	110,949
Diesel-Fuel Oil	39,985	0	0	0
Coal	6,953	10,760	10,760	10,760
Biomass	2,844	5,163	8,921	16,148
Geothermal	0	2,769	9,076	24,844
Wind	1,503	7,493	20,809	50,593
Solar	323	1,979	6,359	16,871
TOTAL	**282,203**	**311,632**	**351,738**	**563,880**

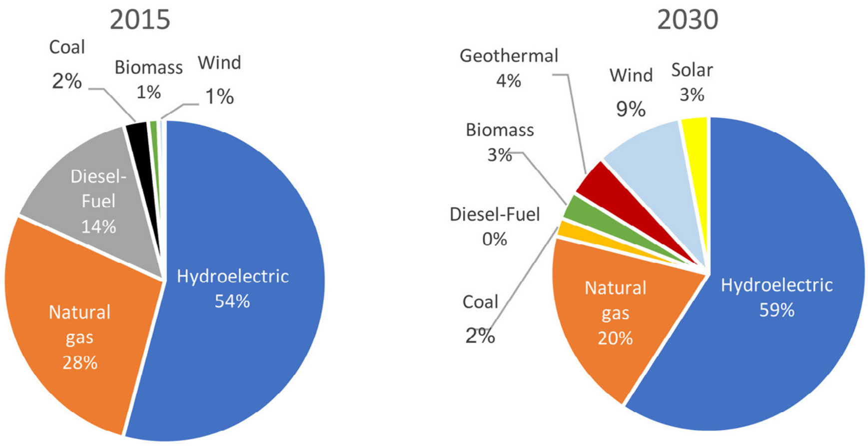
Source: Simulation results

Figure 8.33. Projected electricity generation in the Andean Subregion, NFS



Source: Simulation results

Figure 8.34. Evolution of electricity generation matrix in the Andean Subregion, NFS



Source: Simulation results

Under NFS assumptions, NCRE such as wind, geothermal, biomass and solar power gain in importance in the evolution of the Andean Subregion's electricity generation matrix.

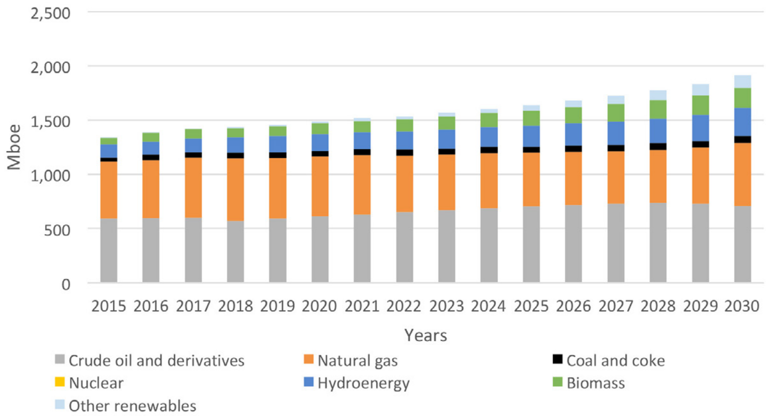
8.5.3 Projected total energy supply

Table 8.24. Projected total energy supply in the Andean Subregion, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	591	611	704	709	1.2%
Natural gas	525	553	493	580	0.7%
Coal and coke	41	54	58	63	3.0%
Hydroenergy	118	153	193	258	5.3%
Biomass	63	99	139	185	7.5%
Other renewables	1	16	51	118	36.3%
TOTAL	**1,339**	**1,486**	**1,639**	**1,914**	**2.4%**

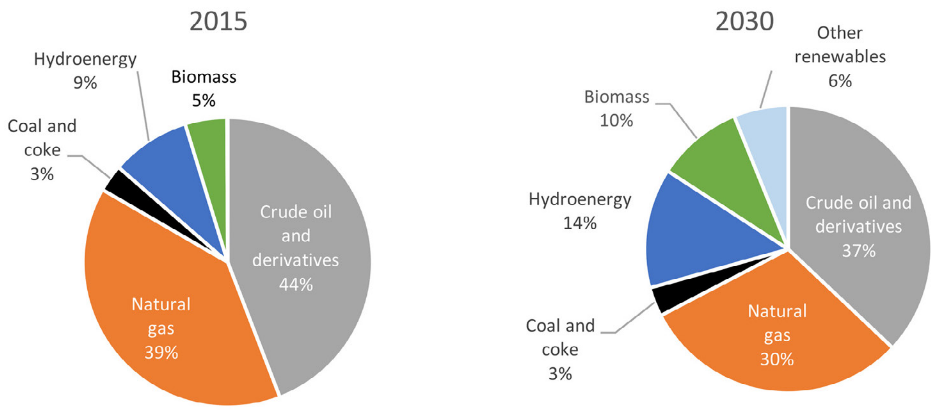
Source: Simulation results

Figure 8.35. Projected total energy supply in the Andean Subregion, NFS



Source: Simulation results

Figure 8.36. Evolution of total energy supply matrix in the Andean subregion, NFS



Source: Simulation results

There is an increased share of renewable energies in the total supply matrix, including hydroenergy, thus displacing hydrocarbons.

8.6 Southern Cone

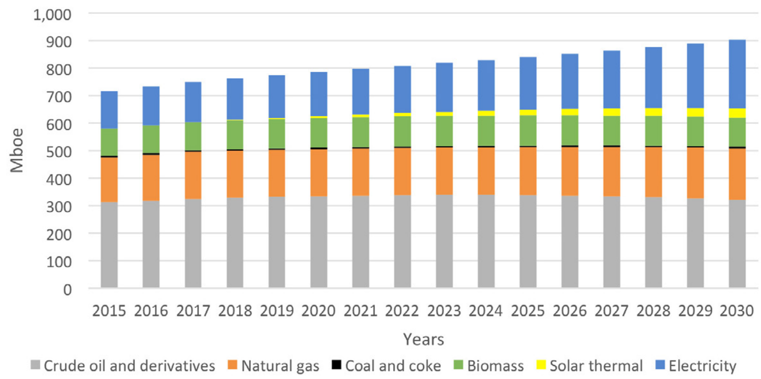
8.6.1 Projected final energy consumption

Table 8.25. Projected final energy consumption in the Southern Cone, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	312	335	338	320	0.2%
Natural gas	163	170	175	188	1.0%
Coal and coke	6	6	6	6	-0.4%
Biomass	100	108	109	107	0.5%
Solar thermal	0	7	20	33	17.6%
Electricity	136	160	192	249	4.1%
TOTAL	**717**	**786**	**840**	**903**	**1.5%**

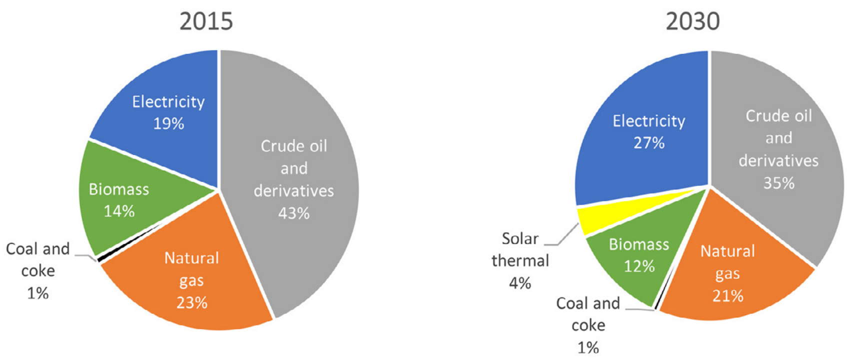
Source: Simulation results

Figure 8.37. Projected final energy consumption in the Southern Cone, NFS



Source: Simulation results

Figure 8.38. Evolution of final energy consumption matrix in the Southern Cone, NFS



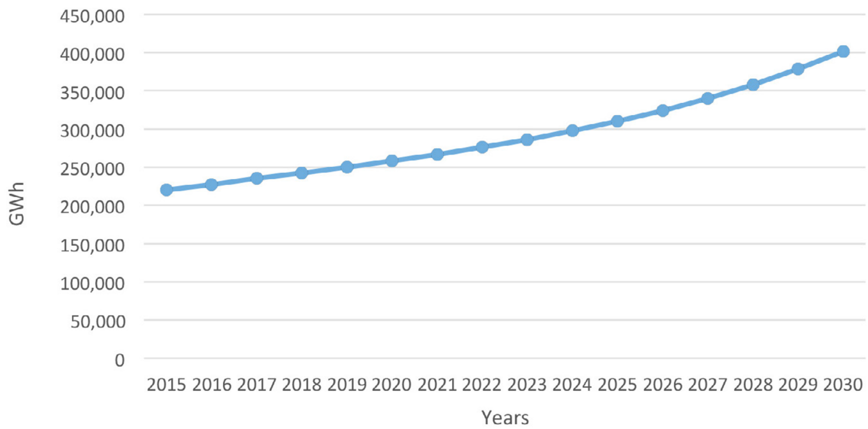
Source: Simulation results

Electricity and incresaed use of solar collectors to heat water allow the share of hydrocarbins in the final consumption matrix to be reduced.

Table 8.26. Projected final energy consumption in the Southern Cone, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Electricity	219,915	258,292	310,016	401,637	4.1%

Figure 8.39. Total electricity consumption in the Southern Cone, NFS



Source: Simulation results

Electricity consumption in the Southern Cone doubles during the projection period under the NFS.

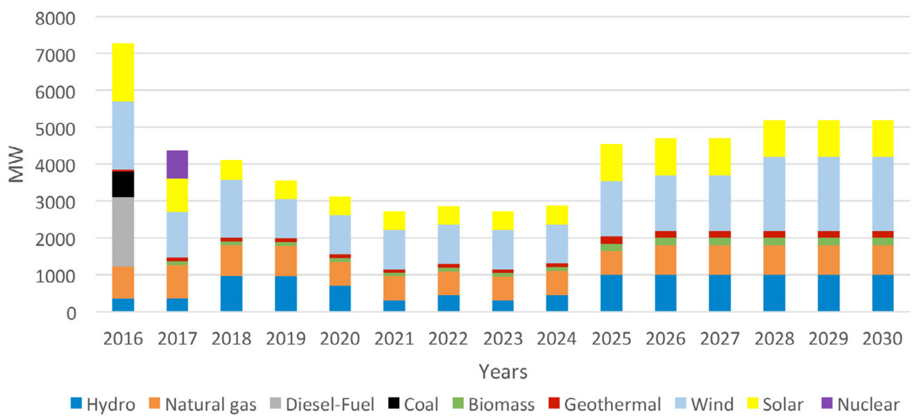
8.6.2 Projected electricity generation

Table 8.27. Timelines for installation/decommissioning of installed capacity (MW) in the Southern Cone NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	356	865	1,888	688	0	48	1,863	1,569	0
2017	362	901	0	0	100	100	1,241	917	745
2018	981	824	0	0	100	100	1,566	535	0
2019	959	824	0	0	100	100	1,066	500	0
2020	706	644	0	0	100	100	1,066	500	0
2021	312	644	0	0	100	100	1,066	500	0
2022	453	644	0	0	100	100	1,066	500	0
2023	309	644	0	0	100	100	1,066	500	0
2024	459	644	0	0	100	100	1,066	500	0
2025	1,000	644	0	0	200	200	1,500	1,000	0
2026	1,000	800	0	0	200	200	1,500	1,000	0
2027	1,000	800	0	0	200	200	1,500	1,000	0
2028	1,000	800	0	0	200	200	2,000	1,000	0
2029	1,000	800	0	0	200	200	2,000	1,000	0
2030	1,000	800	0	0	200	200	2,000	1,000	0

Source: by authors, based on national electricity sector expansion plans

Figure 8.40. Timelines for installation/decommissioning of installed electricity generation capacity in the Southern Cone, NFS



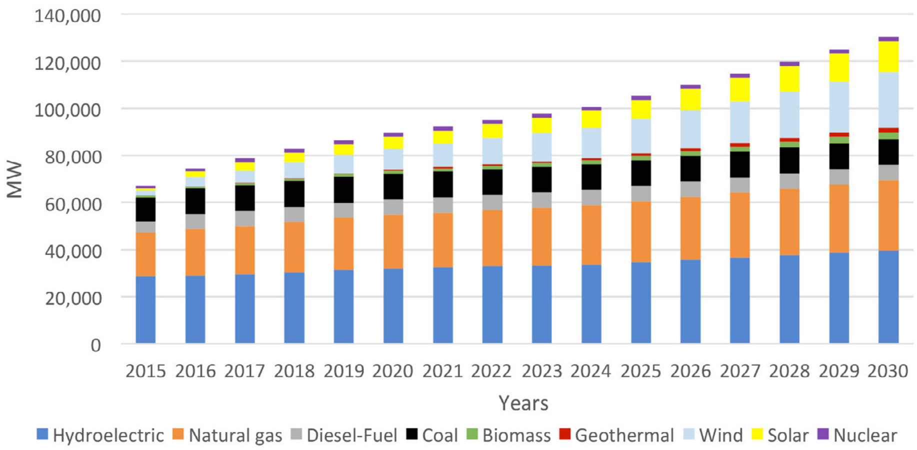
Source: by authors, based on national electricity sector expansion plans

Table 8.28. Projected Installed capacity in the Southern Cone, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	28,732	32,096	34,629	39,629
Natural gas	18,647	22,705	25,925	29,925
Diesel-Fuel Oil	4,513	6,401	6,401	6,401
Coal	10,320	11,008	11,008	11,008
Biomass	829	1,229	1,829	2,829
Geothermal	0	448	1,048	2,048
Wind	2,054	8,856	14,620	23,620
Solar	1,000	5,021	8,021	13,021
Nuclear	1,010	1,755	1,755	1,755
TOTAL	**67,104**	**89,518**	**105,235**	**130,235**

Source: by authors, based on national electricity sector expansion plans

Figure 8.41. Installed electricity generation capacity in the Southern Cone, NFS



Source: by authors, based on national electricity sector expansion plans

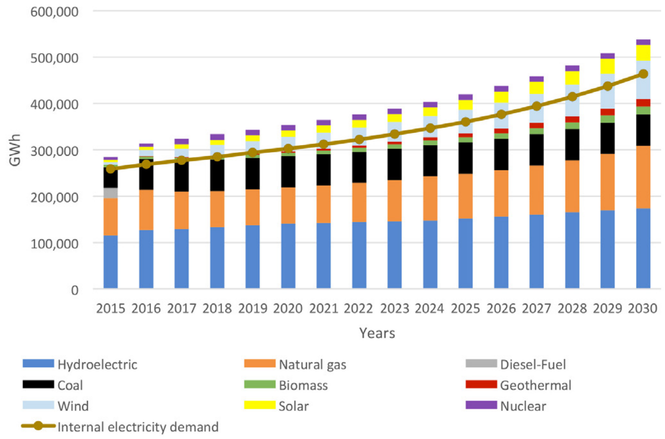
The implementation of wind farms predominates in the expansion of the Southern Cone's installed capacity, rising to the position of third most important technology after hydroelectric and natural gas power plants by 2030.

Table 8.29. Projected electricity generation in the Southern Cone, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	115,574	140,579	151,673	173,573
Natural gas	80,222	77,837	96,664	134,872
Diesel-Fuel Oil	21,789	0	0	0
Coal	44,972	67,499	67,499	67,499
Biomass	4,944	7,320	10,894	16,851
Geothermal	0	3,532	8,262	16,146
Wind	6,112	31,032	51,230	82,766
Solar	3,799	13,195	21,079	34,219
Nuclear	7,081	12,299	12,299	12,299
TOTAL	**284,493**	**353,293**	**419,600**	**538,225**

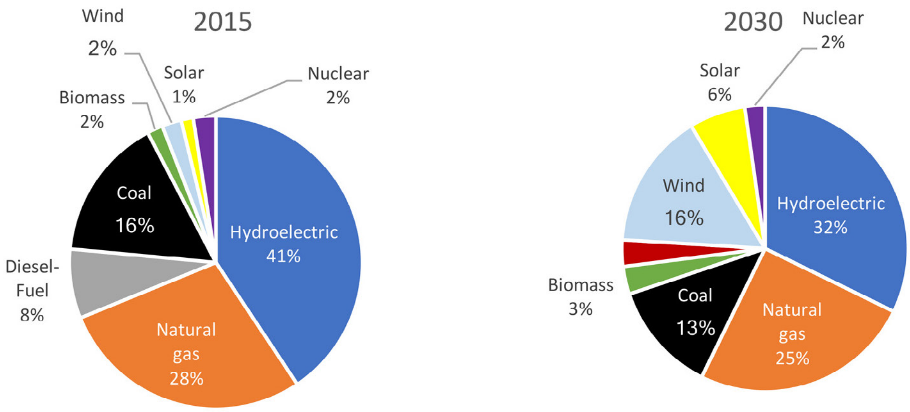
Source: Simulation results

Figure 8.42. Projected electricity generation in the Southern Cone, NFS



Source: Simulation results

Figure 8.43. Evolution of electricity generation matrix in the Southern Cone, NFS



Source: Simulation results

Under NFS assumptions, there is a considerable increase in the share of NCRE in the Southern Cone's electricity generation matrix, with wind power standing out above the others.

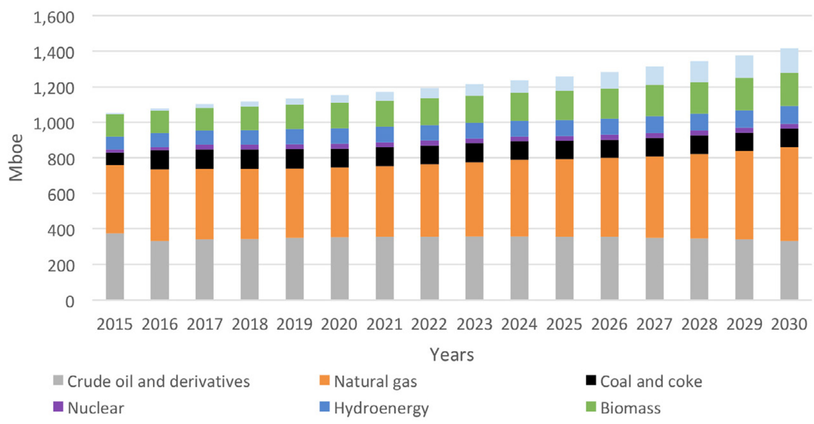
8.6.3 Projected total energy supply

Table 8.30. Projected total energy supply in the Caribbean, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	374	352	356	333	-0.8%
Natural gas	384	394	437	527	2.1%
Coal and coke	71	107	104	105	2.7%
Nuclear	16	28	28	28	3.7%
Hydroenergy	76	86	90	99	1.8%
Biomass	124	144	164	187	2.8%
Other renewables	6	41	82	139	23.1%
TOTAL	**1,052**	**1,152**	**1,260**	**1,417**	**2.0%**

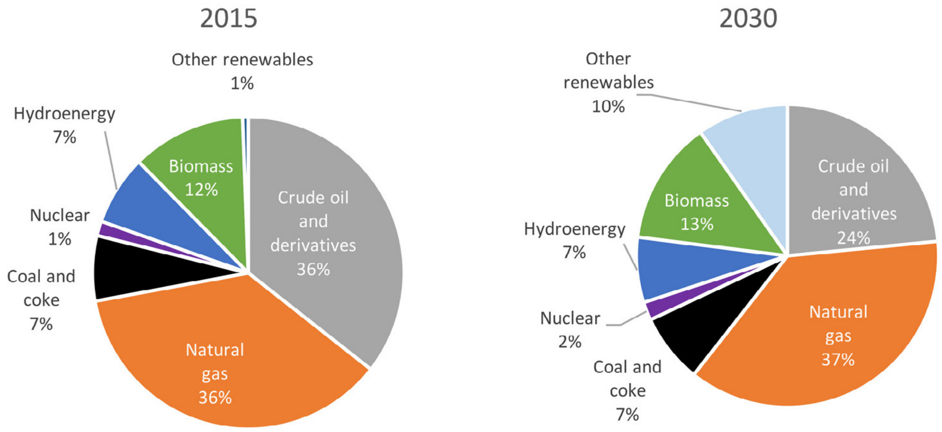
Source: Simulation results

Figure 8.44. Projected total energy supply in the Southern Cone, NFS (Mboe)



Source: Simulation results

Figure 8.45. Evolution of total energy supply in the Caribbean, NFS



Source: Simulation results

The renewability of the Southern Cone's total energy supply matrix improves under the NFS, thanks to penetration by nonconventional renewable sources such as wind, solar and geothermal power. Natural gas and biomass also gain a larger share, taking it from the use of oil products.

8.7 The Caribbean

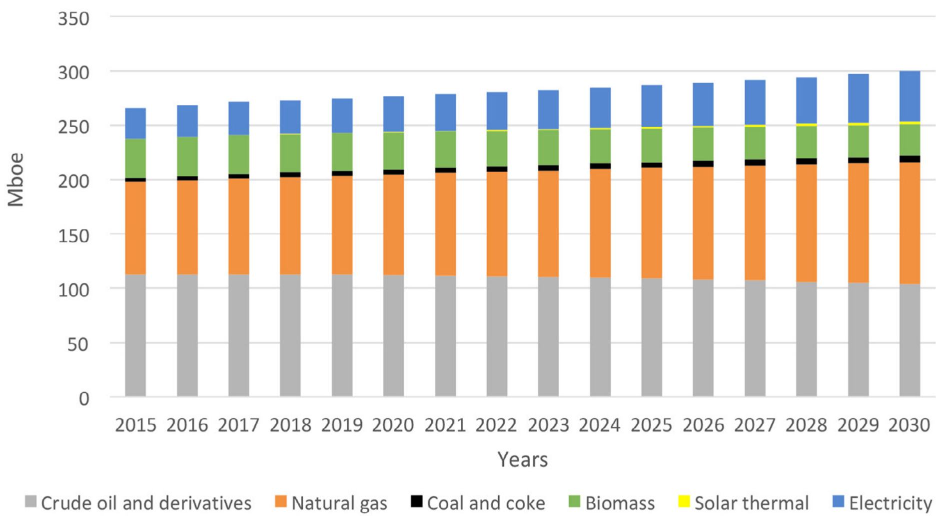
8.7.1 Projected final energy consumption

Table 8.31. Projected final energy consumption in the Caribbean, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	113	112	109	104	-0.6%
Natural gas	85	93	102	112	1.9%
Coal and coke	4	5	5	6	3.0%
Biomass	36	34	31	29	-1.4%
Solar thermal	0	0	1	2	12.7%
Electricity	28	33	38	47	3.4%
TOTAL	**266**	**277**	**287**	**300**	**0.8%**

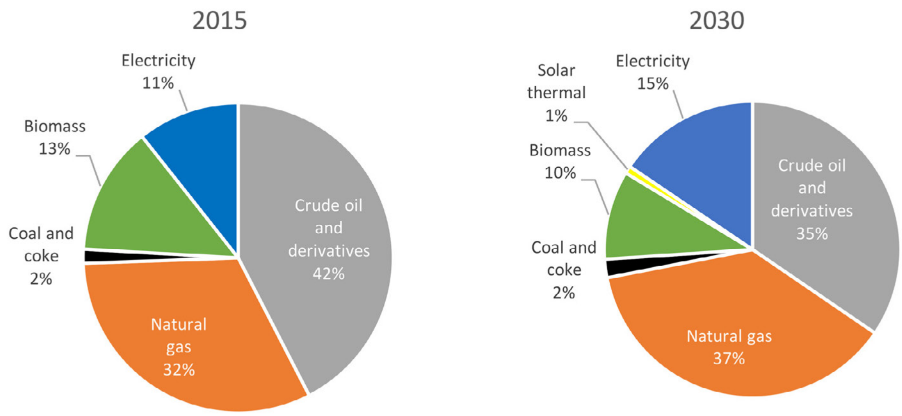
Source: Simulation results

Figure 8.46. Projected final energy consumption in the Caribbean, NFS



Source: Simulation results

Figure 8.47. Evolution of final energy consumption matrix in the Caribbean, NFS



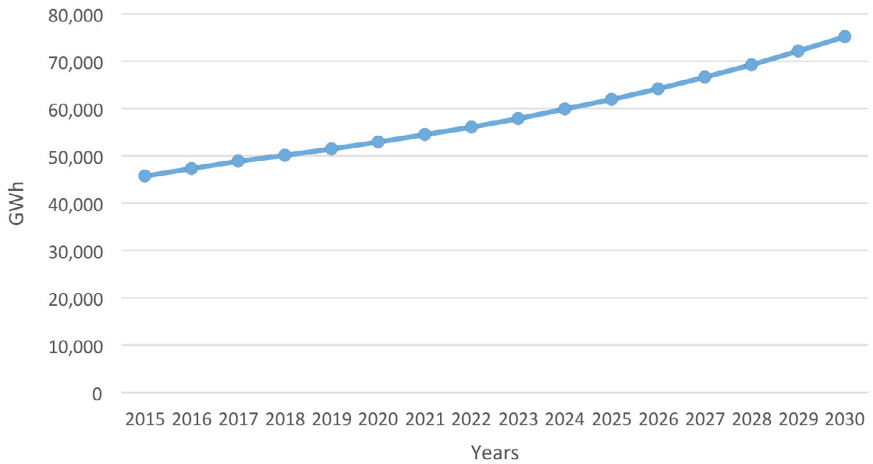
Source: Simulation results

Increased use of electricity and natural gas displaces the share represented by oil products and biomass in the Caribbean's final consumption matrix under the simulated NFS.

Table 8.32. Projected final electricity consumption in the Caribbean NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	45,722	52,920	61,941	75,171	3.4%

Figure 8.48. Total electricity consumption in the Caribbean, NFS



Source: Simulation results

Electricity consumption in the Caribbean increases increases by 64% over the projection period under NFS assumptions.

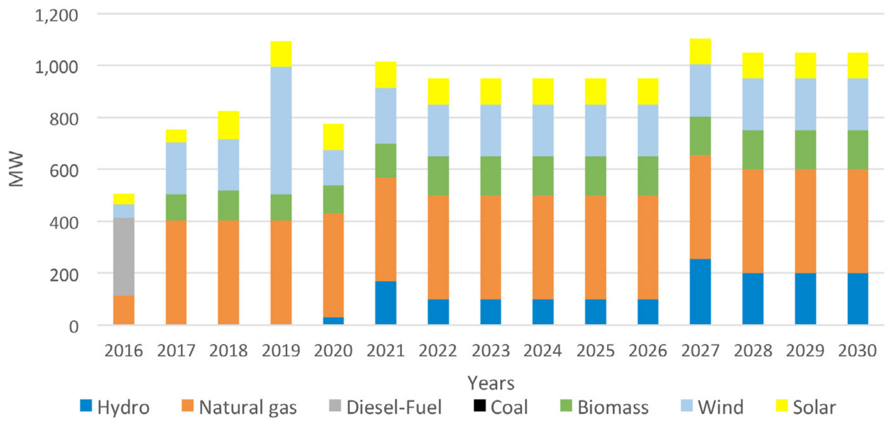
8.7.2 Projected electricity generation

Table 8.33. Timelines for installation/decommissioning of installed capacity (MW) in the Caribbean, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar
2016	0	114	300	0	0	0	52	40
2017	4	400	0	0	100	0	200	50
2018	4	400	0	0	115	0	198	106
2019	4	400	0	0	100	0	491	100
2020	29	400	0	0	110	0	135	102
2021	169	400	0	0	130	0	215	100
2022	100	400	0	0	150	0	200	100
2023	100	400	0	0	150	0	200	100
2024	100	400	0	0	150	0	200	100
2025	100	400	0	0	150	0	200	100
2026	100	400	0	0	150	0	200	100
2027	254	400	0	0	150	0	200	100
2028	200	400	0	0	150	0	200	100
2029	200	400	0	0	150	0	200	100
2030	200	400	0	0	150	0	200	100

Source: by authors, based on national electricity sector expansion plans

Figure 8.49. Timelines for installation/decommissioning of installed electricity generation capacity in the Caribbean, NFS



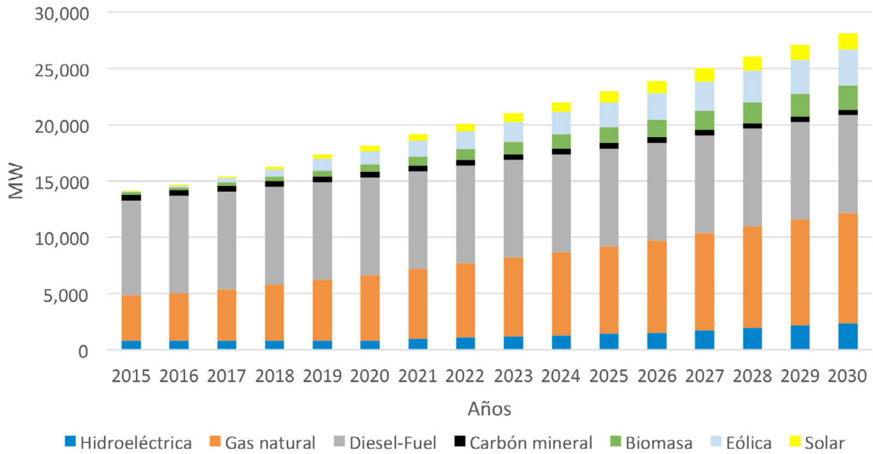
Source: by authors, based on national electricity sector expansion plans

Table 8.34. Projected Installed capacity in the Caribbean, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	800	841	1,410	2,364
Natural gas	4,088	5,802	7,802	9,802
Diesel-Fuel Oil	8,374	8,674	8,674	8,674
Coal	500	500	500	500
Biomass	233	658	1,388	2,138
Wind	114	1,190	2,205	3,205
Solar	60	458	958	1,458
TOTAL	**14,170**	**18,124**	**22,938**	**28,142**

Source: by authors, based on national electricity sector expansion plans

Figure 8.50. Installed electricity generation capacity in the Caribbean, NFS



Source: by authors, based on national electricity sector expansion plans

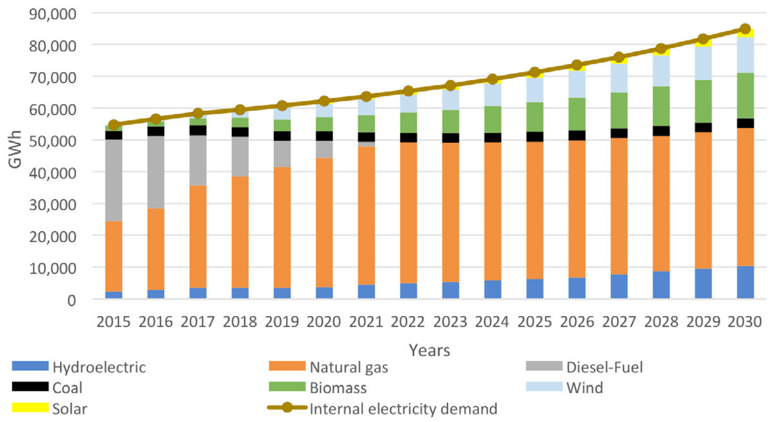
The implementation in installed capacity from renewable energy sources and natural gas predominates in the expansion of the Caribbean's electricity generation system under the NFS.

Table 8.35. Projected electricity generation in the Caribbean, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	2,398	3,684	6,176	10,354
Natural gas	22,039	40,663	43,256	43,341
Diesel-Fuel Oil	25,674	5,347	0	0
Coal	2,696	3,067	3,067	3,067
Biomass	1,573	4,437	9,356	14,410
Wind	308	4,171	7,728	11,232
Solar	81	802	1,678	2,554
TOTAL	**54,769**	**62,171**	**71,261**	**84,958**

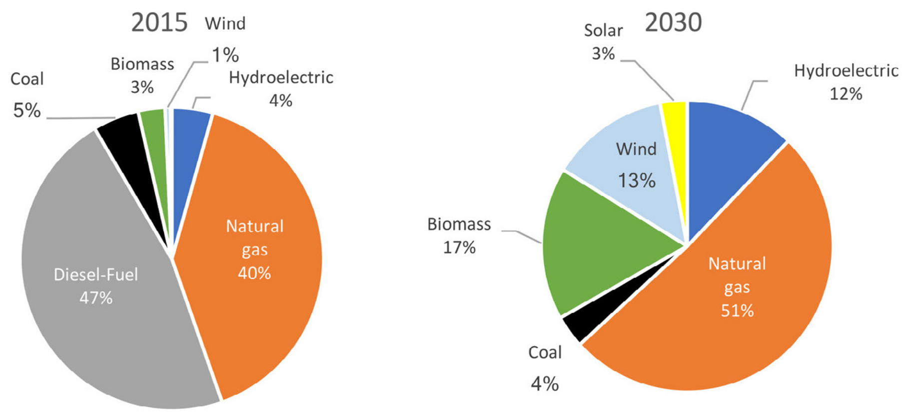
Source: Simulation results

Figure 8.51. Projected electricity generation in the Caribbean, NFS



Source: Simulation results

Figure 8.52. Evolution of electricity generation matrix in the Caribbean, NFS



Source: Simulation results

Under the NFS, the Caribbean electricity generation matrix becomes over 50% dependent on natural gas, while close to the remaining 50% corresponds to renewable energy sources like hydro, biomass, wind and solar power.

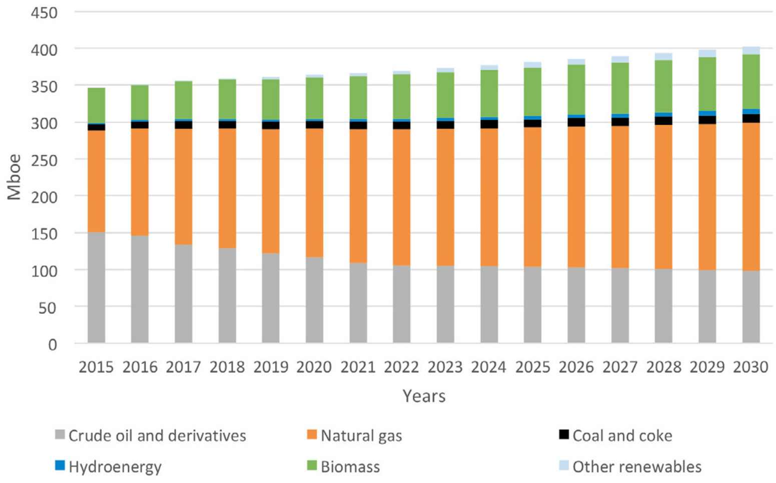
8.7.3 Projected total energy supply

Table 8.36. Projected total energy supply in the Caribbean, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	150	116	104	98	-2.8%
Natural gas	138	175	189	201	2.5%
Coal and coke	9	11	11	12	1.9%
Hydroenergy	2	3	4	7	10.2%
Biomass	47	56	66	74	3.0%
Other renewables	0.2	3.5	7.2	11	29.0%
TOTAL	**347**	**364**	**381**	**403**	**1.0%**

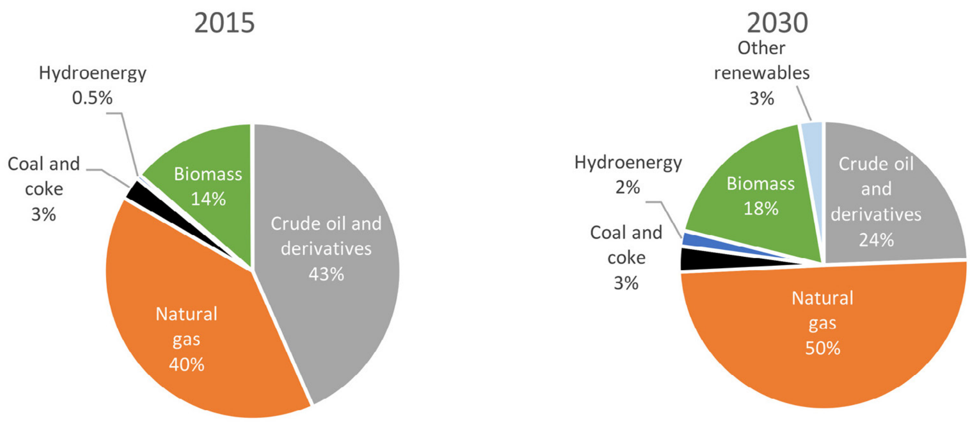
Source: Simulation results

Figure 8.53. Projected total energy supply in the Caribbean, NFS



Source: Simulation results

Figure 8.54. Evolution of total energy supply in the Caribbean, NFS



Source: Simulation results

The renewability of the Caribbean's total supply matrix improves under the NFS, thanks to penetration by renewable sources such as biomass, hydro, wind, solar and geothermal power. Natural gas also gains a larger share, taking it from the use of oil products.

8.8 Latin America and the Caribbean (LAC)

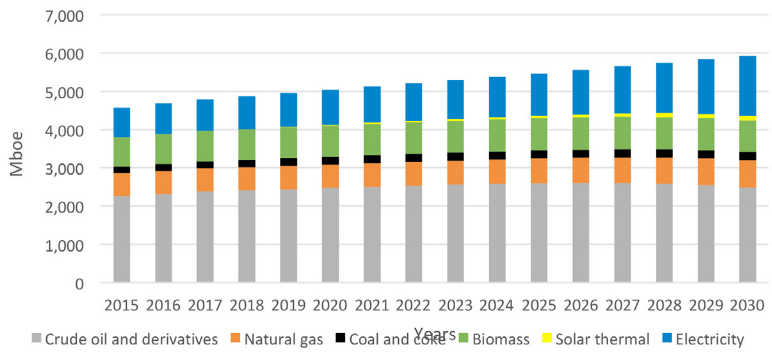
8.8.1 Projected final energy consumption

Table 8.37. Projected final energy consumption in LAC, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	2,261	2,472	2,593	2,482	0.6%
Natural gas	590	615	647	709	1.2%
Coal and coke	174	199	211	213	1.4%
Biomass	767	815	840	839	0.6%
Solar thermal	0	23	71	117	17.6%
Electricity	784	918	1,104	1,559	4.7%
TOTAL	**4,576**	**5,042**	**5,467**	**5,919**	**1.7%**

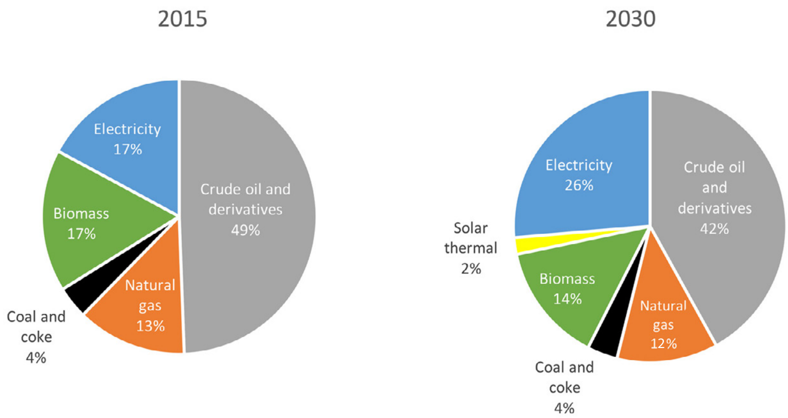
Source: Simulation results

Figure 8.55. Projected final energy consumption in LAC, NFS



Source: Simulation results

Figure 8.56. Evolution of final energy consumption matrix in LAC, NFS



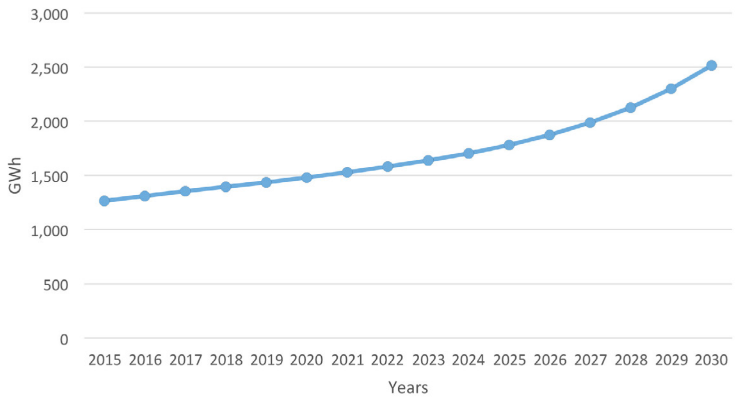
Source: Simulation results

Evolution of the final energy consumption matrix in LAC under the NFS shows very clear penetration by electricity, displacing the use of hydrocarbons and biomass, whose percentage share falls trastically over the projection period.

Table 8.38. Projected final electricity consumption in LAC, NFS (GWh)

Source	2015	2020	2025	2030	a.a.r.
Electricity	1,265	1,482	1,782	2,517	4.7%

Figura 8.57. Consumo total de electricidad de ALC, todos los escenarios



Source: Simulation results

The LAC region shows accelerated growth in electricity consumption, especially in the last five years of the projection period, thanks to the increased electrification of end-uses in the main consumption sectors of the different subregions, simulated as an energy efficiency measure in the NFS.

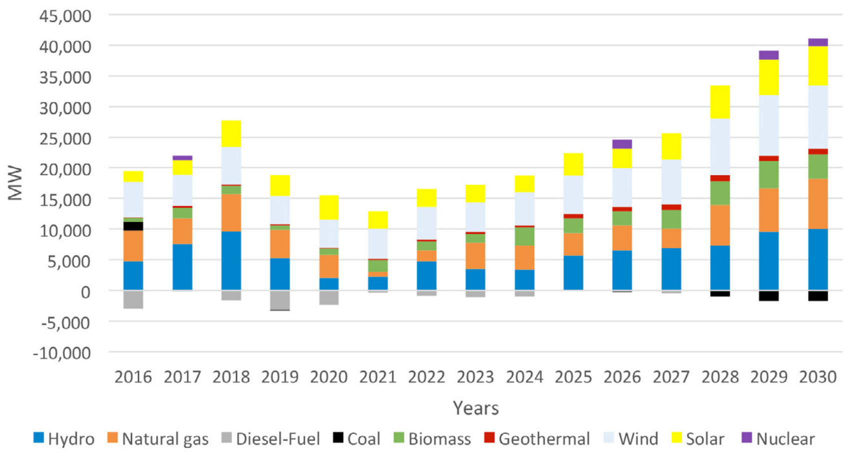
8.8.2 Projected electricity generation

Table 8.39. Timelines for installation/decommissioning of installed capacity (MW) in LAC, NFS

Year	Hydro	Natural gas	Diesel-Fuel Oil	Coal	Biomass	Geothermal	Wind	Solar	Nuclear
2016	4,763	5,025	-2,939	1,394	676	48	5,863	1,715	0
2017	7,596	4,176	-132	0	1,725	301	5,127	2,306	745
2018	9,576	6,114	-1,641	0	1,387	245	6,104	4,286	0
2019	5,250	4,627	-3,211	-16	716	255	4,602	3,363	0
2020	2,071	3,755	-2,366	0	1,006	170	4,553	3,949	0
2021	2,221	856	-320	0	1,860	233	4,931	2,805	0
2022	4,730	1,796	-921	0	1,482	250	5,410	2,895	0
2023	3,564	4,215	-1,058	0	1,453	317	4,822	2,860	0
2024	3,332	3,950	-992	0	3,010	316	5,376	2,720	0
2025	5,694	3,693	-20	0	2,396	733	6,191	3,687	0
2026	6,452	4,169	-125	-90	2,246	730	6,326	3,270	1,405
2027	6,932	3,192	-521	0	2,980	910	7,313	4,252	0
2028	7,351	6,603	0	-1,000	3,900	930	9,300	5,350	0
2029	9,500	7,200	0	-1,700	4,400	930	9,800	5,850	1,360
2030	10,000	8,200	0	-1,700	4,000	930	10,300	6,350	1,361

Source: By authors, based on national electricity sector expansion plans

Figure 8.58. Timelines for installation/decommissioning of installed electricity generation capacity in LAC, NFS



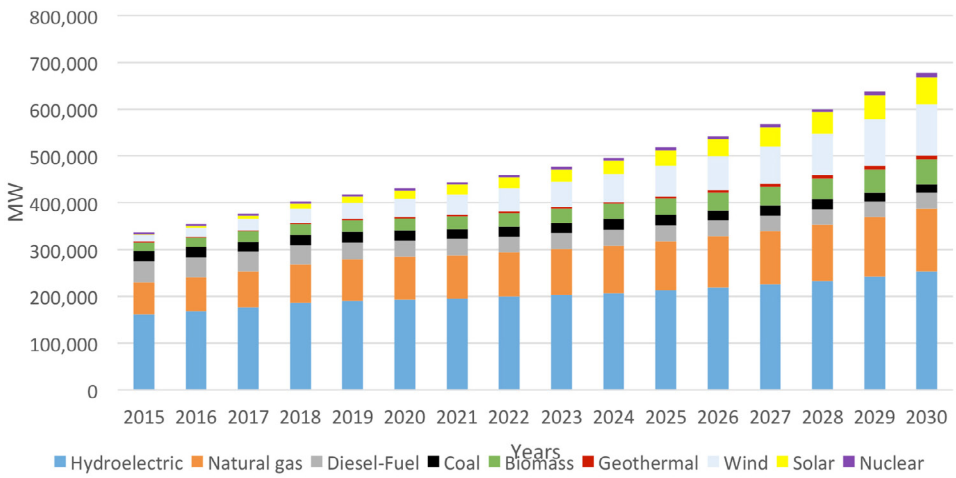
Source: By authors, based on national electricity sector expansion plans

Table 8.40. Projected installed capacity in LAC, NFS (MW)

Technology	2015	2020	2025	2030
Hydroelectric	162,241	192,730	212,271	252,507
Natural gas	67,798	91,495	106,005	135,370
Diesel-Fuel Oil	45,260	34,971	33,374	33,069
Coal	20,736	22,114	22,114	17,775
Biomass	19,833	25,344	35,544	53,070
Geothermal	1,484	2,503	4,352	8,782
Wind	13,099	39,348	66,078	109,117
Solar	2,091	17,710	32,676	57,748
Nuclear	4,510	5,255	5,255	9,381
TOTAL	**337,051**	**431,469**	**517,670**	**676,819**

Source: By authors, based on national electricity sector expansion plans

Figure 8.59. Installed electricity generation capacity in LAC, NFS



Source: By authors, based on national electricity sector expansion plans

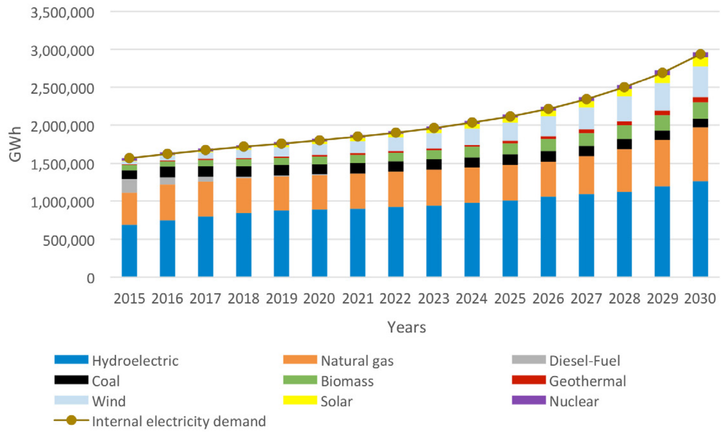
In the expansion of the installed capacity in LAC under NFS assumptions, NCRE like biomass, wind and solar gain significant importance in the LAC region's electricity generation, with wind capacity standing out and becoming the third most important technology by 2030.

Table 8.41. Projected electricity generation in LAC, NFS (GWh)

Source	2015	2020	2025	2030
Hydroelectric	686,983	890,701	1,005,480	1,266,606
Natural gas	427,355	452,264	471,704	707,327
Diesel-Fuel Oil	178,285	8,386	0	0
Coal	112,917	138,661	138,661	111,433
Biomass	69,732	98,813	144,803	216,250
Geothermal	11,861	19,062	33,380	67,431
Wind	39,521	139,764	239,980	404,047
Solar	5,763	36,890	68,367	121,053
Nuclear	33,277	38,551	38,551	69,697
TOTAL	**1,565,695**	**1,823,092**	**2,140,926**	**2,963,845**

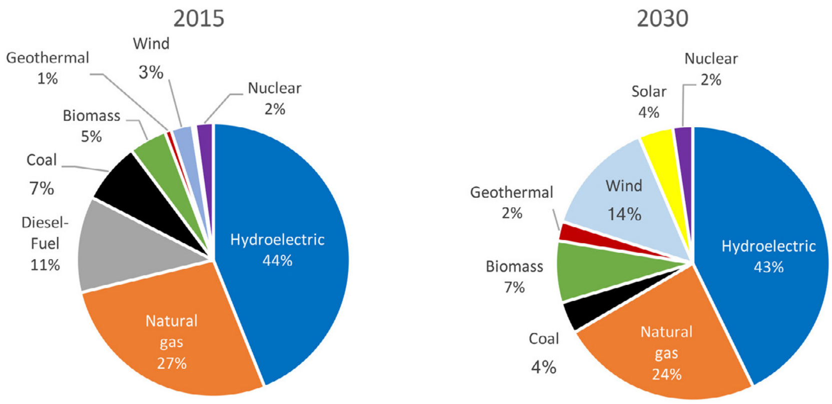
Source: Simulation results

Figure 8.60. Projected electricity generation in LAC, NFS



Source: Simulation results

Figure 8.61. Evolution of electricity generation matrix in LAC, NFS



Source: Simulation results

In the NFS elimination of the use of oil products for electricity generation is offset mainly by increased participation on the part of NCRE. It is worth noting that while there is a significant deployment of new hydroelectric and natural gas power plants, the percentage share that these sources represent in the regional generation matrix declines.

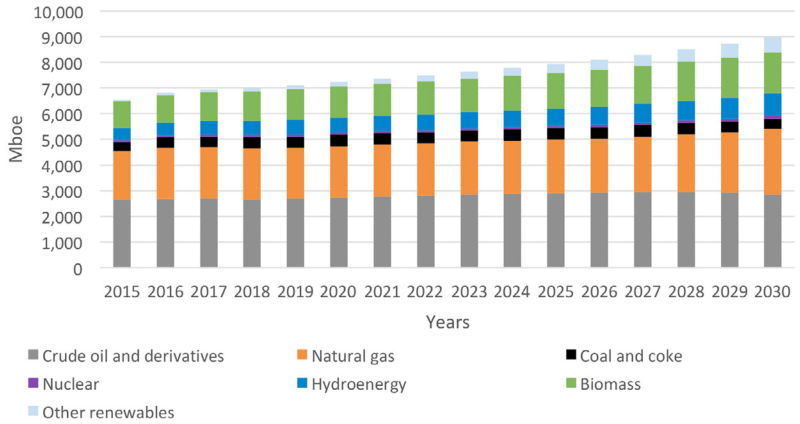
8.8.3 Projected total energy supply

Table 8.42. Projected total energy supply in LAC, NFS (Mboe)

Source	2015	2020	2025	2030	a.a.r.
Crude oil and derivatives	2,634	2,736	2,905	2,852	0.5%
Natural gas	1,895	1,998	2,093	2,557	2.0%
Coal and coke	369	435	443	396	0.5%
Nuclear	64	76	76	133	5.0%
Hydroenergy	471	600	680	856	4.1%
Biomass	1,041	1,208	1,396	1,590	2.9%
Other renewables	57	182	345	608	17.1%
TOTAL	**6,532**	**7,235**	**7,937**	**8,992**	**2.2%**

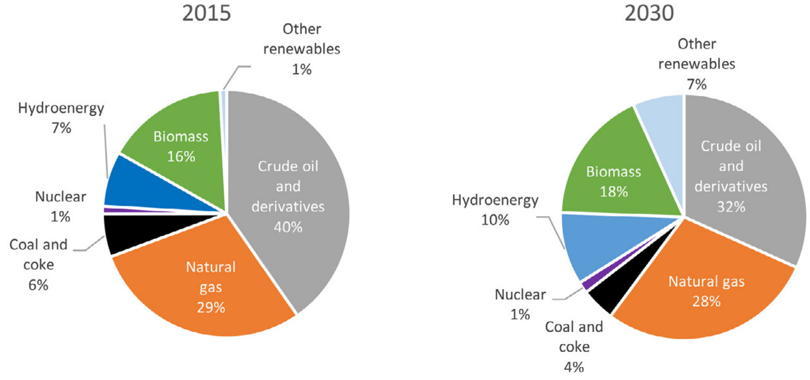
Source: Simulation results

Figure 8.62. Projected total energy supply in LAC, NFS



Source: Simulation results

Figure 8.63. Evolution of total energy supply matrix in LAC, NFS



Source: Simulation results

The proportion of renewable energies in LAC's total energy supply matrix increases very significantly, thus making inroads on hydrocarbons and coal.

9. Analysis of NFS's sensitivity to the effects of climate change

9. Analysis of NFS's sensitivity to the effects of climate change

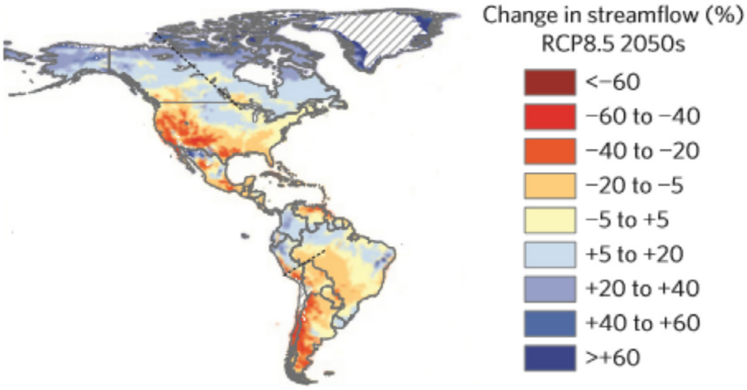
9.1 General Considerations

As mentioned above, this study's projection period is too short to expect any significant impact from climate change on the demand for electricity or the availability of hydroenergy. However, as a test of the proposed NFS's robustness, an eventual premature expression climate change on the aforementioned variables is simulated.

To define the magnitude of the climate change effect on the different subregions, the information contained in the article "Power-generation system vulnerability and adaptation to changes in climate and water resources," published in Nature Climate Change Journal in 2016 [65], was used as a reference, which presents estimates for the variation in water flows by 2050 under the most drastic GHG emissions concentration scenario, such as the RCP8.5 formulated by the IPCC

Figure 9.1 provides a graphic illustration of the geographical distribution of the effects of the CC on water flows in the Americas.

Figure 9.1. Variation in surface water flows by 2050 in the RCP 8.5 climate scenario



Fuente: (Michelle T. H. van Vliet et al., 2016)

As the above figure shows, Mexico and the Southern Cone would be the subregions most affected by CC. In the Andean Subregion, one can see that Venezuela, Bolivia and part of Peru would be affected in certain regions, but in other parts of the subregions the flow variations are positive, which would to a certain degree counteract the effect on a subregional level. As far as Central America is concerned, the specific study undertaken by the OLSDE for countries in this subregion shows that CC effects could begin to show themselves after 2030, meaning that it was considered a low risk during the study period. Regarding the Caribbean, the low level of participation by hydroelectricity means that the effect on this resource would be practically irrelevant.

Based on the results of variations in surface water flows found in the RCP 8.5 climate scenario as a hypothesis of the effect of climate change on the electricity sectors in each of the subregions analyzed, a percentage reduction in the hydroelectric capacity factor was considered for 2030 compared to the factors used in the CPS and NFS. This reduction is distributed progressively throughout the study period, with a value of 10% by 2030 assigned for the subregions most affected by climate change and 5% for those less affected. Although the percentages of affectation that are shown in Figure 9.1, are much larger in some geographic areas, these are referred to the year 2050, so for the year 2030 a minimum range of affectation was considered .

It is reasonable to assume that an increase in ambient temperature associated with climate change could have consequences on electricity consumption, either due to increased energy consumption by refrigeration and air conditioning equipment, or a decline in the use of heating equipment. Thus, the variation in electricity demand due to the CC will depend on the global increase in temperature and each subregion's climate seasonality.

Given that the RCP 8.5 scenario forecasts a 2º C temperature increase by 2100 and 1º C by 2050 (with regard to the temperature in 1900), the temperature increase can be seen to follow an exponential path, and considering that the CC effect on electricity demand is implicit in growth forecasts for the base year of the study (2015), one can interpolate and assume that the temperature for the aforementioned climate scenario in the 15 years of the projection could increase by 0.35 °C. For its part, the elasticity in electricity demand regarding to temperature variation, considered in the OLADE study on Central America was 1.5% and 2.5%, depending on the country. These referential values were used to quantify the CC effects on the supply of hydroelectricity and demand for electricity, producing the values contained in Table 9.1.

Table 9.1. Percentage variation considered due to climate change effect

Subregion	Hydroelectric Plant Factor, 2030	Elasticity in Electricity Demand / Temperature Increase	Global temperature increase, 2015-2030	Industrial, residential and commercial electricity consumption, 2030
Brazil	-5%	2.5%	0.35°C	+0.88%
Mexico	-10%	2.5%	0.35°C	+0.88%
Central America	-5%	2.5%	0.35°C	+0.88%
Andean Subregion	-5%	1.5%	0.35°C	+0.53%
Southern Cone	-10%	0%	0.35°C	0%[8]
The Caribbean	-5%	2.5%	0.35°C	+0.88%

Source: Authors' compilation

[6]*The Capacity Factor of a power plant is defined as the division between the energy actually produced in a given period of time and the theoretical energy that would be produced by the plant operating continuously, at nominal capacity, during the same period.*

[7]*It is difficult to ascertain precisely the variation in time of the flows or of the plant factor of the hydroelectric power plants, for this it would be necessary to carry out for each subregion a similar study to the one that OLADE carried out in Central America [21] and is being carried out in the Andean Subregion where a large number of hydroclimatic variables are analyzed. The affectation values considered in this study would correspond to a minimum range of affectation.*

[8]*For the Southern Cone subregion, it was assumed that, due to the marked climate seasonality, the eventual increase in demand for refrigeration and air conditioning in warm months would be counteracted by lower demand for heading in cold seasons.*

As with the reduced hydroelectric plant factor, the considered effect on electricity demand is progressively distributed over the projection period. That is, it evolves from its original value in 2017 to the value affected by the CC in the year 2030.

It should be noted that the simulation of the aforementioned CC effects was applied both to the proposed NFS, as well as the BAU baseline scenario, thus creating the respective NFS (RCP 8.5) and BAU (RCP 8.5), sensitivity scenarios. This sensitivity is not applied to CPS, because its premises correspond to the official projections of the countries, contained in its expansion plans, and therefore it is assumed that its robustness was validated when preparing said plans.

Given that the simulation of the BAU and BAU (RCP 8.5) scenarios does not use the plant factor variable to calculate electricity generation, since the projected generation of each technology, does not obey to a dispatch policy, but to its percentage share in the base year matrix, the difference in hydroelectric generation between these scenarios is exclusively due to the difference in projected electricity demand. However, the plant factor does influence calculations of the installed capacity needed to cover said generation.

Regarding the simulation of an eventual effect on the performance of thermoelectric power plants due to an increase in the global temperature, this was ruled out after being considered irrelevant on the study horizon. The timeline for expansion in electricity generation proposed in the NFS is maintained in the NFS (RCP 8.5) simulation.

With the hypotheses presented, the most significant results of the climate change sensitivity analysis are presented blow.

9.2 Brazil

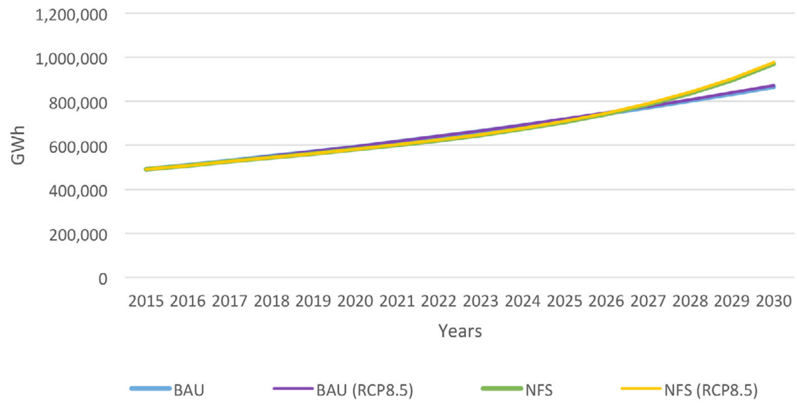
9.2.1 Variation in total electricity consumption

Table 9.2. Variation in total electricity consumption in Brazil due to CC effect (GWh)

	2015	2020	2025	2030	a.a.r.
BAU Scenario	491,255	593,026	716,277	865,616	3.8%
BAU (RCP 8.5) scenario	491,255	594,615	720,108	872,545	3.9%
NFS	491,255	580,500	706,146	969,997	4.6%
NFS (RCP 8.5)	491,255	581,567	709,436	976,226	4.7%

Source: Simulation results

Figure 9.2. Variation in total electricity consumption in Brazil due to CC effect



Source: Simulation results

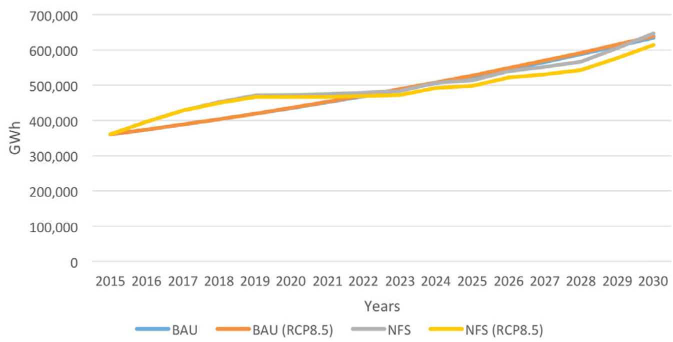
9.2.2 Variation in hydroelectric generation

Table 9.3. Variation in hydroelectric generation in Brazil due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	359,975	434,567	524,885	634,319
BAU (RCP 8.5) scenario	359,975	435,731	527,691	639,396
NFS	359,975	471,718	513,513	646,782
NFS (RCP 8.5)	359,975	466,275	497,713	614,443

Source: Simulation results

Figure 9.3. Variation in hydroelectric generation in Brazil due to CC effect



Source: Simulation results

9.3 Mexico

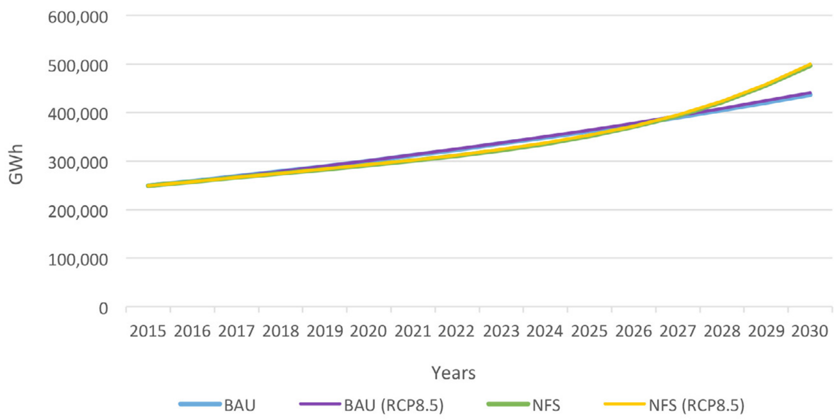
9.3.1 Variation in total electricity consumption

Table 9.4. Variation in total electricity consumption in Mexico due to CC effect (GWh)

	2015	2020	2025	2030	a.a.r.
BAU Scenario	248,895	300,182	362,123	436,943	3.8%
BAU (RCP 8.5) scenario	248,895	300,994	364,089	440,511	3.9%
NFS	248,895	291,779	351,473	496,019	4.7%
NFS (RCP 8.5)	248,895	292,319	353,099	499,031	4.7%

Source: Simulation results

Figure 9.4. Variation in total electricity consumption in Mexico due to CC effect



Source: Simulation results

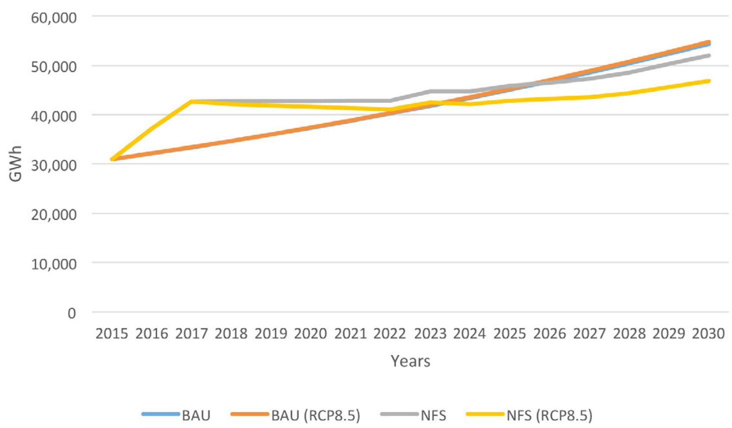
9.3.2 Variation in hydroelectric generation

Table 9.5. Variation in hydroelectric generation in Mexico due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	30,955	37,330	45,033	54,337
BAU (RCP 8.5) scenario	30,955	37,431	45,277	54,781
NFS	30,955	42,787	45,836	52,027
NFS (RCP 8.5)	30,955	41,565	42,889	46,825

Source: Simulation results

Figure 9.5. Variation in hydroelectric consumption in Mexico due to CC effect

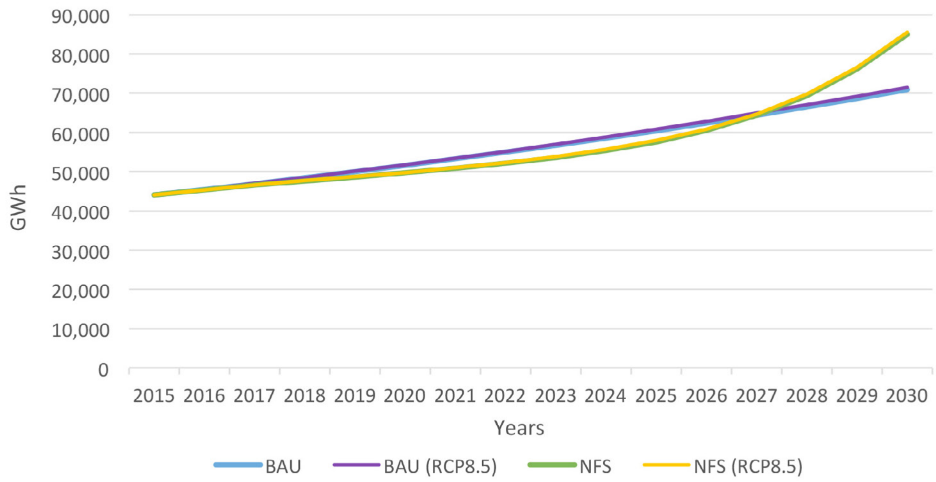


Source: Simulation results

9.4 Central America

9.4.1 Variation in total electricity consumption

Table 9.6. Variation in total electricity consumption in Central America due to CC effect (GWh)



Source: Simulation results

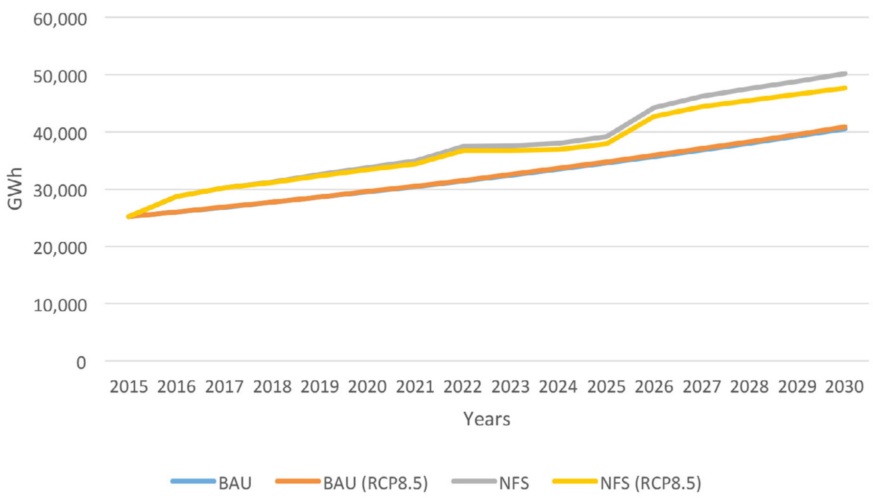
9.4.2 Variation in hydroelectric generation

Table 9.7. Variation in hydroelectric generation in Central America due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	25,195	29,494	34,560	40,535
BAU (RCP 8.5) scenario	25,195	29,580	34,761	40,889
NFS	25,195	33,751	39,141	50,153
NFS (RCP 8.5)	25,195	33,362	37,936	47,645

Source: Simulation results

Figure 9.7. Hydroelectric generation in Central America, CCE Scenario vs. BAU Scenario and CPS



Source: Simulation results

9.5 Andean Subregion

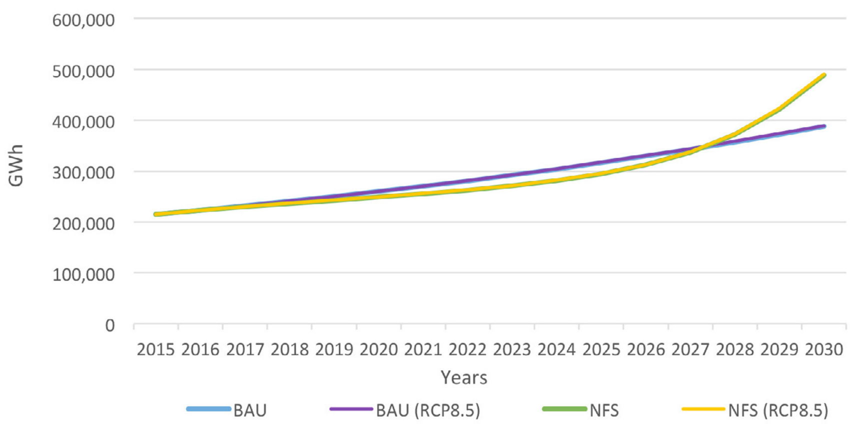
9.5.1 Variation in total electricity consumption

Table 9.8. Variation in total electricity consumption in Andean Subregion due to CC effect (GWh)

	2015	2020	2025	2030	a.a.r..
BAU Scenario	215,097	259,898	316,389	387,884	4%
BAU (RCP 8.5) scenario	215,097	260,299	317,354	389,640	4%
NFS	215,097	248,928	294,494	488,880	5.6%
NFS (RCP 8.5)	215,097	249,191	295,268	490,300	5.6%

Source: Simulation results

Figure 9.8. Variation in total electricity consumption in Andean Subregion due to CC effect



Source: Simulation results

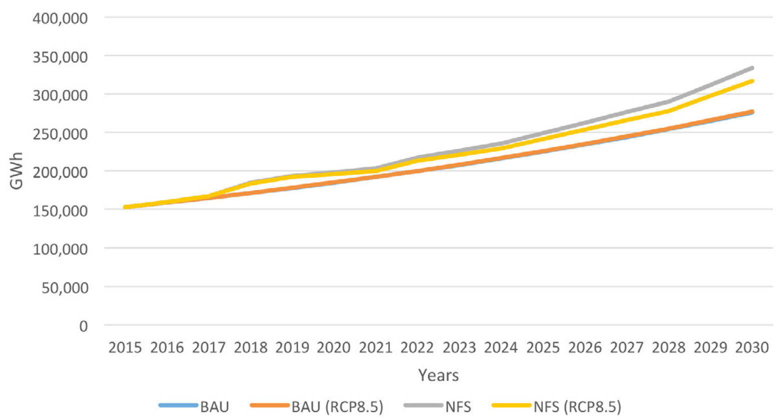
9.5.2 Variation in hydroelectric generation

Table 9.9. Variation in hydroelectric generation in the Andean Subregion due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	152,886	184,859	225,039	275,892
BAU (RCP 8.5) scenario	152,886	185,144	225,726	277,141
NFS	152,886	198,181	249,141	333,716
NFS (RCP 8.5)	152,886	195,895	241,475	317,030

Source: Simulation results

Figure 9.9. Variation in hydroelectric generation in Andean Subregion due to CC effect.



Source: Simulation results

9.6 Southern Cone

9.6.1 Variation in total electricity consumption

As noted in this chapter's general considerations, the Southern Cone subregion does not present any variation in annual electricity consumption due to the effects of climate change.

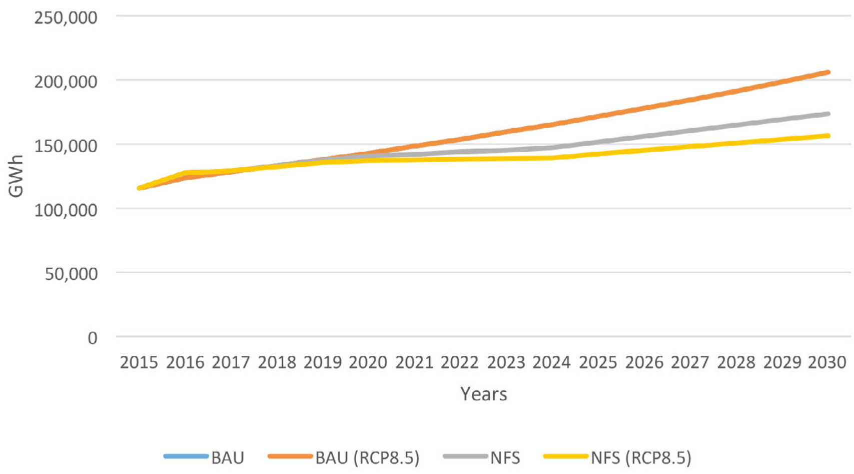
9.6.2 Variation in hydroelectric generation

Table 9.10. Variation in hydroelectric generation in Southern Cone due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	115,574	142,967	171,463	205,879
BAU (RCP 8.5) scenario	115,574	142,967	171,463	205,879
NFS	115,574	140,579	151,673	173,573
NFS (RCP 8.5)	115,574	137,335	142,340	156,216

Source: Simulation results

Figure 9.10. Variation in hydroelectric generation in Southern Cone due to CC effect



Source: Simulation results

9.7 The Caribbean

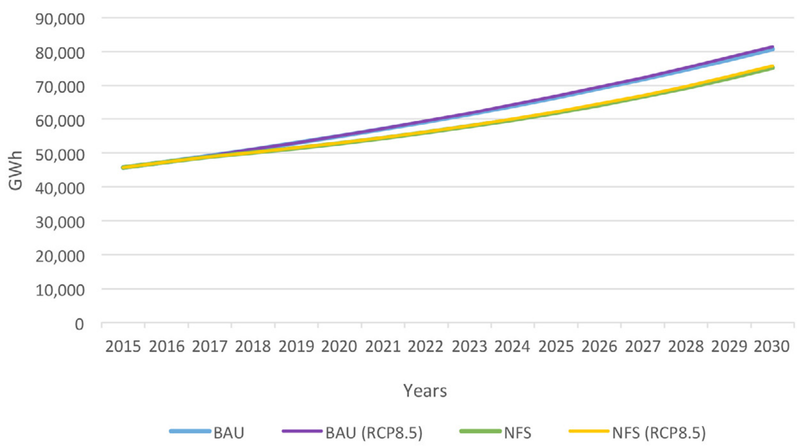
9.7.1 Variation in total electricity consumption

Table 9.11. Variation in total electricity consumption in the Caribbean due to CC effect (GWh)

	2015	2020	2025	2030	a.a.r..
BAU Scenario	45,722	54,961	66,436	80,745	3.9%
BAU (RCP 8.5) scenario	45,722	55,114	66,805	81,416	3.9%
NFS	45,722	52,920	61,941	75,171	3.4%
NFS (RCP 8.5)	45,722	53,021	62,249	75,755	3.4%

Source: Simulation results

Figure 9.11. Variation in total electricity consumption in the Caribbean due to CC effect



Source: Simulation results

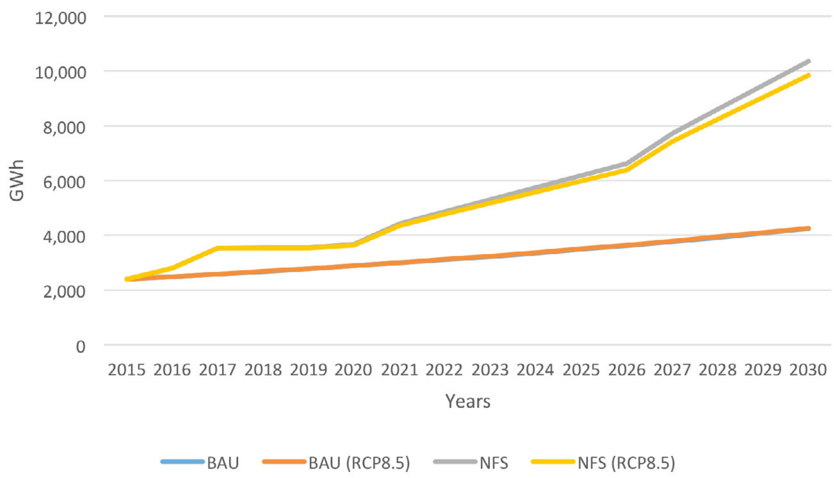
9.7.2 Variation in hydroelectric generation

Table 9.12. Hydroelectric generation in the Caribbean, CCE Scenario vs. BAU Scenario and CPS (GWh)

	2015	2020	2025	2030
BAU Scenario	2,398	2,882	3,484	4,235
BAU (RCP 8.5) scenario	2,398	2,890	3,503	4,270
NFS	2,398	3,684	6,176	10,354
NFS (RCP 8.5)	2,398	3,641	5,986	9,837

Source: Simulation results

Figure 9.12. Variation in hydroelectric generation in Brazil due to CC effect



Source: Simulation results

9.8 Latin America and the Caribbean (LAC)

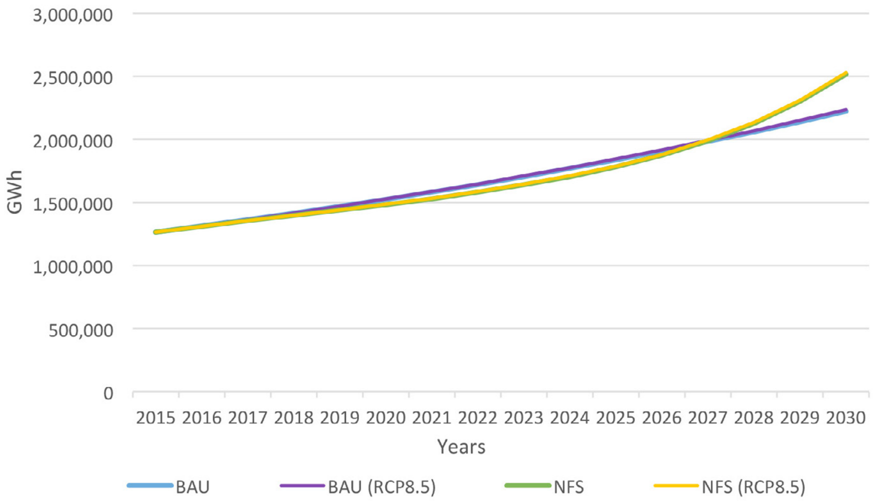
9.8.1 Variation in total electricity consumption

Table 9.13. Variation in total electricity consumption in LAC due to CC effect (GWh)

	2015	2020	2025	2030	a.a.r.
BAU Scenario	1,264,966	1,523,104	1,837,631	2,221,463	3.8%
BAU (RCP 8.5) scenario	1,264,966	1,526,208	1,845,112	2,235,006	3.9%
NFS	1,264,966	1,482,099	1,781,692	2,516,663	4.7%
NFS (RCP 8.5)	1,264,966	1,484,193	1,787,999	2,528,451	4.7%

Source: Simulation results

Figure 9.13. Total electricity consumption in LAC, CCE Scenario vs BAU scenario and CPS



Source: Simulation results

As can be seen in the tables and graphs on variations in electricity consumption due to the effects of climate change in each of the subregions analyzed, the difference between between the the BAU and NFSs and their respective BAU (RCP 8.5) and NFS (RCP 8.5) sensitivity scenarios are negligible, meaning that, as was to be expected, the same thing happens on a regional level, with percentage variations of 0.6% and 0.5%, respectively through 2030.

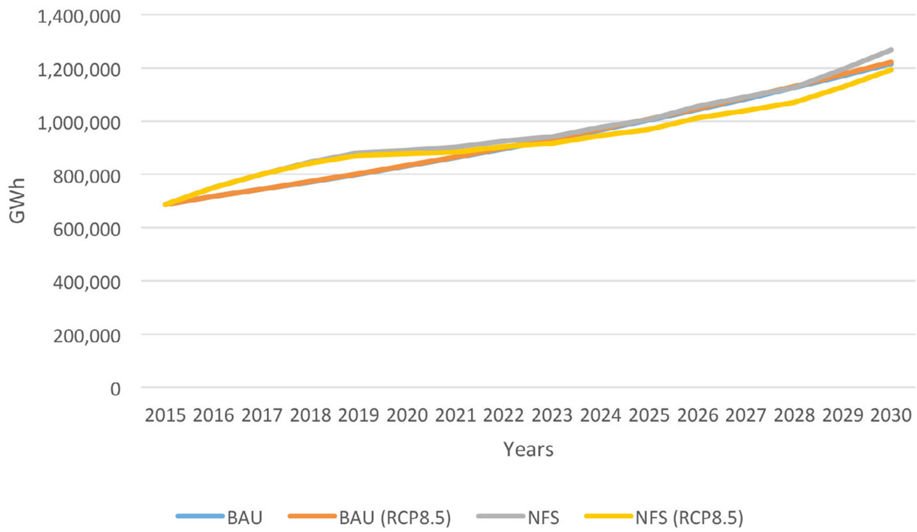
9.8.2 Variation in hydroelectric generation

Table 9.14. Variation in hydroelectric generation in LAC due to CC effect (GWh)

	2015	2020	2025	2030
BAU Scenario	686,983	832,100	1,004,464	1,215,196
BAU (RCP 8.5) scenario	686,983	833,743	1,008,422	1,222,355
NFS	686,983	890,701	1,005,480	1,266,606
NFS (RCP 8.5)	686,983	878,072	968,339	1,191,996

Source: Simulation results

Figure 9.14 Variation in hydroelectric generation in LAC due to CC effect



Source: Simulation results

The difference in hydroelectric generation between the BAU and BAU (RCP 8.5) scenarios due to the effects of climate change is very marginal (0.6% by 2030), given that due to the type of simulation used for these scenarios, the electricity generation results do not depend on plant factors, but rather on electricity demand alone, while the difference between the NFS and NFS (RCP 8.5) for the LAC region shows a decline of about 6% by 2030, which can already be considered significant.

10. Comparative analysis of the simulated scenarios using energy and environmental indicators

10. Comparative analysis of the simulated scenarios using energy and environmental indicators

10.1 General Considerations

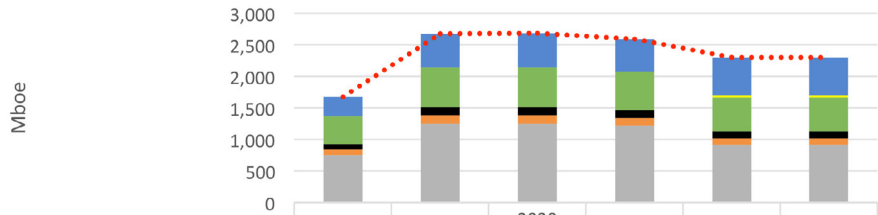
After presenting the individual energy results of simulating the different scenarios in the preceding chapters, and in order to show more explicitly, the effect of the premises used in each of them, on the state of the energy matrix in the study horizon, this chapter attempts to analyze the most significant differences between these scenarios using energy and environment related comparative indicators. Environmental indicators refer to CO2e emissions and the percentage they are reduced with regard to the BAU baseline scenario, both for the total energy supply matrix as well as for the electricity generation matrix.

The emissions factors proposed by the IPCC were used to calculate CO2e emissions for the technologies method (2006 review), which are contained in OLADE's Energy Information System (SIEALAC) and shown in Annex V.

10.2 Brazil

10.2.1 Projected final energy consumption and structure

Figure 10.1 Projected final energy consumption in Brazil, all scenarios

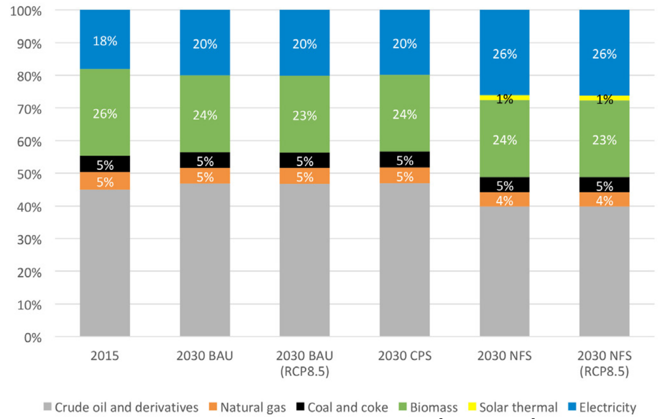


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	304	536	541	514	601	605
Solar thermal	0	0	0	0	34	34
Biomass	443	630	630	609	541	541
Coal and coke	84	127	127	125	108	108
Natural gas	91	129	129	125	100	100
Crude oil and derivatives	753	1,254	1,254	1,217	917	917
TOTAL	1,676	2,677	2,681	2,590	2,301	2,305

Source: Simulation results

The CPS generates 3% savings in total energy consumption in Brazil compared to the BAU scenario, while that percentage of savings rises to 14% under the NFS.

Figure 10.2 Structure of the final energy consumption matrix in Brazil, all scenarios

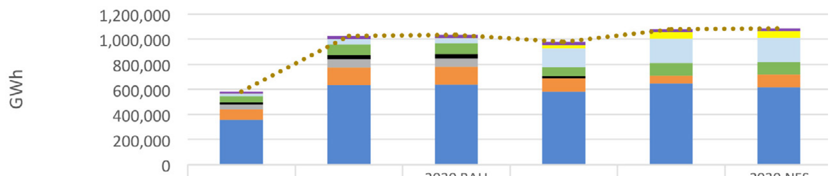


Source: Simulation results

The BAU Scenario and CPS have approximately the same structure in the final consumption matrix in 2030, while the share of hydrocarbons in said matrix falls significantly in the NFS.

10.2.2 Projected electricity generation and structure

Figure 10.3 Projected electricity generation in Brazil, all scenarios

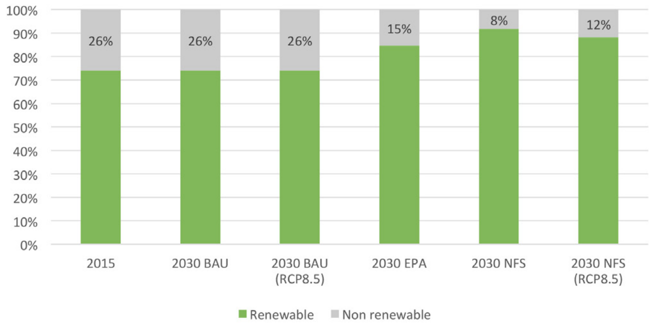


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Nuclear	14,744	25,980	26,188	25,153	25,153	25,153
Solar	59	104	105	28,753	50,828	50,828
Wind	21,640	38,132	38,437	149,269	195,292	195,291
Biomass	49,059	86,447	87,139	69,561	99,858	99,857
Coal	19,108	33,671	33,941	19,888	0	0
Diesel-Fuel	37,735	66,494	67,026	0	0	0
Natural gas	79,541	140,161	141,283	105,909	63,228	102,915
Hydroelectric	359,975	634,319	639,396	580,862	646,782	614,443
TOTAL	581,861	1,025,309	1,033,516	979,395	1,081,142	1,088,485

Source: Simulation results

The CPS achieves 4% savings in electricity generation in Brazil compared to the BAU scenario, while generation increases by 5% over the same reference level in the NFS thanks to greater penetration by electricity in final consumption sectors.

Figure 10.4 Renewability index of electricity generation in Brazil, all scenarios

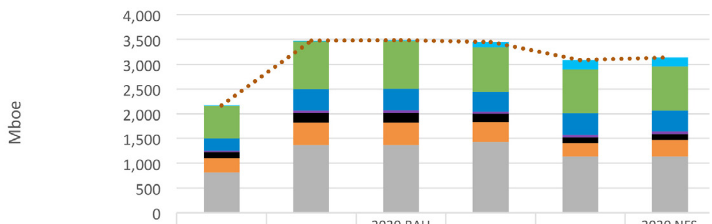


Source: Simulation results

While Brazil already has a fairly high renewability index in electricity generation in the base year, this indicator improves substantially in the current policy scenario, CPS, and even more so in the proposed NFS, though it loses a few percentages points in this index with the sensitivity to climate change effects (NFS (RCP 8.5)).

10.2.3 Projected total energy supply and structure

Figure 10.5 Projected total energy supply in Brazil, all scenarios

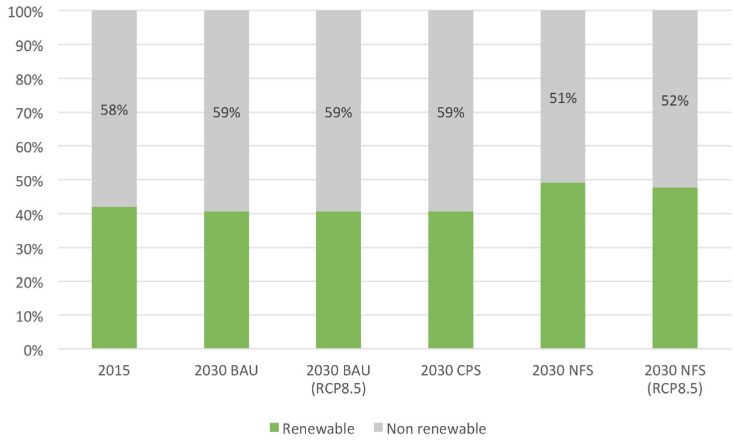


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	13	24	24	107	187	187
Biomass	655	960	961	898	893	893
Hydroenergy	244	429	433	396	438	418
Nuclear	28	49	49	47	47	47
Coal and coke	127	200	200	171	120	120
Natural gas	281	452	454	398	271	342
Crude oil and derivatives	821	1,366	1,367	1,432	1,132	1,132
TOTAL	2,169	3,479	3,488	3,449	3,088	3,138

Source: Simulation results

Under the current policies scenario, Brazil manages just 1% savings in total energy supply compared to the BAU scenario; however, these savings reach 11% in the proposed NFS.

Figure 10.6Renewability index for total energy supply in Brazil, all scenarios



Source: Simulation results

Though the renewability index for the total energy supply is maintained in the current policies scenario (CPS) when compared to the BAU scenario, this indicator improves in the NFS and approaches 50%, though it loses one percentage point for sensitivity to climate change.

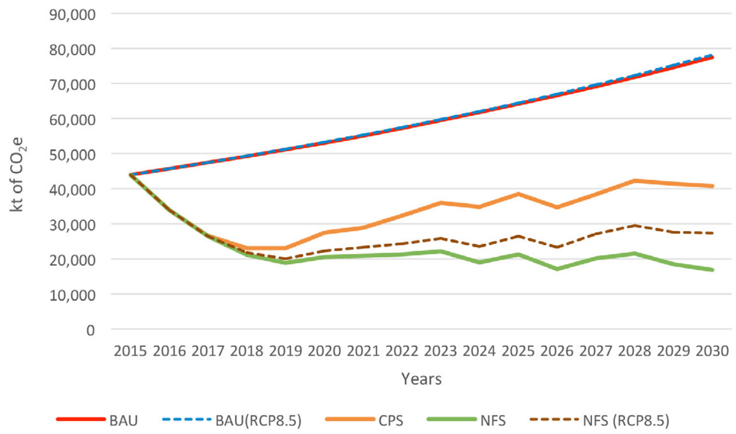
10.2.4 CO2e emissions from electricity generation and percentage reduction

Table 10.1. CO2e emissions from electricity generation in Brazil, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	43,972	43,972	43,972	43,972	43,972
2016	45,659	45,684	33,936	33,936	33,936
2017	47,411	47,461	26,537	26,445	26,445
2018	49,230	49,309	22,998	21,170	21,741
2019	51,120	51,230	23,028	18,841	20,028
2020	53,084	53,226	27,500	20,484	22,276
2021	55,125	55,302	28,895	20,903	23,313
2022	57,245	57,460	32,328	21,207	24,257
2023	59,448	59,703	35,947	22,162	25,867
2024	61,738	62,035	34,804	19,004	23,514
2025	64,117	64,460	38,516	21,263	26,502
2026	66,589	66,980	34,672	17,097	23,262
2027	69,158	69,601	38,320	20,070	27,081
2028	71,827	72,326	42,256	21,555	29,473
2029	74,602	75,159	41,406	18,459	27,608
2030	77,485	78,105	40,772	16,759	27,278
TOTAL	**947,809**	**952,013**	**545,889**	**363,328**	**426,555**

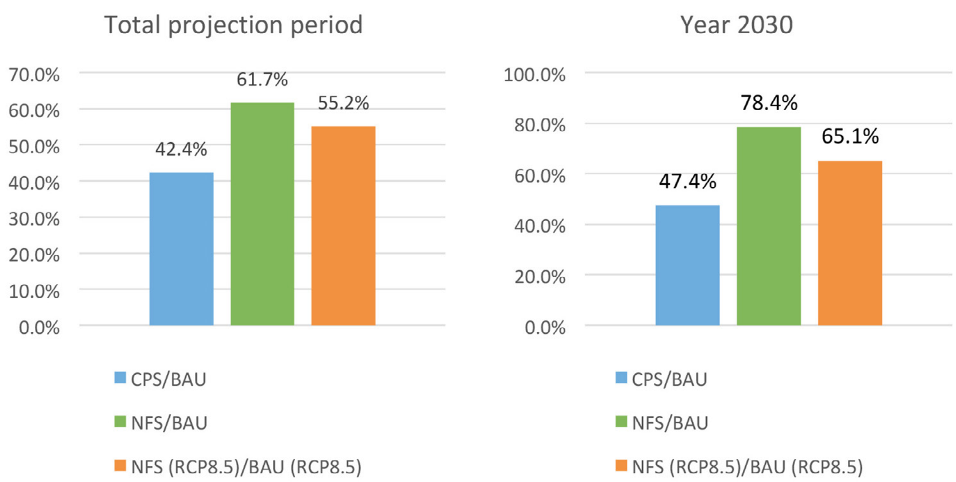
Source: Simulation results

Figure 10.7 CO2e emissions from electricity generation in Brazil, all scenarios



Source: Simulation results

Figure 10.8 Percentage reduction in CO2 e emissions from electricity generation in Brazil



Source: Simulation results

Thanks to the fact that the timeline that Brazil proposes for expanding its electricity generation capacity in the CPS considers a considerable increase in the renewable component, which is further intensified in the NFS, the result for both scenarios produces significant percentage reductions in emissions when compared to the BAU scenario.

Given the Brazilian electricity generation matrix's high dependence on hydroenergy, we can see that, with sensitivity to climate change, the variation in the percentage of CO2e emissions is also very significant (Figure 10.8).

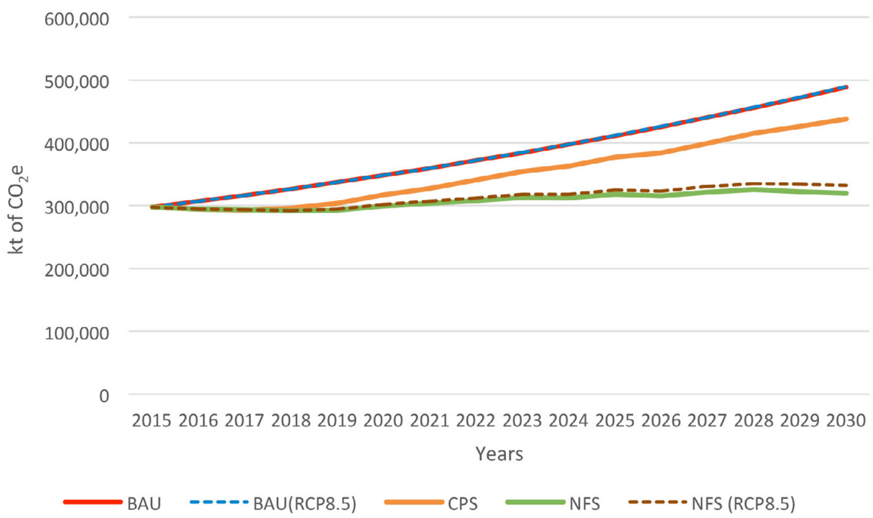
10.2.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.2. CO2e emissions in Brazil's energy matrix, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	297,672	297,672	297,672	297,672	297,672
2016	306,875	306,903	294,419	294,419	294,419
2017	316,512	316,570	292,792	293,644	293,644
2018	326,599	326,689	296,245	291,559	292,281
2019	337,148	337,273	303,841	293,178	294,677
2020	348,175	348,337	317,518	299,407	301,670
2021	359,696	359,898	327,676	304,109	307,151
2022	371,727	371,971	340,838	308,252	312,102
2023	384,285	384,575	354,393	313,221	317,867
2024	397,389	397,727	362,958	312,511	318,206
2025	411,057	411,448	377,420	318,536	325,150
2026	425,310	425,756	383,609	315,757	323,542
2027	440,169	440,674	398,845	321,615	330,467
2028	455,656	456,224	415,147	325,322	335,318
2029	471,794	472,428	425,948	322,213	333,764
2030	488,607	489,313	437,832	319,562	332,843
TOTAL	6,138,672	6,143,457	5,627,150	4,930,978	5,010,772
a.a.r. 2030/2015	**3.4%**	**3.4%**	**2.6%**	**0.5%**	**0.7%**

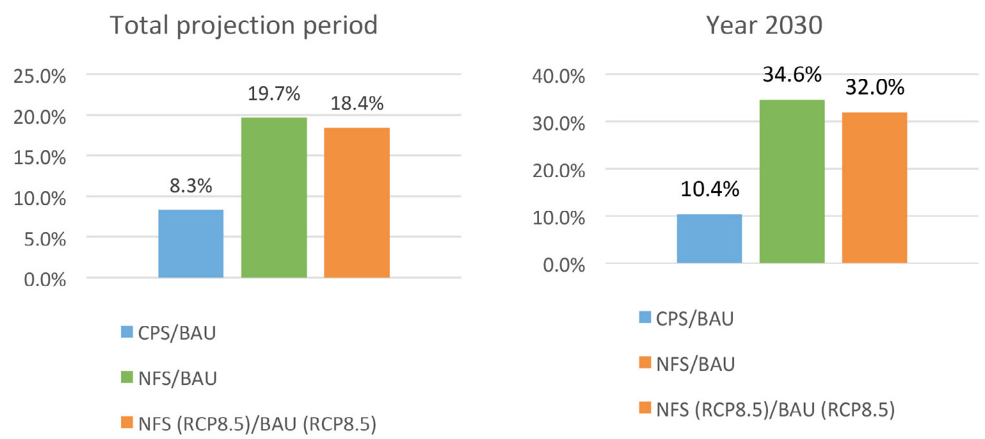
Source: Simulation results

Figure 10.9 CO2e emissions in Brazil's energy matrix, all scenarios



Source: Simulation results

Figure 10.10 Percentage reduction in CO2 e emissions in Brazil's energy matrix



Source: Simulation results

As mentioned in chapter 7, Brazil does not specify a specific GHG emission reduction target for the energy sector in its NDCs, but rather an overall reduction target of 43% by 2030 compared to total emissions in 2005. As was also pointed out in that same chapter, the percentages of reduction obtained in the CPS scenario, with respect to the BAU scenario, are below the targets established in the NDCs of most of the countries of the region and the average annual growth rate of said emissions in the projection period (2.6%), surpasses that expected for the energy sector (1.8%), in the year made by the MME on the contribution of the different sectors to the compliance of the NDCs.

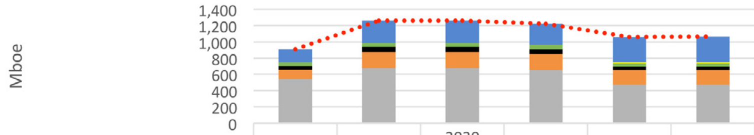
However, under the assumptions of the NFS scenario, the percentage of reduction exceeds 30% by 2030, even with sensitivity to climate change, and the average annual growth rate of emissions decreases to 0.5%, which is lower than the maximum expected by the MME of 1.8% for compliance with the NDCs

It should also be noted that of the total reduction of emissions achieved in the NFS, compared to the BAU (169 Mt of CO2e), 36% (60.7 Mt of CO2e) correspond to the electricity generation sector (see tables 10.1 and 10.2).

10.3 Mexico

10.3.1 Projected final energy consumption and structure

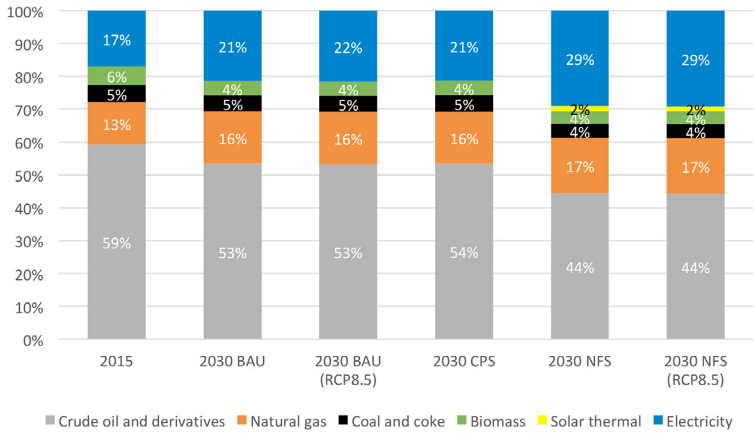
Figure 10.11 Projected final energy consumption in Mexico, all scenarios



	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	154	271	273	260	307	309
Solar thermal	0	0	0	0	17	17
Biomass	52	54	54	54	41	41
Coal and coke	47	61	61	61	45	45
Natural gas	118	201	201	193	179	179
Crude oil and derivatives	539	674	674	654	471	471
TOTAL	910	1,261	1,263	1,223	1,061	1,063

Source: Simulation results

Figure 10.12 Structure of the final energy consumption matrix in Mexico, all scenarios

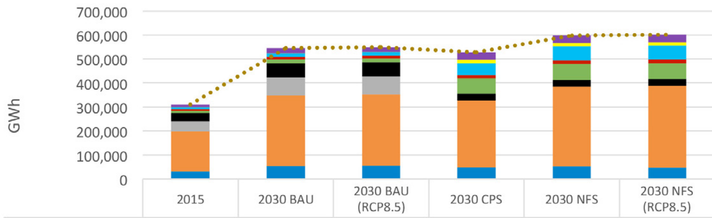


Source: Simulation results

Final energy consumption in Mexico falls by 3% under CPS when compared to the BAU scenario, but it maintains approximately the same proportional structure of the consumption matrix. However, in the NFS the savings in terms of final energy consumption total 16% and the decline in the share of oil products is very clear, being displaced by natural gas and electricity (Figures 10.11 and 10.12).

10.3.2 Projected electricity generation and structure

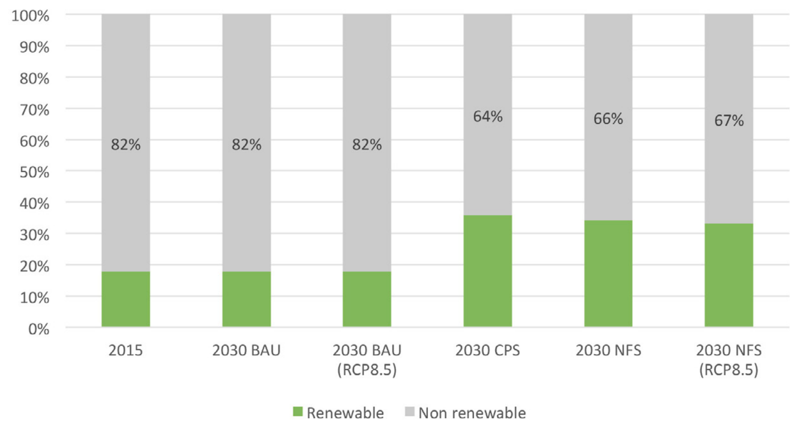
Figure 10.13 Projected electricity generation in Mexico, all scenarios



	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Nuclear	11,453	20,105	20,269	32,245	32,245	32,245
Solar	93	163	164	12,625	13,003	13,003
Wind	8,667	15,214	15,339	51,113	57,252	57,252
Geothermal	6,191	10,867	10,956	11,956	16,270	16,270
Biomass	9,503	16,681	16,817	64,641	65,954	65,954
Coal	33,741	59,228	59,711	28,288	27,474	27,474
Diesel-Fuel	42,099	73,899	74,502	0	0	0
Natural gas	167,842	294,625	297,031	279,009	333,749	342,483
Hydroelectric	30,955	54,337	54,781	48,523	52,027	46,825
TOTAL	310,544	545,120	549,571	528,401	597,976	601,506

Source: Simulation results

Figure 10.14Renewability index of electricity generation in Mexico, all scenarios

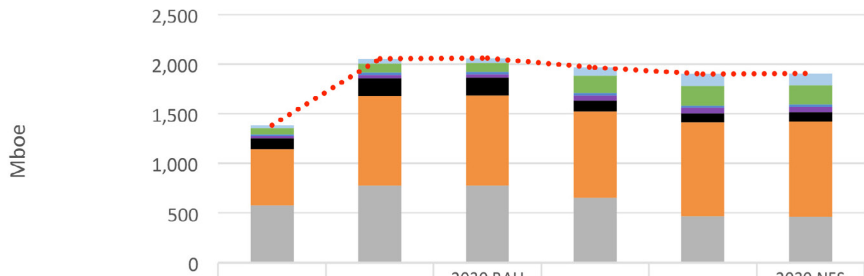


Source: Simulation results

CPS allows the same proportion in electricity generation savings as the decline in electricity consumption with regard to the BAU Scenario (4%), while generation increases by 10% in the NFS due to the increased electrification of sectors like transportation and industry. Due to the faster pace of renewable energy penetration, the renewability index under CPS doubles compared to the BAU scenario, but in the NFS it falls a bit thanks to the expansion to natural gas to meet the additional demand for electricity. One can also see that the sensitivity to climate change also affects this indicator (Figure 10.13 and 10.14).

10.3.3 Projected total energy supply and structure

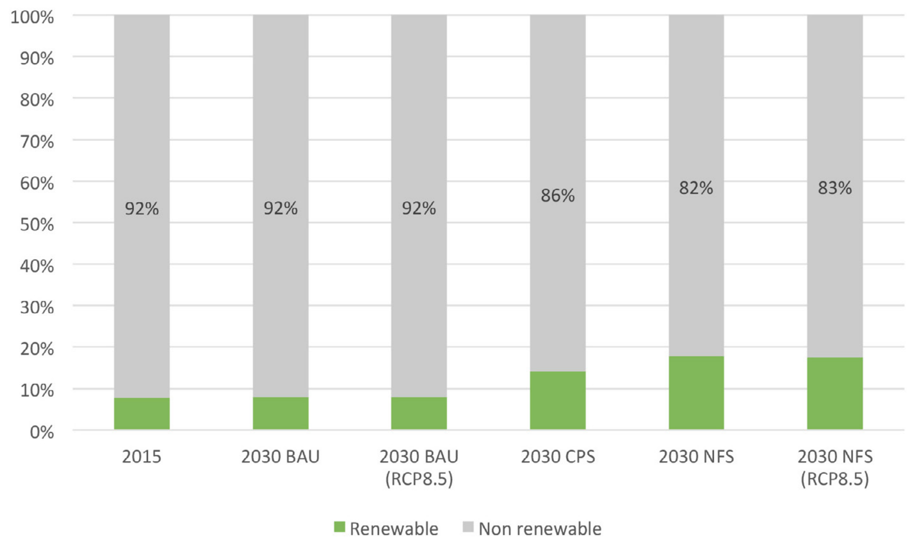
Figure 10.15 Projected total energy supply in Mexico, all scenarios



	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	23	50	50	84	121	121
Biomass	69	85	85	174	194	194
Hydroenergy	15	26	27	20	22	19
Nuclear	21	36	37	58	58	58
Coal and coke	109	171	172	108	90	90
Natural gas	566	905	909	866	945	960
Crude oil and derivatives	580	778	779	656	469	465
TOTAL	1,382	2,052	2,059	1,967	1,898	1,907

Source: Simulation results

Figure 10.16 Renewability index for total energy supply in Mexico, all scenarios



Source: Simulation results

The CPS generates a 4% savings in total energy supply in Mexico when compared to the BAU scenario and that savings increases to 7% in the NFS. furthermore, while the renewability index of the total energy supply matrix in Mexico improves by 7 percentage points in the CPS when compared to the BAU scenario, another 10 percentage points are added to this indicator in the NFS. Sensitivity to climate change in the NFS affects the renewability of the total energy supply by one percentage point (Figures 10.15 and 10.16).

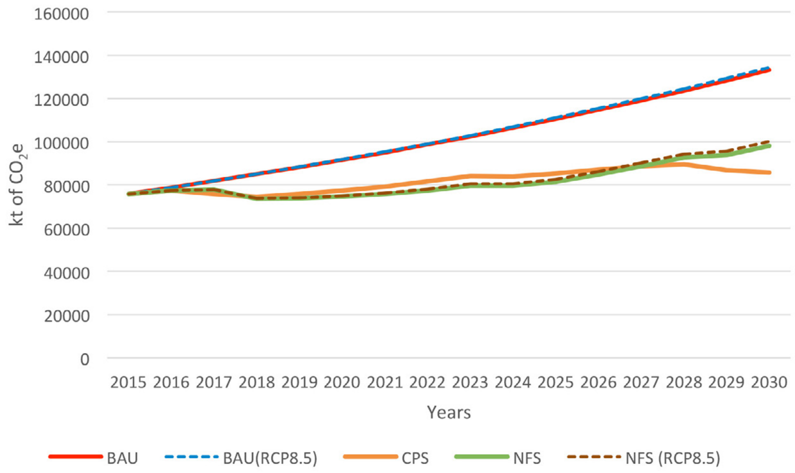
10.3.4 CO2e emissions from electricity generation and percentage reduction

Table 10.3. CO2e emissions from electricity generation in Mexico, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	75,930	75,930	75,930	75,930	75,930
2016	78,821	78,863	77,378	77,378	77,378
2017	81,829	81,918	75,773	77,745	77,745
2018	84,954	85,092	74,464	73,497	73,690
2019	88,198	88,389	75,843	73,742	74,058
2020	91,568	91,816	77,451	74,596	75,038
2021	95,067	95,376	79,294	75,740	76,310
2022	98,701	99,075	81,594	77,478	78,178
2023	102,474	102,919	84,251	79,685	80,539
2024	106,393	106,912	83,955	79,600	80,591
2025	110,463	111,062	85,245	81,535	82,685
2026	114,689	115,374	87,133	84,851	86,157
2027	119,078	119,854	88,561	88,729	90,199
2028	123,636	124,510	89,561	92,741	94,392
2029	128,370	129,347	86,771	93,755	95,604
2030	133,286	134,374	85,753	98,078	100,136
TOTAL	**1,633,455**	**1,640,811**	**1,308,955**	**1,305,081**	**1,318,629**

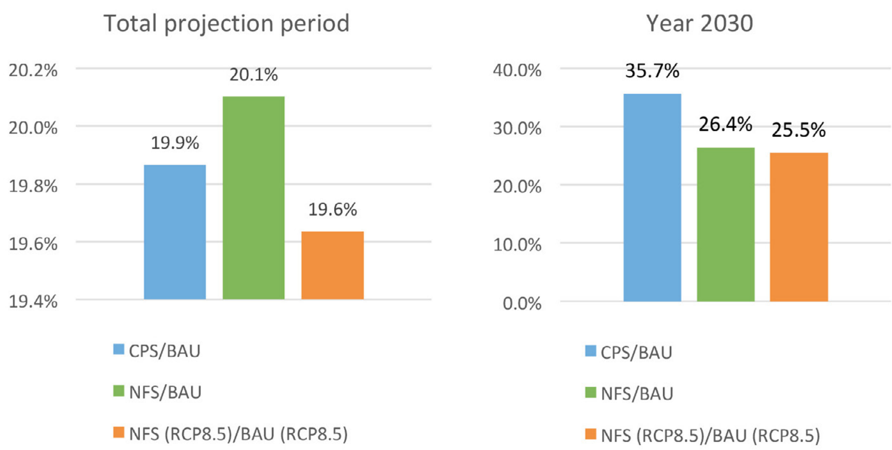
Source: Simulation results

Figure 10.17 CO2e emissions from electricity generation in Mexico, all scenarios



Source: Simulation results

Figure 10.18 Percentage reduction in CO2 e emissions from electricity generation in Mexico



Source: Simulation results

Mexico presents the unique feature that, while accumulated emissions for the study period fall by a larger proportion of the BAU Scenario under the NFS when compared to CPS, by the end of the projection period the percentage reduction in the NFS and is less than in the CPS. This is due to increased demand for electricity and greater penetration of natural gas to meet it.

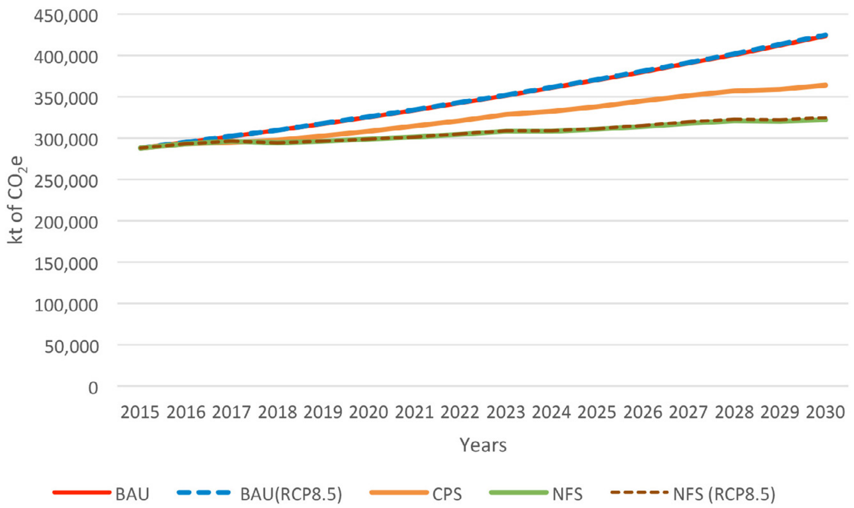
10.3.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.4 CO2e emissions in Mexico's energy matrix, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	288,006	288,006	288,006	288,006	288,006
2016	294,917	294,970	290,105	290,105	290,105
2017	302,117	302,227	292,262	291,923	291,923
2018	309,595	309,766	297,016	292,240	292,084
2019	317,355	317,592	302,151	294,226	294,360
2020	325,400	325,708	307,807	295,561	295,993
2021	333,736	334,119	315,227	297,857	298,596
2022	342,369	342,834	322,101	300,407	301,463
2023	351,307	351,859	327,569	301,993	303,402
2024	360,557	361,202	332,914	302,954	304,701
2025	370,128	370,873	339,021	304,669	306,788
2026	380,030	380,881	345,868	307,147	309,644
2027	390,273	391,237	352,135	309,795	312,688
2028	400,868	401,953	358,001	312,276	315,594
2029	411,825	413,039	361,725	311,853	315,632
2030	423,157	424,508	367,952	311,325	315,588
TOTAL	**5,601,641**	**5,610,773**	**5,199,861**	**4,812,338**	**4,836,566**

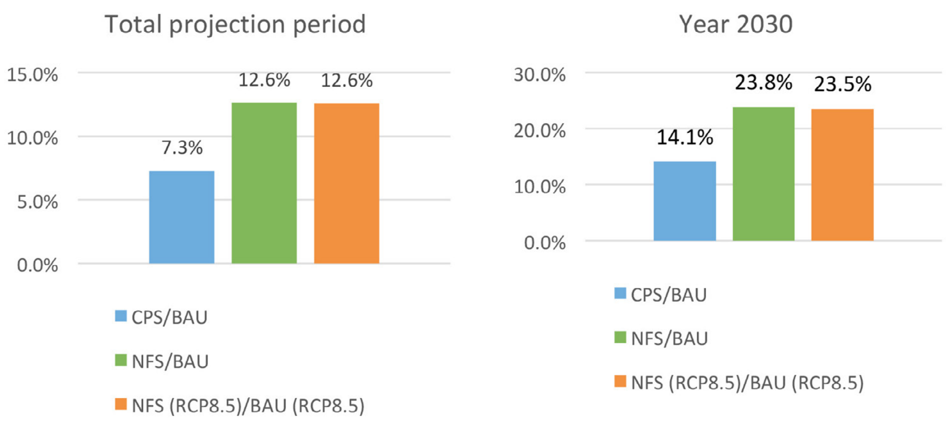
Source: Simulation results

Figure 10.19 CO2e emissions in Mexico's energy matrix, all scenarios



Source: Simulation results

Figure 10.20 Percentage reduction in CO2 e emissions in Mexico's energy matrix



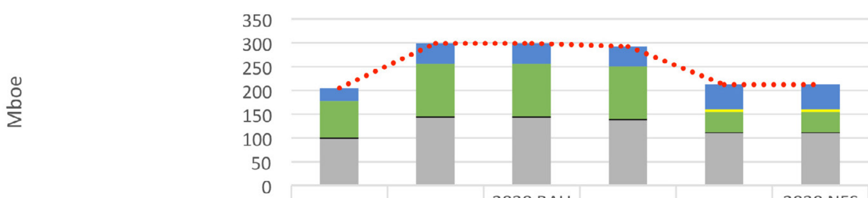
Source: Simulation results

While the CPS scenario achieves an emission reduction of only 14.1% compared to the BAU scenario, which is far below the total percentage of reductions proposed by Mexico as an unconditional target for 2030 in its NDCs of 25% compared to the BAU scenario (see Annex II); with the NFS scenario, said reduction would reach nearly 24%, which represents a value very close to the aforementioned target and very significant for a country highly dependent on natural gas in its energy matrix. Given the low share of hydropower in Mexico's energy matrix, sensitivity to climate change is virtually irrelevant to total CO2e emissions. Of the total reduction of GHG emissions from the energy sector, achieved in the NFS scenario, compared to the BAU scenario (100.7 Mt of CO2e.), in 2030, 35% corresponded to the electricity generation sector (see Tables 10.3 and 10.4).

10.4 Central America

10.4.1 Projected final energy consumption and structure

Figure 10.21 Projected final energy consumption in Central America, all scenarios

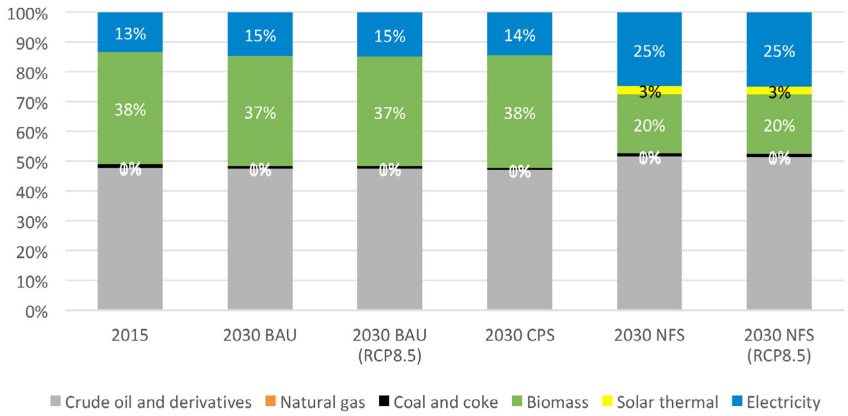


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	27	44	44	42	53	53
Solar thermal	0	0	0	0	6	6
Biomass	77	110	110	110	42	42
Coal and coke	3	2	2	2	2	2
Natural gas	0	0	0	0	0	0
Crude oil and derivatives	98	142	142	137	109	109
TOTAL	205	299	299	292	212	212

Source: Simulation results

The savings in final energy consumption in the current policies scenario, CPS, is just 2% compared to the BAU scenario, but that savings becomes very significant under the proposed NFS: 29% regarding to BAU and 27% regarding to CPS. This is mainly due to substitution of firewood with modern sources such as LPG and electricity, in addition to the increased penetration of efficient stoves fueled with firewood (Figure 10.21).

Figure 10.22 Structure of the final energy consumption matrix in Central America, all scenarios

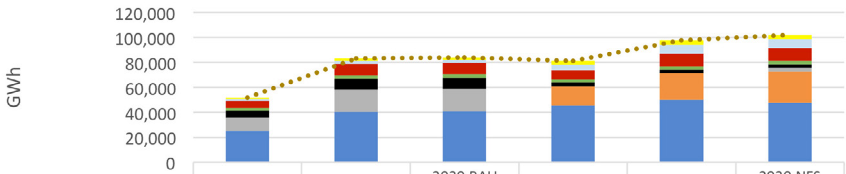


Source: Simulation results

By the same fact of the aggressive substitution of wood for LPG and simulated electricity in the NFS scenario, although energy efficiency gains are made in the total consumption, the share of petroleum products increases drastically in the NFS scenario, as can be seen in Figure 10.22 (48% BAU, 47% CPS and 52% NFS). On the other hand, electricity also gains percentage space in the final consumption matrix (25% NFS vs 14% CPS and 15% BAU).

10.4.2 Projected electricity generation and structure

Figure 10.23 Projected electricity generation in Central America, all scenarios

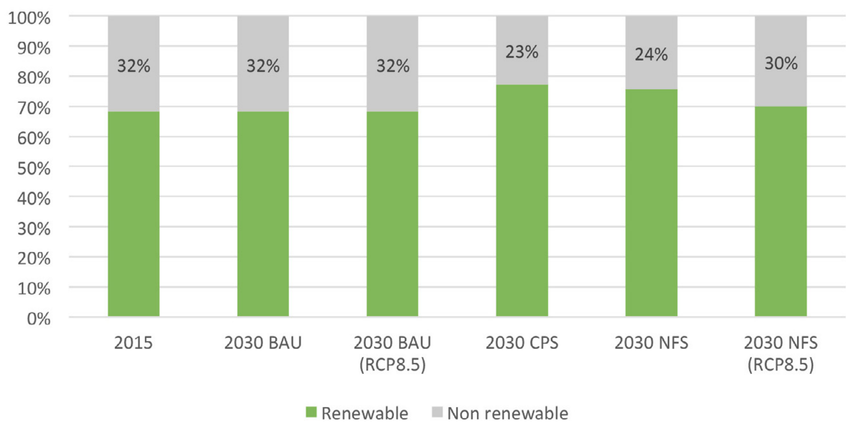


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Solar	1,408	2,266	2,285	3,100	3,577	3,577
Wind	1,291	2,077	2,095	4,408	6,913	6,913
Geothermal	5,670	9,122	9,202	7,490	10,170	10,170
Biomass	1,810	2,912	2,937	2,205	3,030	3,028
Coal	5,446	8,761	8,838	3,229	2,633	2,633
Diesel-Fuel	11,004	17,703	17,858	0	0	2,975
Natural gas	0	0	0	15,212	21,187	25,089
Hydroelectric	25,195	40,535	40,889	45,460	50,153	47,645
TOTAL	51,824	83,376	84,104	81,104	97,665	102,031

Source: Simulation results

Electricity generation in Central America increases very significantly under the NFS when compared to BAU and the CPS, given the need to meet the demand of increased end-use electrification, especially the replacement of part of firewood consumption with electricity (Figure 10.23).

Figure 10.24 Renewability index of electricity generation in Central America, all scenarios

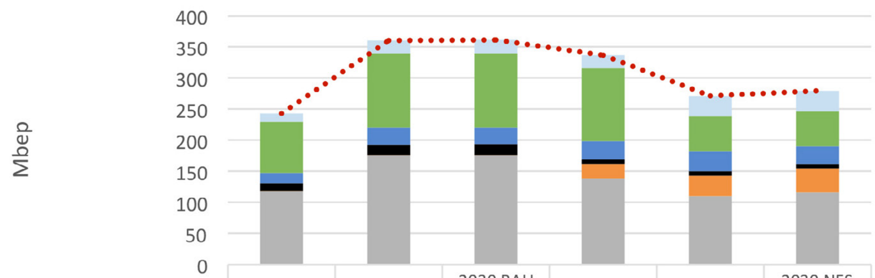


Source: Simulation results

Although the main change in the power generation matrix in Central America is the introduction of natural gas use (22% NFS and 19% CPS), it also stands out both in the CPS scenario and in the proposed NFS scenario, the greater renewability of the matrix, thanks to the increase in the share of hydropower, wind power, geothermal and solar energy (68% BAU, 77% CPS and 76% NFS). It can also be seen in Figure 10.24 that, given the high participation of hydropower in Central America's electricity matrix, sensitivity to climate change does significantly affect the matrix's renewability index (70% NFS(RCP8.5)).

10.4.3 Projected total energy supply and structure

Figure 10.25 Projected total energy supply in Central America, all scenarios

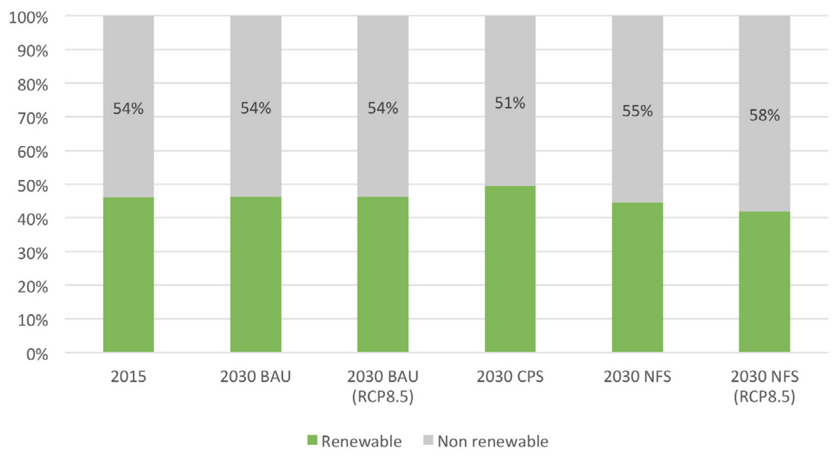


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	13	21	22	20	33	33
Biomass	82	119	119	117	56	56
Hydroenergy	17	27	27	29	32	28
Coal and coke	12	18	18	8	7	7
Natural gas	0	0	0	24	33	39
Crude oil and derivatives	118	176	176	138	110	117
TOTAL	243	361	362	336	272	280

Source: Simulation results

Total energy supply also experiences a decline in the NFS over the BAU scenario that is consistent with the savings in terms of final energy consumption, or in this case 25%. As can be seen in Figure 10.24, there is a small negative effect on this total energy savings with sensitivity to CC.

Figure 10.26 Renewability index for total energy supply in Central America, all scenarios



Source: Simulation results

The renewability of total energy supply in CPS improves with regard to the BAU scenario, but the indicator declines in the proposed NFS. This is because of a very significant increase in electricity consumption and generation in the NFS, which therefore requires greater participation by steady energy, in this case provided by natural gas-fired power plants. Sensitivity to CC also affects the renewability of total supply thanks to the importance of hydroenergy in this subregion.

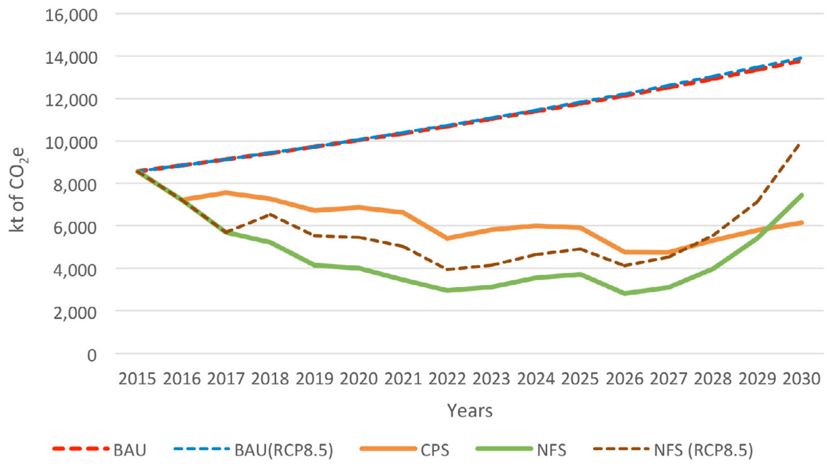
10.4.4 CO2e emissions from electricity generation and percentage reduction

Table 10.5. CO2e emissions from electricity generation in Central America, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	8,566	8,566	8,566	8,566	8,566
2016	8,839	8,844	9,493	9,493	9,493
2017	9,122	9,132	9,835	9,285	9,285
2018	9,414	9,430	9,847	8,877	8,966
2019	9,715	9,738	9,148	8,272	8,439
2020	10,027	10,056	9,337	7,186	7,436
2021	10,349	10,385	9,127	6,769	6,964
2022	10,682	10,726	8,020	6,200	6,456
2023	11,026	11,078	8,416	6,289	6,596
2024	11,382	11,442	8,746	6,649	7,010
2025	11,749	11,818	8,955	6,840	7,262
2026	12,129	12,207	7,934	6,006	6,532
2027	12,522	12,609	7,965	6,471	7,078
2028	12,928	13,026	8,569	7,295	7,989
2029	13,347	13,456	9,083	8,631	9,420
2030	13,781	13,901	9,482	10,512	11,400
TOTAL	**175,580**	**176,414**	**142,522**	**123,341**	**128,893**

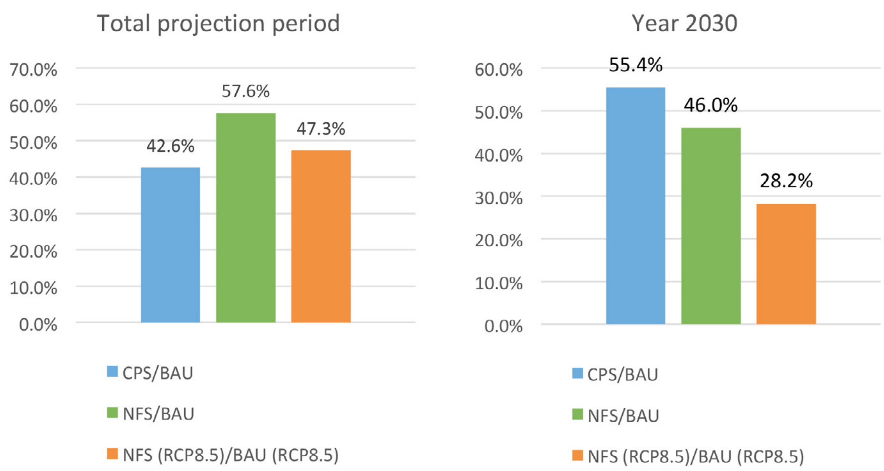
Source: Simulation results

Figure 10.27 CO2e emissions from electricity generation in Central America, all scenarios



Source: Simulation results

Figure 10.28 Percentage reduction in CO2e emissions from electricity generation in Central America



Source: Simulation results

Though the percentage reduction in CO2e emissions accumulated over the projection period is greater in the NFS than in the CPS, by the annual percentage reduction is less than in the CPS, thanks to the accelerated increase in electricity generation, which obliges larger amounts of natural gas to be used. One can also see that with sensitivity to climate change the percentage reduction in CO2e emissions falls significantly, especially toward the end of the projection period.

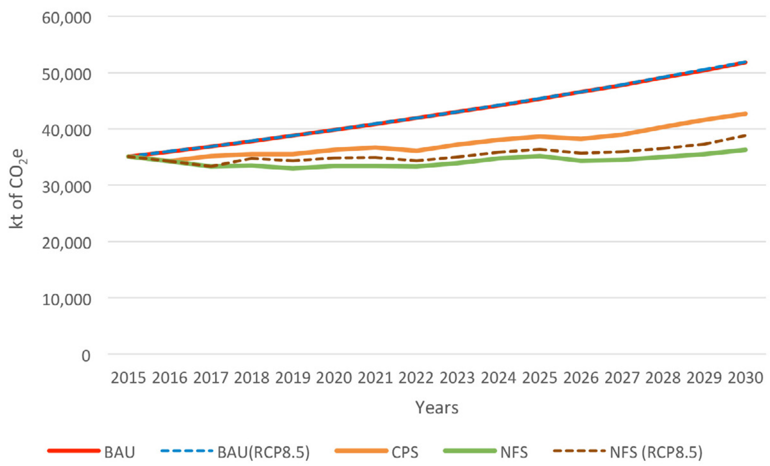
10.4.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.6. CO2e emissions by the energy matrix in Central America, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	35,101	35,101	35,101	35,101	35,101
2016	35,988	35,993	34,302	34,302	34,302
2017	36,904	36,914	35,207	33,342	33,342
2018	37,848	37,864	35,506	33,472	34,765
2019	38,821	38,844	35,548	32,992	34,371
2020	39,825	39,854	36,308	33,382	34,851
2021	40,860	40,896	36,682	33,374	34,936
2022	41,928	41,972	36,114	33,361	34,335
2023	43,030	43,081	37,191	33,946	34,982
2024	44,166	44,226	38,061	34,738	35,842
2025	45,338	45,407	38,662	35,156	36,342
2026	46,548	46,625	38,243	34,349	35,665
2027	47,796	47,883	38,983	34,524	35,960
2028	49,084	49,182	40,313	34,979	36,546
2029	50,413	50,522	41,565	35,566	37,288
2030	51,785	51,905	42,742	36,312	38,845
TOTAL	**685,432**	**686,268**	**600,528**	**548,895**	**567,473**

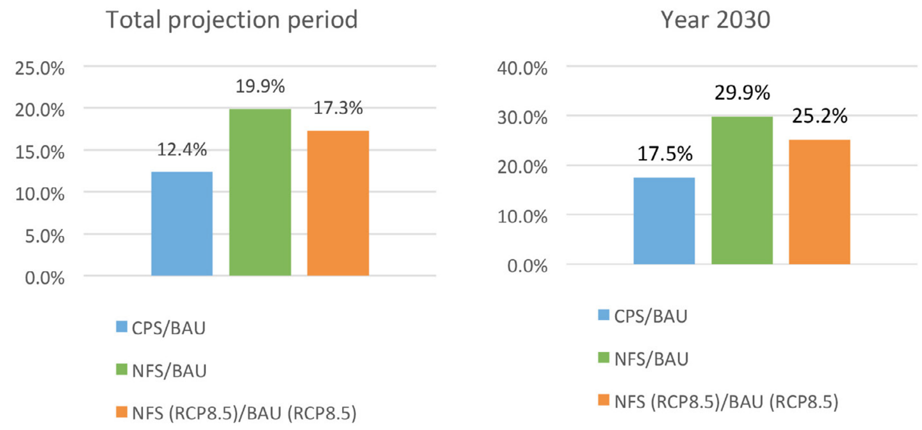
Source: Simulation results

Figure 10.29 CO2e emissions by the energy matrix in Central America, all scenarios



Source: Simulation results

Figure 10.30 Percentage reduction in CO2 e emissions by the energy matrix in Central America



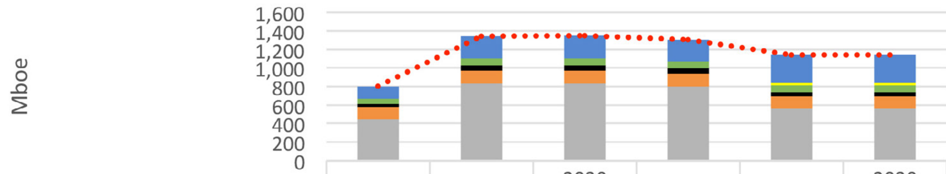
Source: Simulation results

Although the percentage of GHG emissions reduction achieved with the CPS scenario in 2030, compared to the BAU scenario, is important (17.5%), some NDCs, conditional of countries of the subregion, still propose more ambitious goals (example: Guatemala 22.6%), while with the NFS scenario, this percentage of reduction would reach a value close to 30%. Although there is great heterogeneity in the way in which Central American countries propose their NDCs, which makes it difficult to aggregate emission reduction targets at the subregional level, it can be assured that with a 30% integral reduction in the energy sector, the expectations of the subregion will be exceeded (see Annex II), even in the NFS scenario, with sensitivity to climate change (NFS (RCP8.5)). In the total reduction of GHG emissions achieved in the NFS scenario, with respect to the BAU scenario (15.5 Mt of CO2e.), the electricity generation sector contributes 41% (see Tables 10.5 and 10.6).

10.5 Andean Subregion

10.5.1 Projected final energy consumption and structure

Figure 10.31 Structure of the final energy consumption matrix in the Andean Subregion, all scenarios

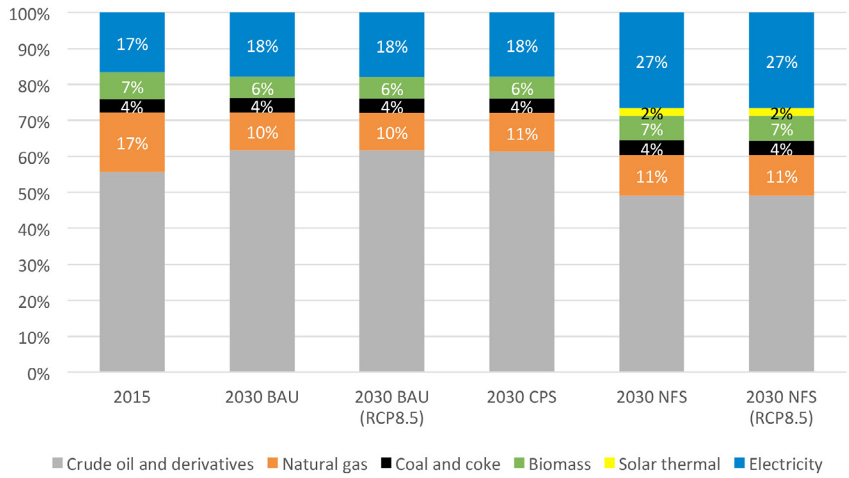


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	133	240	241	231	303	304
Solar thermal	0	0	0	0	25	25
Biomass	60	79	79	79	78	78
Coal and coke	29	54	54	54	46	46
Natural gas	134	140	140	140	129	129
Crude oil and derivatives	447	832	832	800	561	561
TOTAL	803	1,346	1,347	1,304	1,142	1,143

Source: Simulation results

The Andean Region CPS allows a 3% savings in final energy consumption compared to the BAU scenario, while that savings increases to 15% in the NFS, which means a reduction of 12% with respect to the CPS.

Figure 10.32 Structure of the final energy consumption matrix in the Andean Subregion, all scenarios

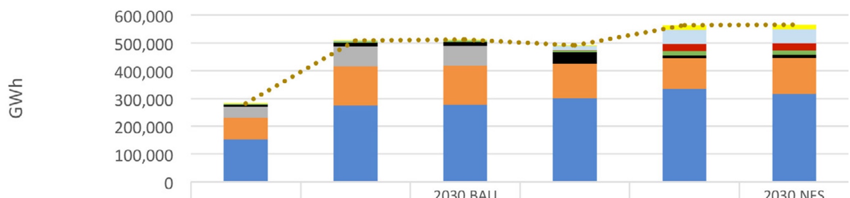


Source: Simulation results

With regard to the structure of final consumption under the NFS, the displacement of use of oil products and the increase on the use of the electricity and thermal solar power to heat water stand out.

10.5.2 Projected electricity generation and structure

Figure 10.33 Projected electricity generation in the Andean Subregion, all scenarios

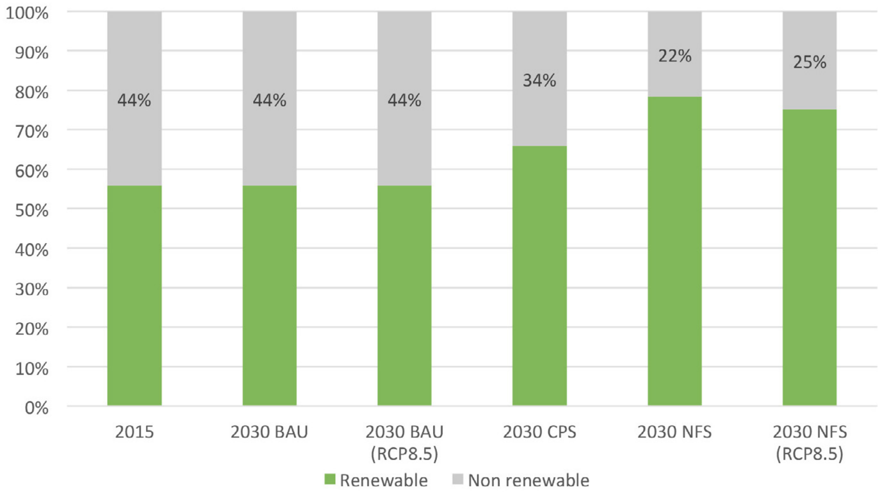


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Solar	323	582.49	585.13	1,857.84	16,870.72	16,870.72
Wind	1,503	2,711.50	2,723.78	15,264.90	50,592.53	50,592.53
Geothermal	0	0	0	1,473.89	24,844.30	24,844.30
Biomass	2,844	5,132.34	5,155.57	4,757.93	16,147.56	16,147.56
Coal	6,953	12,547.73	12,604.52	42,193.76	10,759.77	10,759.77
Diesel-Fuel	39,985	72,155.60	72,482.16	0	0	0
Natural gas	77,709	140,231.30	140,865.90	125,128.90	110,948.70	129,264.60
Hydroelectric	152,886	275,892.00	277,140.70	300,761.20	333,716.00	317,030.30
TOTAL	282,203	509,252.90	511,557.80	491,438.40	563,879.60	565,509.70

Source: Simulation results

The additional electricity generation required in the NFS for the Andean Subregion is supplied with renewable energy sources like hydro, wind, solar and geothermal power. The climate change effects simulated in the NFS (RCP 8.5) lead to a slight increase in total generation.

Figure 10.34 Renewability index for electricity generation in the Andean Subregion, all scenarios

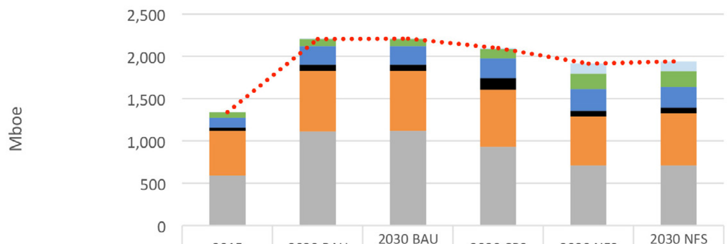


Source: Simulation results

While the CPS already manages a clear improvement in the renewability of electricity generation in the Andean Subregion compared to the BAU Scenario, this indicator increases to over three-quarters of the matrix under the NFS (56% BAU, 66% CPS and 78% NFS).

10.5.3 Projected total energy supply and structure

Figure 10.35 Projected total energy supply in the Andean Subregion, all scenarios

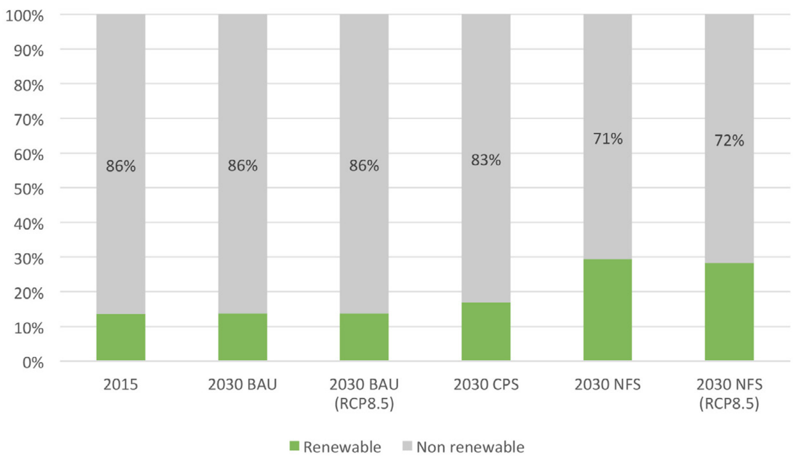


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	1	2	2	14	118	118
Biomass	63	86	86	108	185	185
Hydroenergy	118	214	215	233	258	245
Nuclear	0	0	0	0	0	0
Coal and coke	41	75	75	134	63	63
Natural gas	525	711	712	679	580	618
Crude oil and derivatives	591	1,114	1,115	929	709	709
TOTAL	1,339	2,202	2,205	2,097	1,914	1,939

Source: Simulation results

The CPS achieves a 5% savings in total energy supply compared to the BAU scenario, while energy efficiency measures under the NFS increase this percentage of savings to 13%. It is also important to highlight the reduction in the share of oil and its derivatives in the total energy supply matrix for the year 2030 (51% BAU, 44% CPS and 37% NFS).

Figure 10.36 Renewability index for total energy supply in the Andean Subregion, all scenarios



Source: Simulation results

While the total energy supply matrix in the Andean Subregion continues to be highly dependent on fossil fuels through the end of the projection period under all scenarios that were simulated, the NFS obtains a renewability index of this matrix of 29%, against 14% of the BAU scenario and 17% of the CPS.

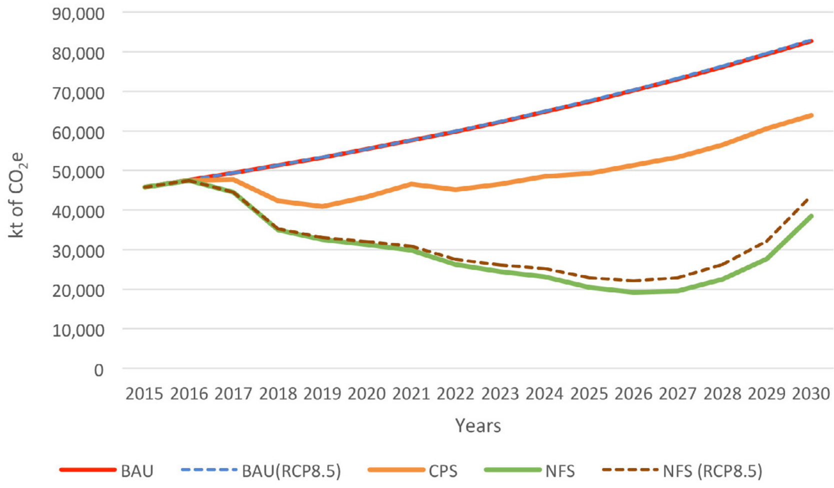
10.5.4 CO2e emissions from electricity generation and percentage reduction

Table 10.7. CO2e emissions from electricity generation in the Andean Subregion (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	45,807	45,807	45,807	45,807	45,807
2016	47,577	47,592	47,433	47,433	47,433
2017	49,397	49,428	47,792	44,542	44,542
2018	51,302	51,350	42,332	35,000	35,251
2019	53,297	53,363	40,873	32,609	33,088
2020	55,386	55,472	43,374	31,276	32,008
2021	57,575	57,681	46,546	29,884	30,884
2022	59,867	59,996	45,189	26,210	27,538
2023	62,270	62,422	46,576	24,437	26,090
2024	64,787	64,965	48,473	23,184	25,184
2025	67,425	67,631	49,239	20,454	22,860
2026	70,191	70,426	51,275	19,233	22,077
2027	73,090	73,356	53,415	19,561	22,872
2028	76,130	76,430	56,480	22,484	26,295
2029	79,318	79,654	60,643	27,668	32,115
2030	82,661	83,035	63,986	38,467	43,600
TOTAL	**996,081**	**998,607**	**789,432**	**488,250**	**517,645**

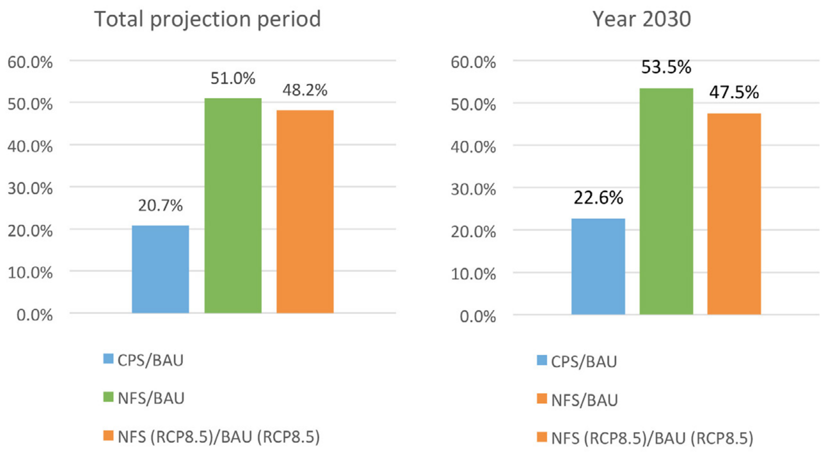
Source: Simulation results

Figure 10.37 CO_2e emissions from electricity generation in the Andean Subregion, all scenarios



Source: Simulation results

Figure 10.38 Percentage reduction in CO_2e emissions from electricity generation in the Andean Subregion



Source: Simulation results

The percentage reduction in emissions from electricity generation in the Andean Subregion is very significant under the proposed NFS, as it is over 50%, both with regard to the entire study period as well as with regard to 2030. This percentage is more than double what is achieved under CPS when compared to the BAU scenario. Sensitivity to climate change affects the percentage of emissions reductions more clearly by the last year of the projection period.

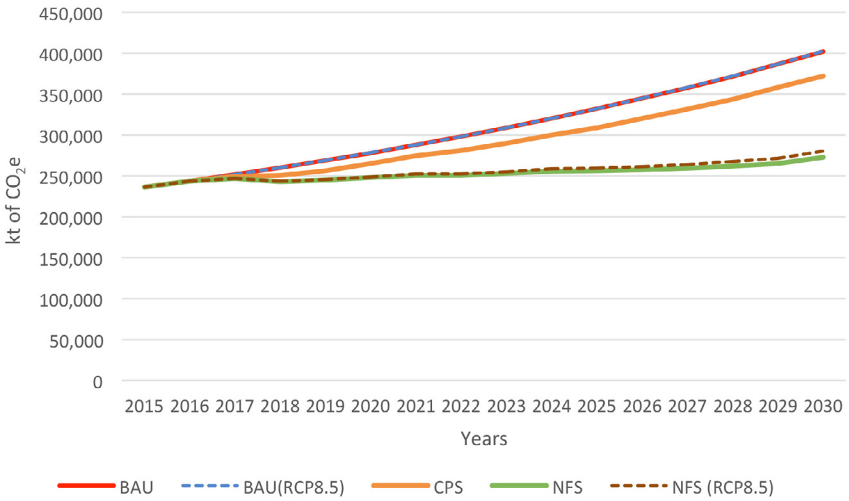
10.5.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.8. CO2e emissions by the energy matrix in the Andean Subregion, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	236,365	236,365	236,365	236,365	236,365
2016	243,893	243,911	243,468	243,468	243,468
2017	251,781	251,819	249,453	246,706	246,706
2018	260,092	260,151	250,677	243,062	243,662
2019	268,847	268,929	256,012	244,735	245,574
2020	278,070	278,176	264,930	247,892	249,174
2021	287,784	287,916	274,783	250,934	252,678
2022	298,014	298,174	280,747	250,675	252,969
2023	308,788	308,978	289,979	252,983	255,824
2024	320,133	320,355	299,907	255,783	259,206
2025	332,080	332,336	309,176	256,031	260,123
2026	344,660	344,953	320,138	257,608	262,415
2027	357,908	358,240	331,685	259,301	264,871
2028	371,858	372,232	343,822	262,275	268,658
2029	386,548	386,966	358,130	265,494	272,890
2030	402,018	402,484	372,350	273,011	281,495
TOTAL	**4,948,835**	**4,951,985**	**4,681,620**	**4,046,322**	**4,096,075**

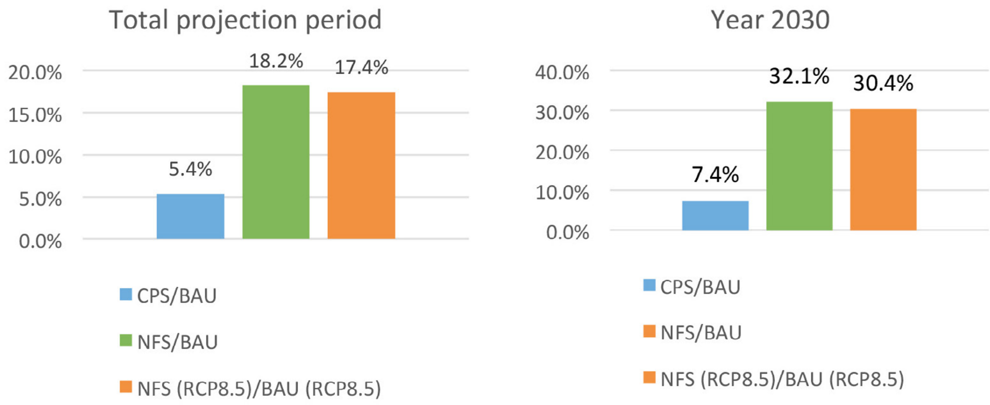
Source: Simulation results

Figure 10.39 CO2 e emissions by the energy matrix in the Andean Subregion, all scenarios



Source: Simulation results

Figure 10.40 Percentage reduction in CO2e emissions by the energy matrix in the Andean Subregion



Source: Simulation results

In the Andean Sub-region, by 2030, GHG emissions from the CPS energy scenario are 7.4% lower than those of the BAU, which is far from a benchmark of between 20% and 25% according to the NDCs, stated by the countries of this subregion. However, the reduction in GHG emissions that would be obtained if the assumptions of the NFS scenario were met is 32%, which is more consistent with the benchmark target for the energy sector in the subregion and the NDCs proposed by the countries that make up the subregion (see Annex II), such as: Colombia, 20 to 30%; Ecuador, 20 to 25%; Peru, 20 to 30%; Venezuela, 20%, compared to the BAU scenario. This favorable scenario is maintained, despite the effects of CC considered in the NFS scenario (RCP8.5).

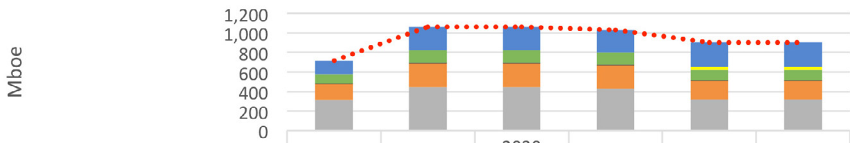
It should also be noted that in the total reduction of GHG emissions achieved with the NFS scenario (129 Mt of CO2e), compared to the BAU scenario, 34% corresponds to the electricity generation sector (see Tables 10.7 and 10.8).

It should also be noted that in the total reduction of GHG emissions achieved with the NFS (129 Mt CO2e), with respect to the BAU scenario, 34% corresponds to the electricity generation sector (see Tables 10.7 and 10.8).

10.6 Southern Cone

10.6.1 Projected final energy consumption and structure

Figure 10.41 Projected final energy consumption in the Southern Cone, all scenarios

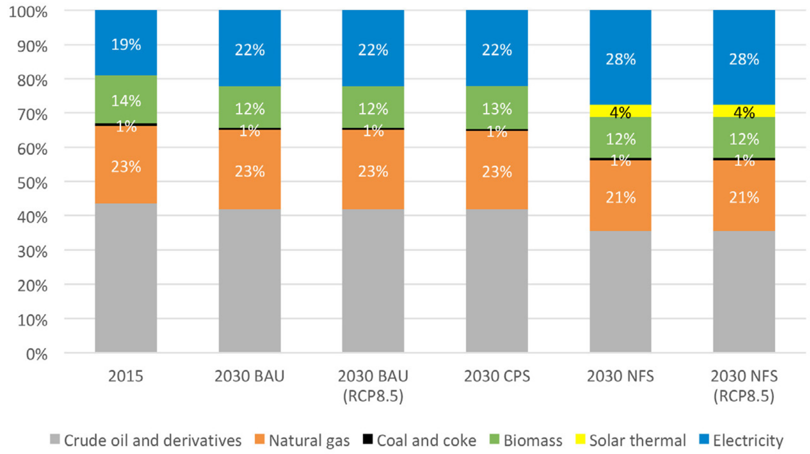


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	136	235	235	227	249	249
Solar thermal	0	0	0	0	33	33
Biomass	100	130	130	130	107	107
Coal and coke	6	6	6	6	6	6
Natural gas	163	247	247	236	188	188
Crude oil and derivatives	312	443	443	432	320	320
TOTAL	717	1,061	1,061	1,030	903	903

Source: Simulation results

By the end of the projection period the CPS achieves 3% savings in annual energy consumption, while under the NFS the savings represents 15% over the BAU scenario.

Figure 10.42 Structure of the final energy consumption matrix in the Southern Cone all scenarios

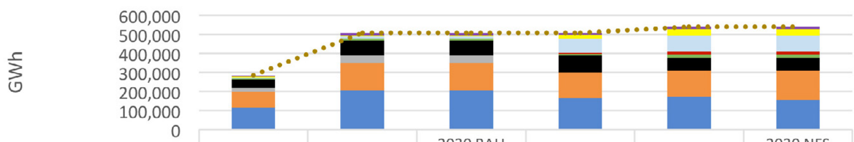


Source: Simulation results

While the final consumption matrix in the Southern Cone does not undergo significant changes in the BAU and CPS scenarios, in the NFS, there is a significant reduction in the share of hydrocarbons, giving ground to electricity (28% NFS vs 22% CPS and 22% BAU) and solar thermal energy (4% NFS).

10.6.2 Projected electricity generation and structure

Figure 10.43Projected electricity generation in the Southern Cone, all scenarios

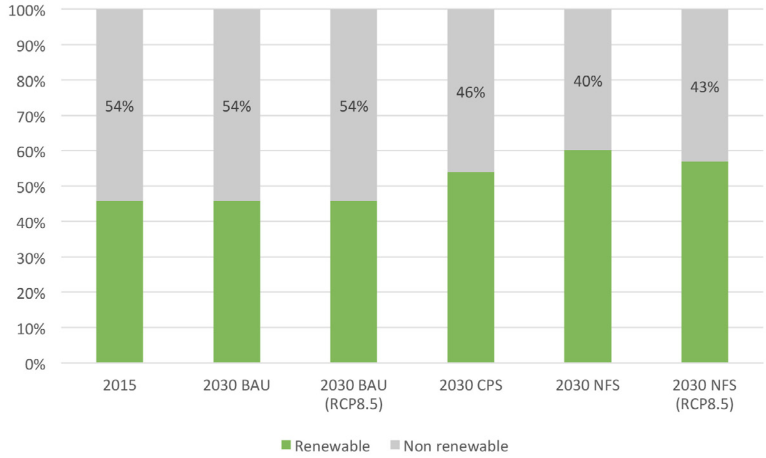


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Nuclear	7,081	12,613	12,613	12,299	12,299	12,303
Solar	3,799	6,768	6,768	20,638	34,219	34,219
Wind	6,112	10,888	10,888	72,835	82,766	82,766
Geothermal	0	0	0	4,320	16,146	16,146
Biomass	4,944	8,806	8,806	9,166	16,851	16,873
Coal	44,972	80,112	80,112	88,341	67,499	67,499
Diesel-Fuel	21,789	38,813	38,813	0	0	0
Natural gas	80,222	142,905	142,905	133,349	134,872	152,202
Hydroelectric	115,574	205,879	205,879	166,556	173,573	156,216
TOTAL	284,493	506,784	506,784	507,506	538,225	538,225

Source: Simulation results

NCRE like wind and solar power gain in importance in the Southern Cone's electricity generation matrix under both the CPS as well as the NFS, with this aspect becoming even clearer under the NFS, which even includes geothermal power (Figure 10.43).

Figure 10.44 Renewability index of electricity generation in the Southern Cone, all scenarios

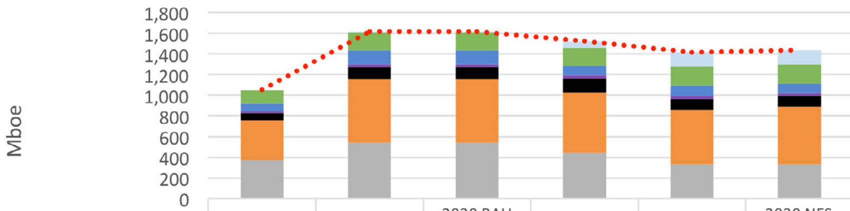


Source: Simulation results

As shown in Figure 10.44, the CPS scenario already produces a significant increase in the renewability index of the power generation matrix in the Southern Cone, however, with the NFS scenario, this indicator improves even more (60% NFS vs 54% CPS and 46% BAU), to the detriment of the use of coal and mainly of petroleum. The sensitivity to climate change affects the mentioned indicator by three percentage points (57% NFS(RCP8.5)), given the importance of hydro energy in the matrix.

10.6.3 Projected total energy supply and structure

Figure 10.45 Projected total energy supply in the Southern Cone all scenarios

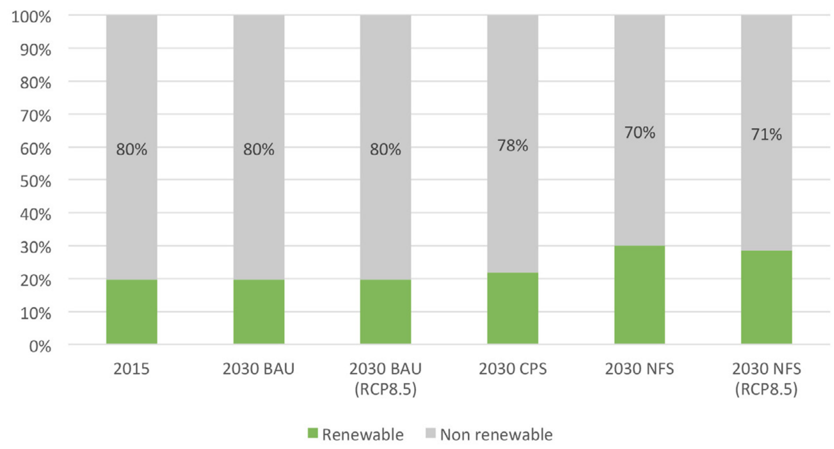


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	6	11	11	67	139	139
Biomass	124	172	172	173	187	188
Hydroenergy	76	135	135	92	99	84
Nuclear	16	28	28	28	28	28
Coal and coke	71	116	116	134	105	105
Natural gas	384	614	614	583	527	559
Crude oil and derivatives	374	541	541	445	333	333
TOTAL	1,052	1,618	1,618	1,521	1,417	1,435

Source: Simulation results

The EAPS scenario, which allows savings in total energy supply of 3% and the proposed NFS scenario, increases these savings to 15%, thanks to the energy efficiency measures simulated in this scenario (Figure 10.45). As in the electricity generation matrix, the increase in the participation of NCRE in the CPS scenario is evident, but mainly in the NFS scenario, with a substantial decrease in the supply of petroleum products (23% NFS vs. 29% CPS and 33% BAU).

Figure 10.46 Renewability index for total energy supply in the Southern Cone, all scenarios



Source: Simulation results

As shown in Figure 10.46, the renewability of the Southern Cone's energy matrix is relatively low, due to the high dependence of this subregion on fossil sources, especially Argentina and Chile, however, with the NFS scenario, this indicator improves notably by 10 percentage points, compared to the BAU scenario (30% NFS vs 22% CPS and 20% BAU).

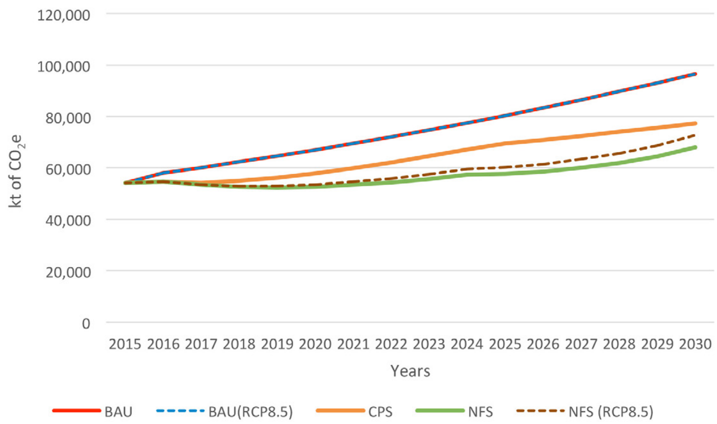
10.6.4 CO2e emissions from electricity generation and percentage reduction

Table 10.9. CO2e emissions from electricity generation in the Southern Cone, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	54,194	54,194	54,194	54,194	54,194
2016	58,017	58,017	53,332	53,332	53,332
2017	60,147	60,147	50,077	49,599	49,599
2018	62,359	62,359	50,650	49,035	49,314
2019	64,655	64,655	51,954	49,004	49,579
2020	67,039	67,039	53,674	47,547	48,429
2021	69,514	69,514	55,823	46,283	47,485
2022	72,084	72,084	58,089	45,263	46,798
2023	74,753	74,753	60,656	44,554	46,435
2024	77,524	77,524	63,178	43,876	46,134
2025	80,401	80,401	65,619	41,165	43,893
2026	83,389	83,389	66,974	39,018	42,252
2027	86,492	86,492	68,360	37,528	41,305
2028	89,715	89,715	69,900	36,792	41,147
2029	93,063	93,063	71,358	36,899	41,870
2030	96,539	96,539	72,984	37,928	43,552
TOTAL	**1,189,887**	**1,189,887**	**966,823**	**712,015**	**745,320**

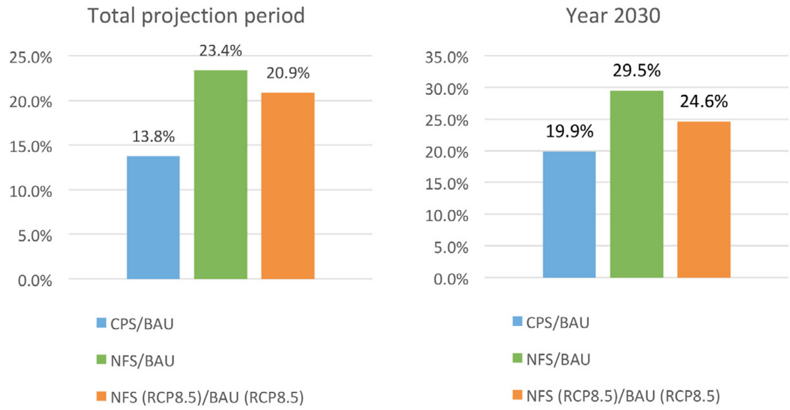
Source: Simulation results

Figure 10.47 CO2e emissions from electricity generation in the Southern Cone, all scenarios



Source: Simulation results

Figure 10.48 Percentage reduction in CO2 e emissions from electricity generation in the Southern Cone



Source: Simulation results

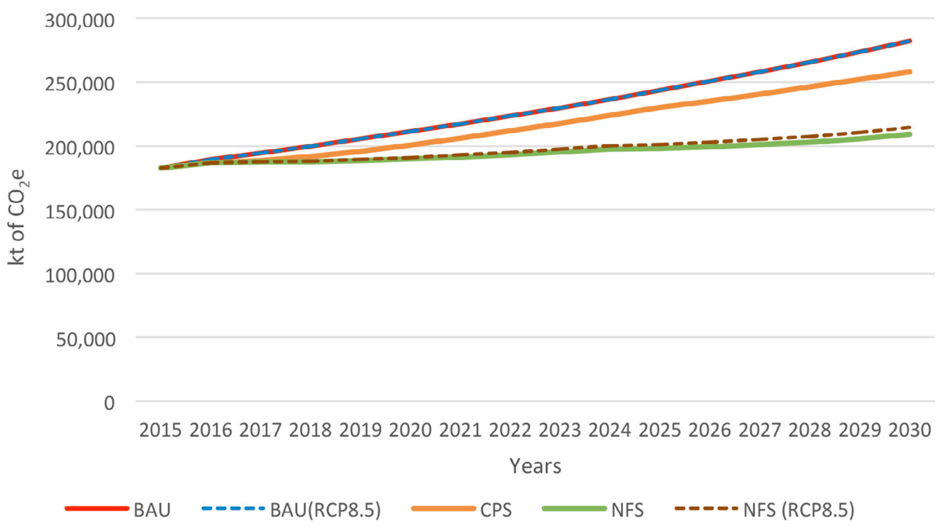
The percentage reduction in CO2e emissions from electricity generation is relatively less than in the other subregions because natural gas plays a predominant role in expansion plans, both in the CPS as well as under the proposed NFS.

10.6.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.10. CO2e emissions by the energy matrix in the Southern Cone, all scenarios (kt)

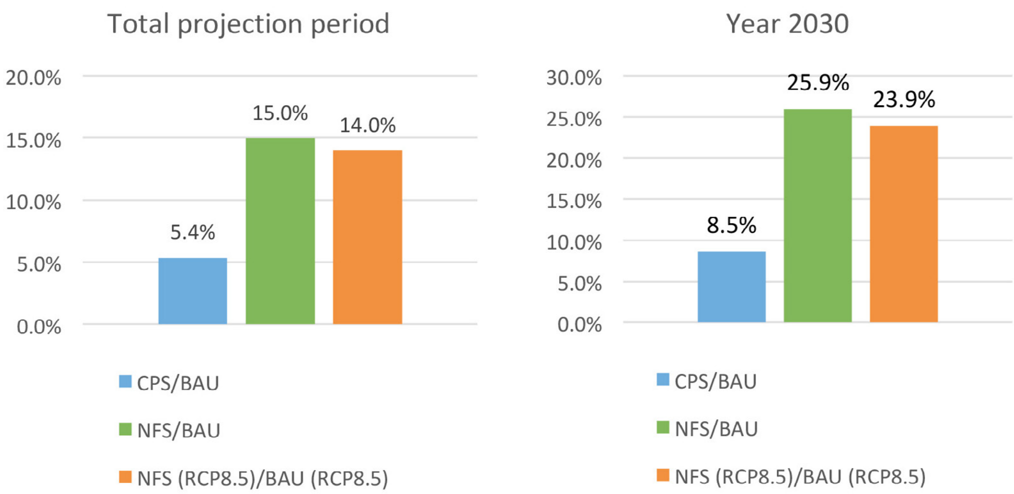
Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	182,611	182,611	182,611	182,611	182,611
2016	189,517	189,517	186,055	186,055	186,055
2017	194,674	194,674	185,368	185,060	185,060
2018	200,025	200,025	188,473	185,565	185,906
2019	205,579	205,579	192,943	186,547	187,249
2020	211,341	211,341	197,766	185,625	186,702
2021	217,320	217,320	203,074	184,787	186,254
2022	223,523	223,523	209,088	184,106	185,979
2023	229,957	229,957	215,093	183,675	185,970
2024	236,632	236,632	221,145	183,152	185,907
2025	243,556	243,556	227,749	180,014	183,342
2026	250,738	250,738	232,693	177,414	181,359
2027	258,188	258,188	237,790	175,445	180,053
2028	265,914	265,914	243,781	174,199	179,514
2029	273,928	273,928	249,213	173,764	179,830
2030	282,240	282,240	254,966	174,223	181,085
TOTAL	**3,665,744**	**3,665,744**	**3,427,806**	**2,902,239**	**2,942,875**

Figure 10.49 CO2e emissions by the energy matrix in the Southern Cone, all scenarios



Source: Simulation results

Figure 10.50 Percentage reduction in CO2 e emissions by the energy matrix in the Southern Cone



Source: Simulation results

While the CPS produces a very modest percentage reduction in CO2e emissions by the Southern Cone’s energy matrix when compared to the BAU scenario (8.5%), under the NFS this percentage improves until reaching the end of the study period, close to 26%.

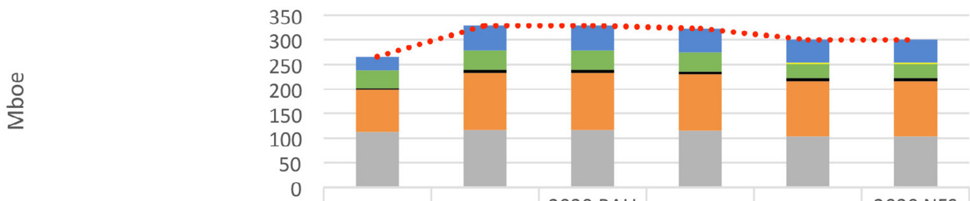
If you take as a reference the unconditional goal of Argentina, which has the greatest weight in the sub-region with respect to emissions from the energy sector, which sets out in its NDCs a 20% reduction of its CO2e emissions by 2030 (Annex II), a 25% CO2e reduction at sub-regional level, with the proposed NFS, could be considered a success. Other values mentioned in the NDCs for this sub-region are: a 30% reduction in emissions in Chile with respect to 2007 values, a 10% reduction in Paraguay, compared to the BAU scenario and a 25% reduction in emissions intensity, to the year 1990 in Uruguay. Although the scenario with CC effect would reduce the percentage of emissions reduction to a value close to 24%, it could still be considered valid with respect to the subregional reference goal. The conditional goals, however, pose a greater challenge, and the premises considered for the NFS, although positive, would still be insufficient.

Of the total emission reduction observed when comparing the NFS and BAU energy scenarios in the year 2030 (73.2 Mt of CO2e), the electric sector contributes with 39% (see Tables 10.9 and 10.10).

10.7 The Caribbean

10.7.1 Projected final energy consumption and structure

Figure 10.51 Projected final energy consumption in the Caribbean, all scenarios

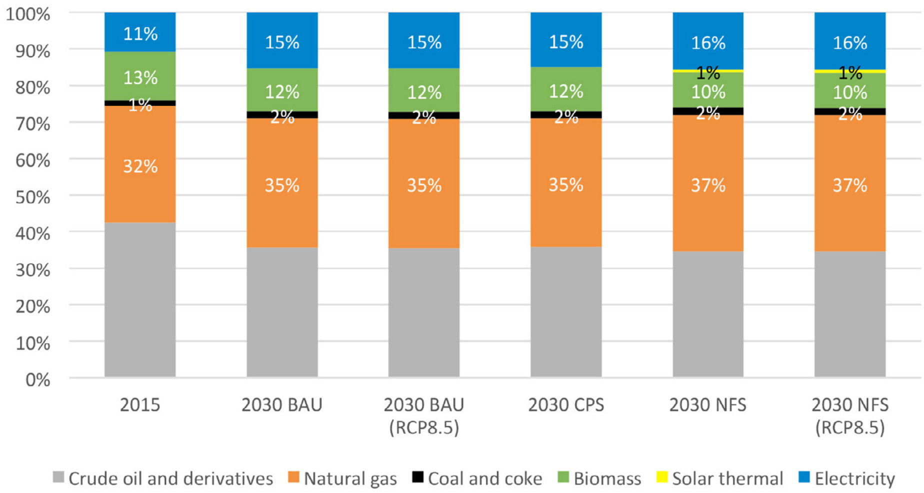


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	28	50	50	48	47	47
Solar thermal	0	0	0	0	2	2
Biomass	36	39	39	39	29	29
Coal and coke	4	6	6	6	6	6
Natural gas	85	116	116	114	112	112
Crude oil and derivatives	113	117	117	115	104	104
TOTAL	266	328	329	322	300	300

Source: Simulation results

The CPA achieves a 2% savings in final energy consumption compared to the BAU scenario, while this percentage reaches 9% under the NFS.

Figura 10.52 Estructura de la matriz de consumo final de energía de El Caribe, todos los escenarios

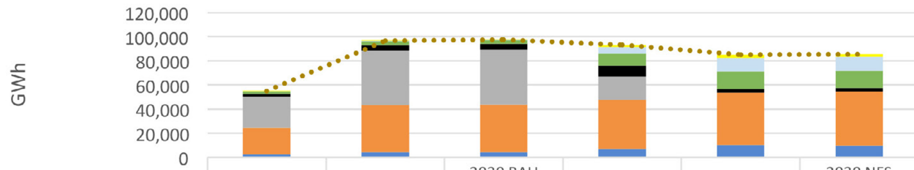


Source: Simulation results

There are no major changes in the final consumption matrix between the BAU scenario and CPS, though under the NFS and there is an increased share of natural gas and electricity, which displace oil products and biomass.

10.7.2 Projected electricity generation and structure

Figure 10.53 Projected electricity generation in the Caribbean, all scenarios

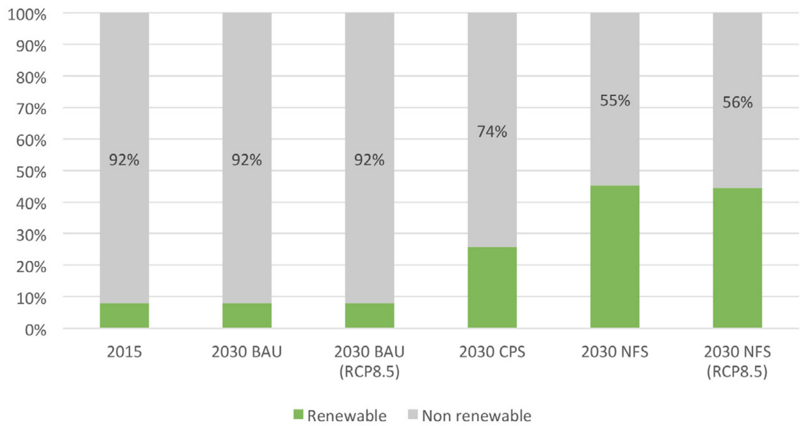


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Solar	81	143	144	1,747	2,554	2,554
Wind	308	544	549	5,531	11,232	11,232
Biomass	1,573	2,778	2,801	9,828	14,410	14,410
Coal	2,696	4,762	4,801	9,395	3,067	3,067
Diesel-Fuel	25,674	45,341	45,717	19,163	0	0
Natural gas	22,039	38,922	39,245	40,663	43,341	44,519
Hydroelectric	2,398	4,235	4,270	6,938	10,354	9,837
TOTAL	54,769	96,724	97,528	93,264	84,958	85,618

Source: Simulation results

Though there is greater penetration by electricity in final consumption, total electricity generation in the Caribbean declines in the CPS and NFS due to energy efficiency measures and the reduction in electricity transmission and distribution losses. Increased penetration by hydroenergy, biomass, wind and solar energy stands out in the NFS, completely displacing oil products and reducing the use of coal to a minimum.

Figure 10.54 Renewability index of electricity generation in the Caribbean, all scenarios

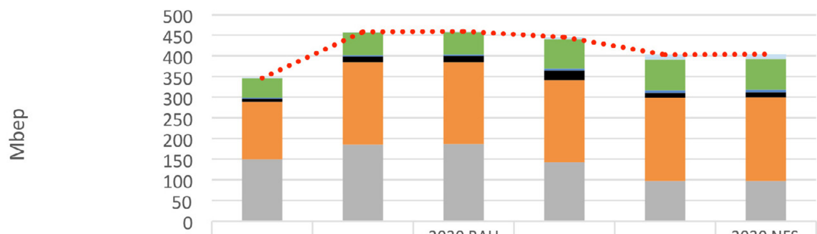


Source: Simulation results

As can be seen in Figure 10.54, the renewability of electricity generation in the Caribbean is relatively low in the base year and in the BAU scenario due to the high dependence on fossil fuel generation, while in the CPS this indicator improves significantly, and even more so under the NFS, thanks to increased penetration by hydro energy and NCRE (45% NFS, 26% CPS and 8% BAU). It is also important to highlight the increase in the share of natural gas in electricity generation (51% NFS, 44% CPS and 40% BAU); significantly displacing the use of coal and oil products.

10.7.3 Projected total energy supply and structure

Figure 10.55 Projected total energy supply in the Caribbean, all scenarios

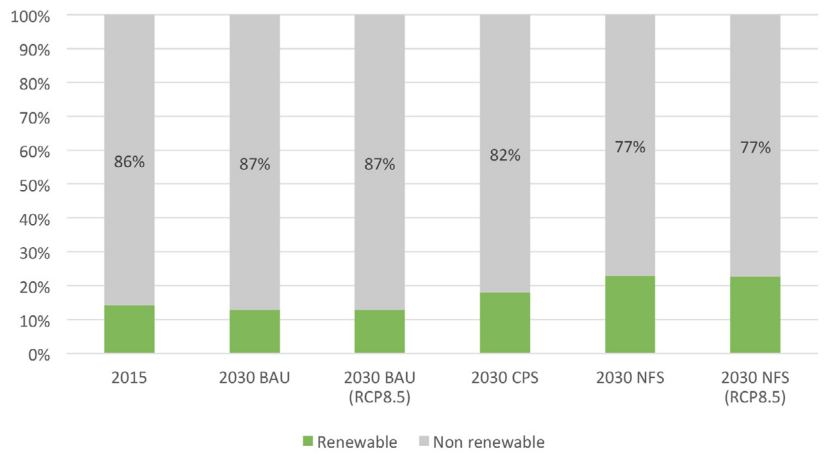


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	0	0	0	5	11	11
Biomass	47	55	55	71	74	74
Hydroenergy	2	3	3	5	7	7
Coal and coke	9	15	15	23	12	12
Natural gas	138	199	200	199	201	202
Crude oil and derivatives	150	185	186	143	98	98
TOTAL	347	458	459	445	403	404

Source: Simulation results

The savings in total energy supply under the CPS for the Caribbean is just 2% compared to the BAU scenario, while under the NFS this savings rises to 9%. While there is an increase in the share of biomass and other renewable sources in the energy matrix, it continues to be mainly dependent on natural gas and oil products.

Figure 10.56 Renewability index for total energy supply in the Caribbean, all scenarios



Source: Simulation results

With both the CPS scenario and the NFS scenario, the sub-region of the Caribbean improves the renewability index of the energy matrix in an important way with respect to the BAU scenario (23% NFS vs 18% CPS and 13% BAU). Although this matrix is still predominantly non-renewable in all scenarios, there is an increase in the share of natural gas (50% NFS, 45% CPS and 43% BAU), to the detriment of oil and its derivatives.

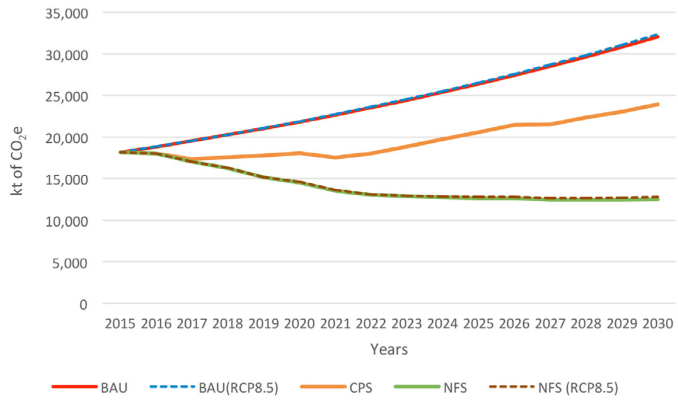
10.7.4 CO2e emissions from electricity generation and percentage reduction

Table 10.11. CO2e emissions from electricity generation in the Caribbean, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	18,152	18,152	18,152	18,152	18,152
2016	18,824	18,835	18,077	18,077	18,077
2017	19,526	19,547	18,185	18,148	18,148
2018	20,258	20,292	18,554	17,638	17,660
2019	21,022	21,069	18,944	17,224	17,269
2020	21,820	21,881	19,314	17,198	17,267
2021	22,653	22,729	18,881	16,355	16,454
2022	23,524	23,615	19,429	16,508	16,634
2023	24,433	24,542	20,249	16,837	16,991
2024	25,383	25,510	21,146	17,264	17,447
2025	26,376	26,522	22,033	17,378	17,597
2026	27,413	27,581	22,942	17,572	17,829
2027	28,498	28,687	23,068	17,217	17,526
2028	29,632	29,845	23,905	16,881	17,244
2029	30,817	31,056	24,664	16,644	17,064
2030	32,057	32,323	25,619	16,514	16,996
TOTAL	**390,387**	**392,185**	**333,161**	**275,605**	**278,355**

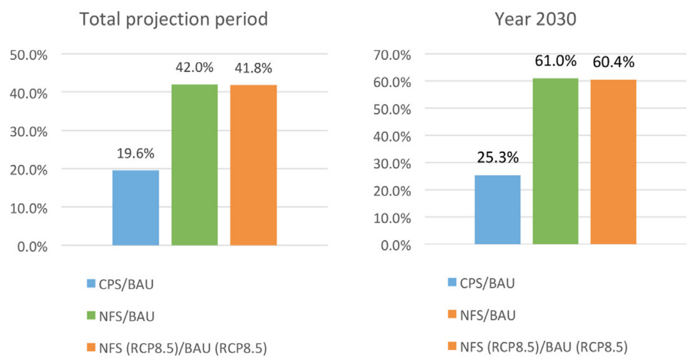
Source: Simulation results

Figure 10.57 CO2e emissions from electricity generation in the Caribbean, all scenarios



Source: Simulation results

Figure 10.58 Percentage reduction in CO2 e emissions from electricity generation in the Caribbean



Source: Simulation results

The percentage reduction in CO2e emissions from electricity generation in the Caribbean is very significant under the NFS, due in part to a decline in electricity generation and also to an increase in the renewability of that activity (Figure 10.58).

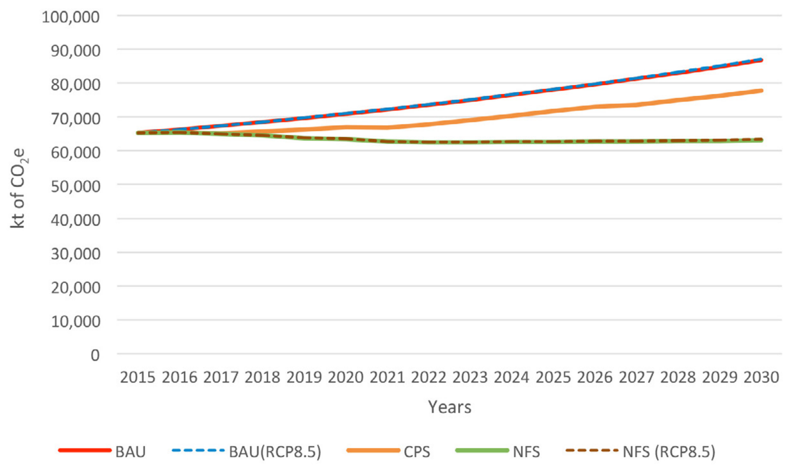
10.7.5 Total energy matrix CO2e emissions and percentage reduction

Table 10.12. CO2e emissions by the energy matrix in the Caribbean, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	65,319	65,319	65,319	65,319	65,319
2016	66,228	66,239	65,371	65,371	65,371
2017	67,327	67,349	65,090	65,018	65,018
2018	68,473	68,509	65,685	64,573	64,595
2019	69,670	69,720	66,252	63,763	63,808
2020	70,920	70,983	66,946	63,453	63,523
2021	72,223	72,302	66,783	62,686	62,786
2022	73,582	73,678	67,738	62,483	62,564
2023	75,000	75,114	68,992	62,504	62,605
2024	76,479	76,612	70,339	62,554	62,677
2025	78,021	78,175	71,679	62,635	62,782
2026	79,630	79,805	73,059	62,752	62,924
2027	81,306	81,505	73,629	62,724	62,930
2028	83,054	83,279	74,976	62,801	63,042
2029	84,877	85,128	76,226	62,923	63,200
2030	86,777	87,057	77,732	63,091	63,409
TOTAL	1,198,888	1,200,776	1,115,815	1,014,648	1,016,552

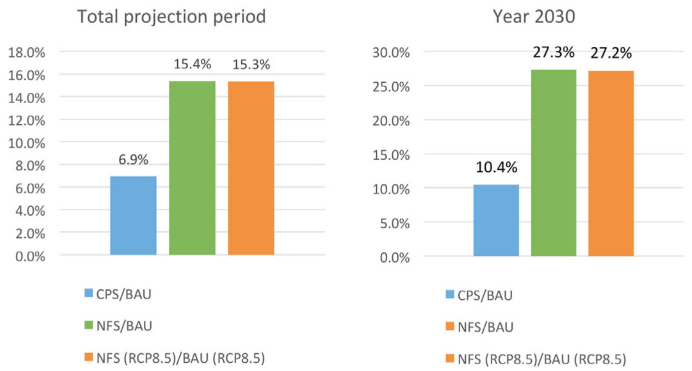
Source: Simulation results

Figure 10.59 CO2e emissions by the energy matrix in the Caribbean, all scenarios



Source: Simulation results

Figure 10.60 Percentage reduction in CO2 e emissions by the energy matrix in the Caribbean



Source: Simulation results

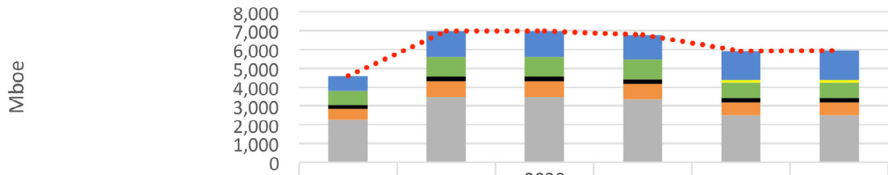
In Figure 10.60, it is observed for the year 2030, that compared to an incipient 10.4% reduction of CO2e emissions from the CPS, compared to the BAU scenario (see chapter 7), with the NFS, this percentage reaches 27.3%. This value exceeds, for example the conditional goals proposed by the Dominican Republic and Trinidad and Tobago, the countries that carry the greatest weight in the subregion when it comes to CO2e emissions (25% and 15%, respectively). Given the low incidence of hydropower in the subregion's energy supply, the CC sensitivity scenario (NFS (RCP8.5)) has an almost imperceptible effect.

The contribution of the electricity sector to the total emission reduction observed when comparing the NFS and BAU energy scenarios in the year 2030 (23.7 Mt CO2e), is particularly important in this subregion, reaching an approximate value of 83% (see Tables 10.11 and 10.12).

10.8 Latin America and the Caribbean (LAC)

10.8.1 Projected final energy consumption and structure

Figure 10.61 Projected final energy consumption in LAC, all scenarios

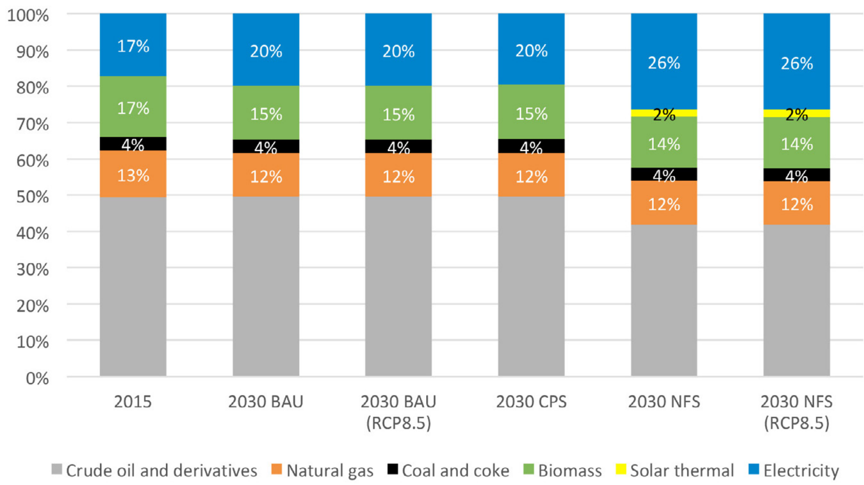


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Electricity	784	1,376	1,385	1,323	1,559	1,567
Solar thermal	0	0	0	0	117	117
Biomass	767	1,042	1,042	1,022	839	839
Coal and coke	174	256	256	255	213	213
Natural gas	590	834	834	808	709	709
Crude oil and derivatives	2,261	3,462	3,462	3,355	2,482	2,482
TOTAL	4,576	6,971	6,980	6,762	5,919	5,926

Source: Simulation results

As shown in Figure 10.61, the CPS allows 3% savings in final energy savings for the LAC region as a whole, while under the NFS this savings increases to 15% compared to the BAU scenario and 12% compared to the CPS.

Figure 10.62 Structure of the final energy consumption matrix in LAC, all scenarios

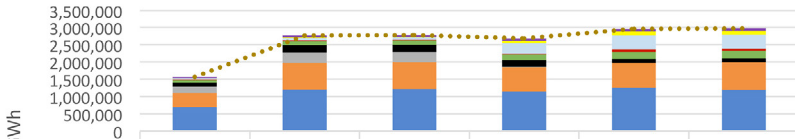


Source: Simulation results

On the other hand, Figure 10.62 shows that the structure of the consumption matrix remains practically the same as in the base year under the BAU scenario and CPS, but a significant increase in the share of electricity is registered under the NFS (26% NFS vs. 20% CPS and 20% BAU), displacing mainly petroleum products (42% NFS vs. 50% CPS and 50% BAU).

10.8.2 Projected electricity generation and structure

Figure 10.63 Projected electricity generation in LAC, all scenarios

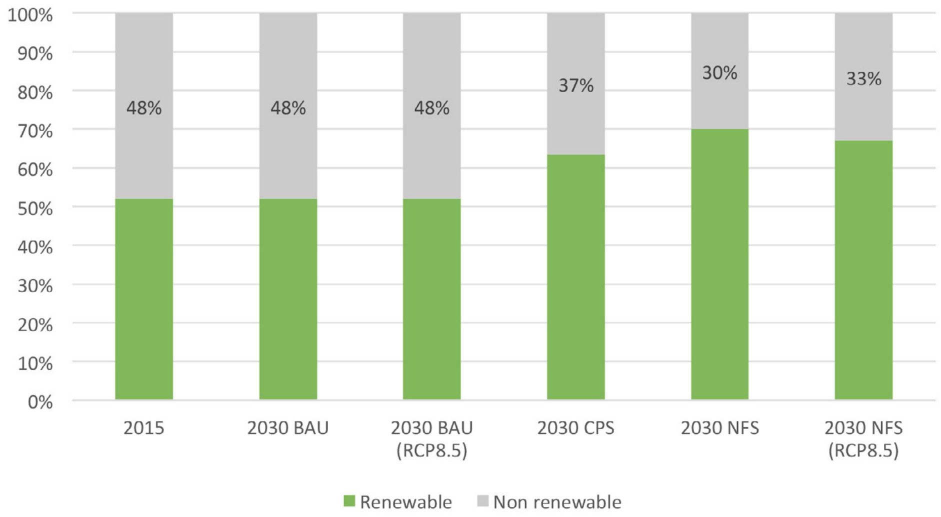


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Nuclear	33,277	58,698	59,070	69,697	69,697	69,702
Solar	5,763	10,025	10,051	68,720	121,053	121,052
Wind	39,521	69,567	70,032	298,421	404,047	404,046
Geothermal	11,861	19,989	20,158	25,240	67,431	67,431
Biomass	69,732	122,757	123,657	160,159	216,250	216,269
Coal	112,917	199,082	200,008	191,335	111,433	111,433
Diesel-Fuel	178,285	314,406	316,399	19,163	0	2,975
Natural gas	427,355	756,844	761,330	699,272	707,327	796,471
Hydroelectric	686,983	1,215,196	1,222,355	1,149,101	1,266,606	1,191,996
TOTAL	1,565,695	2,766,565	2,783,060	2,681,108	2,963,845	2,981,375

Source: Simulation results

Due to the assumption of increased electrification of end-uses in the different subregions analyzed, the LAC region as a whole registers an increase in electricity generation associated with the NFS, when compared to the BAU scenario and the CPS. One can also see how that increased generation is mainly covered by NCRE like wind, solar, biomass and geothermal power (Figure 10.63).

Figure 10.64 Renewability index of electricity generation in the Caribbean, all scenarios

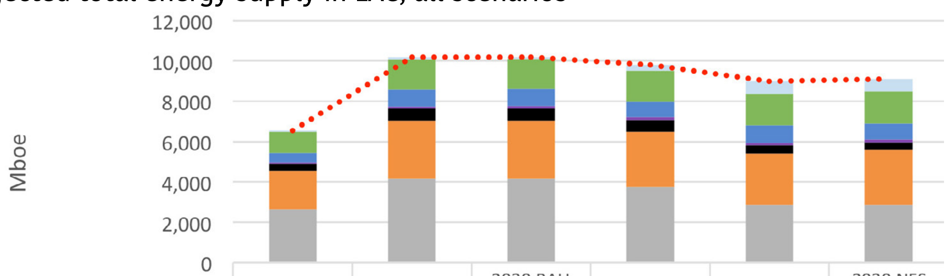


Source: Simulation results

Thanks to the increase in the use in hydroenergy and NCRE registered under the NFS in the different subregions analyzed, the renewability of the LAC region's electricity generation matrix increases substantially under that scenario (70% NFS vs. 63% CPS and 52% BAU), replacing coal and petroleum products (Figure 10.64).

10.8.3 Projected total energy supply and structure

Figure 10.65 Projected total energy supply in LAC, all scenarios

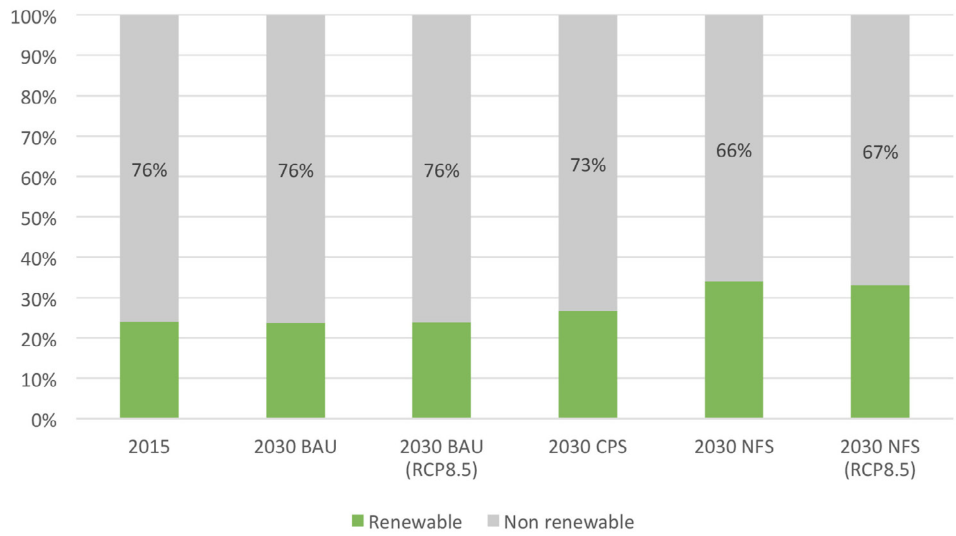


	2015	2030 BAU	2030 BAU (RCP8.5)	2030 CPS	2030 NFS	2030 NFS (RCP8.5)
Other renewables	57	109	109	296	608	608
Biomass	1,041	1,477	1,479	1,542	1,590	1,590
Hydroenergy	471	834	839	775	856	801
Nuclear	64	113	114	133	133	133
Coal and coke	369	594	596	578	396	396
Natural gas	1,895	2,881	2,889	2,749	2,557	2,721
Crude oil and derivatives	2,634	4,161	4,164	3,743	2,852	2,854
TOTAL	6,532	10,169	10,190	9,816	8,992	9,104

Source: Simulation results

Energy efficiency measures generate 3% savings in total energy supply in the LAC region under CPS and 12% in the NFS by 2030 when compared to the BAU scenario. With sensitivity to climate change this savings under the NFS (RCP 8.5) falls to 11%. It is also important to note the decrease in the share of oil and its derivatives in this matrix (41% BAU, 38% CPS and 32% NFS).

Figure 10.66 Renewability index for total energy supply in LAC, all scenarios



Source: Simulation results

A significant increase in the renewability index of the LAC region's energy matrix is achieved thanks to more aggressive penetration on the part of renewable sources of energy, conventional as well as nonconventional, in the electricity generation matrix and also an increased use of biofuels in the transportation sector, measures that were considered as premises of the NFS, as can be seen in Figure 10.66 (34% NFS, 27% CPS and 24% BAU). It is also worth noting that sensitivity to climate change in the simulated NFS (RCP 8.5) affects this indicator very slightly.

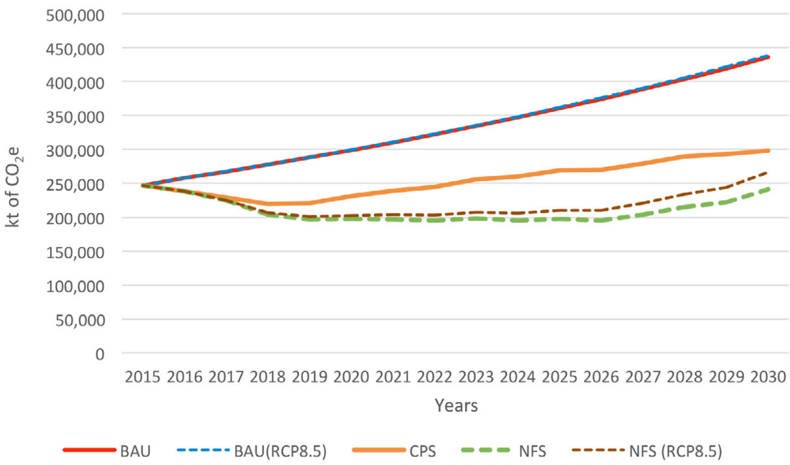
10.8.4 CO2e emissions from electricity generation and percentage reduction

Table 10.13. CO2e emissions from electricity generation in LAC, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	246,621	246,621	246,621	246,621	246,621
2016	257,738	257,835	239,649	239,649	239,649
2017	267,432	267,634	228,199	225,765	225,765
2018	277,516	277,831	218,845	205,216	206,623
2019	288,008	288,444	219,789	199,691	202,461
2020	298,925	299,490	230,650	198,286	202,455
2021	310,283	310,987	238,565	195,934	201,411
2022	322,103	322,956	244,650	192,866	199,861
2023	334,404	335,416	256,096	193,964	202,517
2024	347,206	348,387	260,302	189,577	199,881
2025	360,531	361,893	269,607	188,636	200,799
2026	374,400	375,957	270,931	183,777	198,109
2027	388,838	390,601	279,687	189,576	206,061
2028	403,868	405,852	290,670	197,748	216,539
2029	419,516	421,735	293,924	202,057	223,682
2030	435,808	438,278	298,595	218,258	242,963
TOTAL	**5,333,198**	**5,349,917**	**4,086,782**	**3,267,621**	**3,415,396**

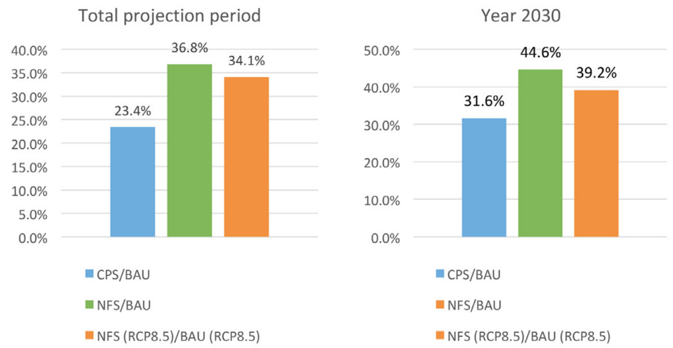
Source: Simulation results

Figure 10.67 CO2e emissions from electricity generation in LAC, all scenarios



Source: Simulation results

Figure 10.68 Percentage reduction in CO2e emissions from electricity generation in LAC



Source: Simulation results

Figure 10.68 shows how the percentage reductions in CO2e emissions in electricity generations are significant under CPS and far more so under the NFS when compared to the BAU scenario, due to the assumption of increased use of renewable energy sources, mainly hydroenergy, biomass, wind and solar power.

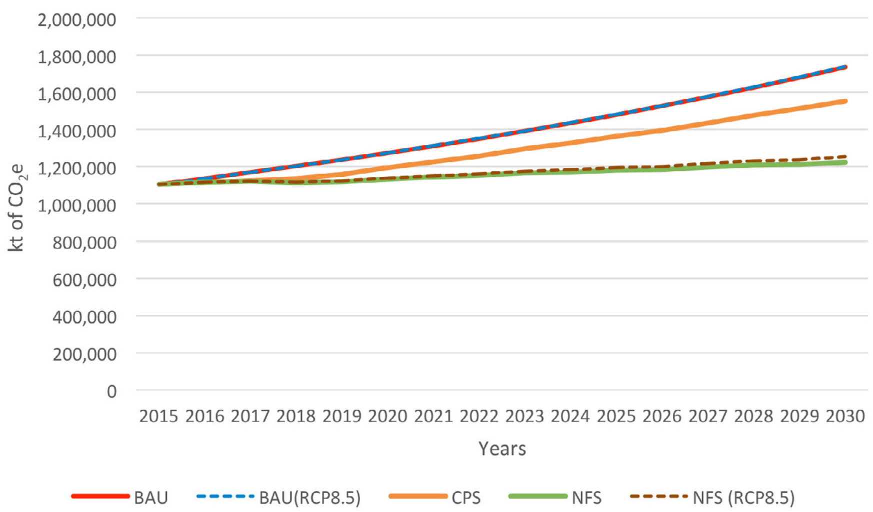
10.8.5 Total energy matrix CO_2e emissions and percentage reduction

Table 10.14. CO_2e emissions in LAC's energy matrix, all scenarios (kt)

Year \ Scenario	BAU	BAU(RCP8.5)	CPS	NFS	NFS(RCP8.5)
2015	1,105,074	1,105,074	1,105,074	1,105,074	1,105,074
2016	1,137,418	1,137,533	1,117,545	1,117,545	1,117,545
2017	1,169,314	1,169,553	1,126,126	1,123,005	1,123,005
2018	1,202,632	1,203,004	1,137,220	1,115,036	1,117,523
2019	1,237,420	1,237,936	1,160,018	1,119,603	1,123,780
2020	1,273,731	1,274,399	1,194,552	1,132,599	1,138,552
2021	1,311,619	1,312,452	1,226,319	1,143,912	1,151,687
2022	1,351,143	1,352,152	1,258,356	1,152,443	1,161,440
2023	1,392,367	1,393,564	1,296,950	1,166,016	1,176,941
2024	1,435,356	1,436,754	1,327,583	1,171,362	1,184,505
2025	1,480,181	1,481,794	1,365,329	1,181,093	1,196,509
2026	1,526,916	1,528,759	1,395,462	1,183,992	1,202,047
2027	1,575,640	1,577,727	1,435,242	1,197,145	1,217,810
2028	1,626,434	1,628,782	1,477,909	1,209,232	1,232,684
2029	1,679,384	1,682,011	1,513,153	1,211,716	1,238,634
2030	1,734,583	1,737,507	1,552,423	1,223,416	1,254,740
TOTAL	**22,239,210**	**22,259,002**	**20,689,260**	**18,553,188**	**18,742,475**

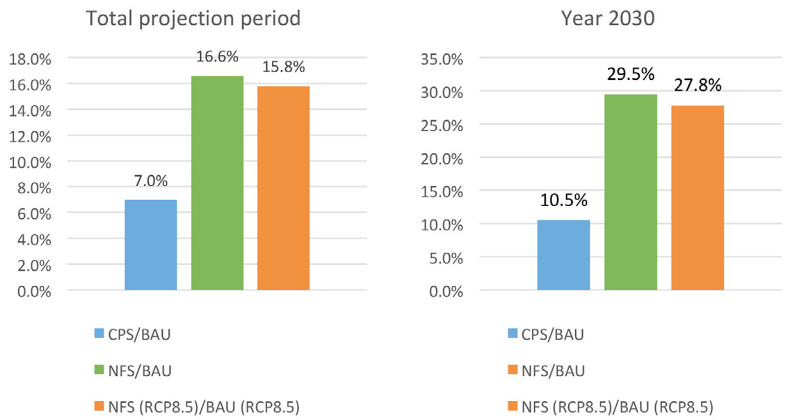
Source: Simulation results

Figure 10.69 CO_2e emissions in LAC's energy matrix, all scenarios



Source: Simulation results

Figure 10.70 Percentage reduction in CO2e emissions by the energy matrix in LAC



Source: Simulation results

Compared to an insufficient 10.5% reduction of CO2e emissions, achieved with the CPS scenario, with respect to the BAU scenario, for the integral region of LAC (see chapter 7), through the simulation of the scenario oriented towards compliance with the NDCs (NFS), this value is close to 30%, as can be seen in Figure 10.70. Given the reference goal established for the region between 25 and 30% reduction of annual emissions of CO2e by 2030 (chapter 4), it can be indicated that this would be coherent and achievable at the regional level, if development policies are formulated energy, similar to the premises proposed for the NFS. (Annex IV). However, perhaps in individual cases such as Mexico, it would be necessary to apply emission reduction policies that are even more ambitious than those set forth in Annex IV in order to achieve the goals set out in their NDCs.

The effect of simulated CC in the NFS (RCP8.5) scenario would imply a slightly lower emission reduction, which is equivalent to an increase of the same with respect to the NFS of 2.6%. This, however, would not jeopardize the robustness of the NFS, since it would simply point to the need to slightly adapt the renewable energy promotion measures foreseen in this scenario to the challenges that could be posed by the effects of climate change in each zone, either by applying adaptation measures in hydroelectric systems or by increasing the use of other renewable sources.

The contribution of electricity generation, in the total reduction of GHG emissions from the energy matrix, reached with the NFS, compared to the BAU scenario, for the year 2030 (511.2 Mt CO2e), is 38% (see tables 10.13 and 10.14).

11. Leveled costs of electricity generation (LCOE), in light of projected international fuel prices

11. Leveled costs of electricity generation (LCOE), in light of projected international fuel prices.

11.1 General Considerations

To complete the study, this chapter analyzes the leveled costs of electricity (LCOE for its acronym in English) for the different generation technologies and subregion and their sensitivity to change in projected international fuel prices. The objective of this analysis is:

- Identify the NCRE technologies, which are more economically competitive compared to conventional sources (LCOE projection by technologies);
- Determine if the measures of greater NCRE penetration in the matrix of power generation proposed to reach the NDCs targets (NFS), have an effect on the cost of the generated energy (Total generation costs and LCOE projection weighted by stage);
- Establish the possible cost overruns in investment for generation systems that the adoption of the measures of greater penetration of NCRE could involve the country or sub-region (total investment costs in the projection period by scenarios).

As is known, LCOE are annual electricity generation costs, which are formed by the cost of investment on new infrastructure, fixed and variable operation and maintenance (O&M) costs and fuel costs for thermoelectric power plants.

The SAME Model automatically calculates the LCOE for each technology based on unit cost information for each component. The fixed and variable costs of O&M for each technology were considered to be the same for all subregions, while a certain discrimination by subregion was made for the unit costs of investment.

The hypothetic evolutions in fuel prices were taken from the reference scenario contained in the document "Annual Energy Outlook" from January 2017`, published by the US Energy Information Administration (EIA). The agency's website also contains reference values for the unit capital and O&M costs for electricity generation technologies.
The unit costs by technology, considered to be the same for all subregions analyzed, are presented below.

[9] LCOE is the cost of the system per unit of energy generated that includes all costs throughout the life of the project: the initial investment, operation and maintenance, the cost of fuel, cost of capital, etc. Knowledge of the LCOE is a useful tool for comparing the costs of different technologies (source: https://www.nrel.gov/analysis/tech-lcoe.html).

Table 11.1. Projected variable costs of O&M (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	5.20	6.45	8.00	9.92	4.4%
Natural gas	3.50	4.34	5.39	6.69	4.4%
Diesel-Fuel Oil	5.85	7.25	8.99	11.16	4.4%
Coal	4.60	5.71	7.08	8.77	4.4%
Biomass	4.20	5.21	6.46	8.02	4.4%
Geothermal	3.50	4.34	5.39	6.69	4.4%
Wind	0.00	0.00	0.00	0.00	
Solar	0.00	0.00	0.00	0.00	
Nuclear	2.30	2.86	3.54	4.39	4.4%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

Table 11.2. Projected fixed costs of O&M (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	30.00	37.21	46.14	57.22	4.4%
Natural gas	11.00	13.65	16.92	20.98	4.4%
Diesel-Fuel Oil	6.9	8.56	10.62	13.18	4.4%
Coal	42.10	52.21	64.75	80.30	4.4%
Biomass	110.00	136.43	169.20	209.83	4.4%
Geothermal	120.00	148.82	184.58	228.92	4.4%
Wind	39.70	39.70	39.70	39.70	0.0%
Solar	23.40	23.40	23.40	23.40	0.0%
Nuclear	100.28	124.37	154.24	191.30	4.4%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

Two scenarios were considered for the case of internationals fuel prices: one with a positive growth rate during the study period and another keeping the values corresponding to the base year constant throughout the entire projection period.

Table 11.3. Internationals fuel prices, scenario with growth (US$/BOE)

Source	2015	2020	2025	2030	a.a.r.
Natural gas	15	18	22	27	4.0%
Coal	2	3	3	3	2.5%
Nuclear	6	6	7	7	1.0%
Diesel Oil	60	75	93	116	4.5%
Fuel Oil	56	69	86	107	4.5%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

Table 11.4. Internationals fuel prices, scenario without growth (US$/BOE)

Source	2015	2020	2025	2030	a.a.r.
Natural gas	15	15	15	15	0.0%
Coal	2	2	2	2	0.0%
Nuclear	6	6	6	6	0.0%
Diesel Oil	60	60	60	60	0.0%
Fuel Oil	56	56	56	56	0.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

Other data needed for to calculate LCOE include the annual discount rate, which was considered to be 10% , and the useful life of the technologies, which are presented in the following table.

Table 11.5. Useful life of electricity generation technologies (years)

Technology	Useful life
Hydroelectric	50
Natural gas	30
Diesel-Fuel Oil	20
Coal	30
Biomass	30
Geothermal	20
Wind	20
Solar	20
Nuclear	50

Then, for each sub-region, the data considered for unit investment costs, the LCOE results for technologies, the total annual electricity generation costs, the total investment costs in the projection period and the LCOE weighted by scenario are presented. In the case of total investment costs, only the three main scenarios (BAU, CPS and NFS) are analyzed, which are the ones that differ in the expansion schedules of the power generation capacity.

11.2 Brazil

11.2.1 Unit costs of investment

Table 11.6. Projection of unit costs of investment in Brazil, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	1,600	1,767	1,950	2,153	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	1,850	1,850	1,750	1,750	-0.4%
Solar	2,000	2,000	1,800	1,800	-0.7%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

[10] Estimated value taking into account the average country risk index in the region "EMBI" and the active interest rates of the countries (Source: ECLAC, 2017, Economic Study of Latin America and the Caribbean 2017, Santiago, Chile).

[11] The LCOE weighted by scenario are calculated by dividing the total generation cost for the total energy generated in each year, which is equivalent to a weighted average of the LCOE of the technologies.

11.2.2 Projected LCOE

Table 11.7. LCOE for Brazil, scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	49	54	59	62	1.6%
Hydroelectric (RCP 8.5)	49	54	61	65	1.9%
Natural gas	55	68	83	102	4.1%
Diesel-Fuel Oil	130	162	202	251	4.5%
Coal	80	98	121	149	4.3%
Biomass	125	134	146	161	1.7%
Geothermal	78	83	88	95	1.3%
Wind	73	73	62	62	-1.1%
Solar	123	123	112	112	-0.6%
Nuclear	116	134	155	179	2.9%

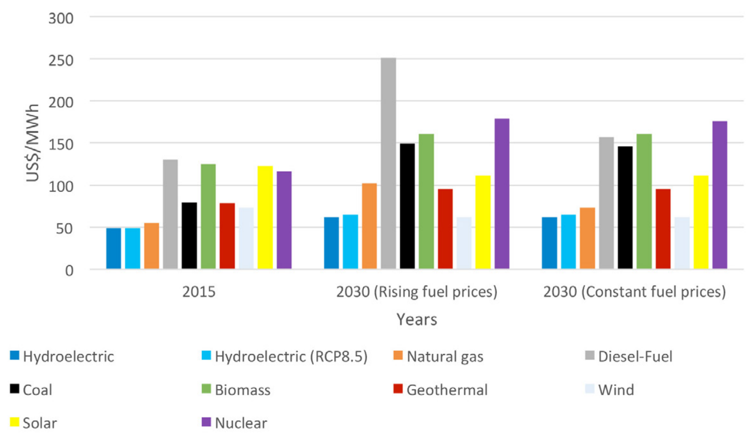
Source: simulation results

Table 11.8. LCOE for Brazil, scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	49	54	59	62	1.6%
Hydroelectric (RCP 8.5)	49	54	61	65	1.9%
Natural gas	55	60	66	73	1.9%
Diesel-Fuel Oil	130	137	146	157	1.3%
Coal	80	97	119	146	4.1%
Biomass	125	134	146	161	1.7%
Geothermal	78	83	88	95	1.3%
Wind	73	73	62	62	-1.1%
Solar	123	123	112	112	-0.6%
Nuclear	116	133	153	176	2.8%

Source: simulation results

Figure 11.1. Projected LCOE for Brazil, according to the fuel price scenarios



Source: simulation results

As shown in Figure 11.1, the LCOE for NCREA like geothermal, wind and photovoltaic solar power remain competitive compared to coal and oil products, even under the constant fuel price scenario. It should be noted that wind power is more competitive that natural gas even in this scenario.

11.2.3 Projected total electricity generation costs

Table 11.9. Total electricity generation cost for Brazil, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	37,866	51,768	70,994	96,317	6.4%
BAU (RCP 8.5) scenario	37,866	52,222	72,490	99,419	6.6%
CPS	37,866	46,077	60,323	78,016	4.9%
NFS	37,866	44,962	59,088	85,303	5.6%
NFS (RCP 8.5)	37,866	45,392	60,656	89,212	5.9%

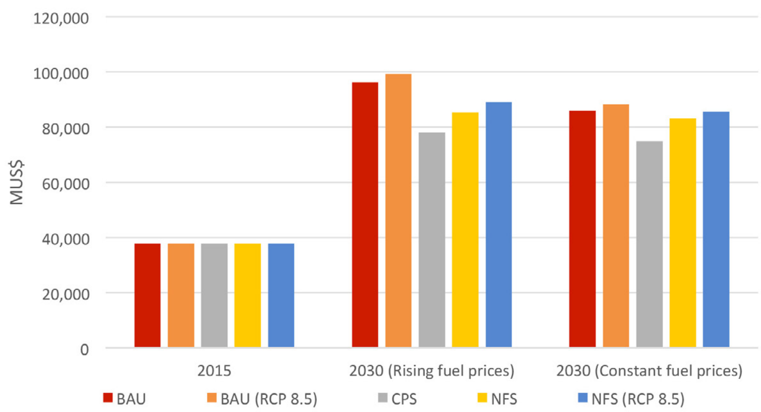
Source: simulation results

Table 11.10. Total electricity generation cost for Brazil, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	37,866	49,870	65,879	85,929	5.6%
BAU (RCP 8.5) scenario	37,866	50,244	67,091	88,374	5.8%
CPS	37,866	45,590	58,568	74,871	4.6%
NFS	37,866	44,612	58,238	83,129	5.4%
NFS (RCP 8.5)	37,866	44,984	59,417	85,720	5.6%

Source: simulation results

Figure 11.2. Projected total cost of electricity generation for Brazil, according to the fuel price scenarios



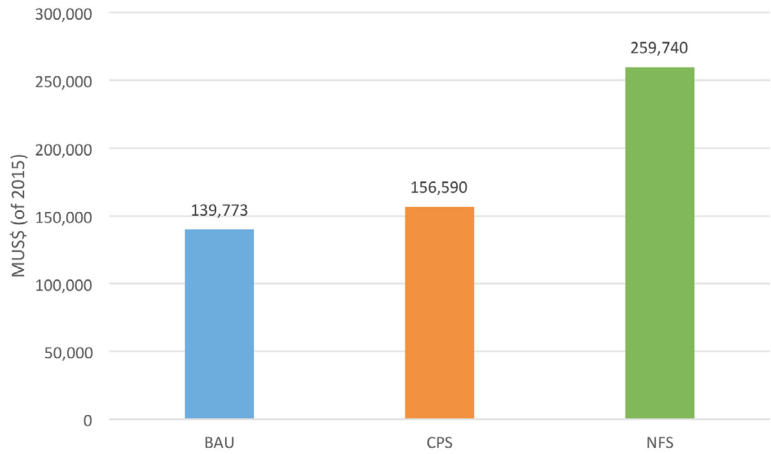
Source: simulation results

In Brazil the proposed NFS generates 11% savings in generation costs by 2030 compared to the BAU scenario under the scenario of rising fuel prices. However, that savings falls to 3% when fuel prices remain constant. The cost in the NFS and is higher than under CPS due to increased electricity demand .

[12] Although the total cost of electricity generation is greater in the NFS due to the greater requirement of electricity, this is not contradictory with the fact that, as seen in the previous chapters, the greater penetration of electricity in consumption Finally, displacing fossil sources, it produces a net decrease in total emissions from the energy sector in the NFS in relation to the CPS..

11.2.4 Total investment cost in electricity generation

Figure 11.3. Total investment cost in electricity generation for Brazil in the projection period



Source: simulation results

While economic savings are made with total generation costs, valuing the LCOE under the CPS and NFS when compared to the BAU scenario, as can be seen in Figure 11.3, the total investment cost over the course of the study period is 12% and 86% higher, respectively.

11.2.5 Projected total LCOE by energy scenarios

Table 11.11. Total LCOE in Brazil, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	65	74	84	94	2.5%
BAU (RCP 8.5) scenario	65	74	85	96	2.6%
CPS	65	67	73	80	1.4%
NFS	65	67	74	79	1.3%
NFS (RCP 8.5)	65	67	75	82	1.5%

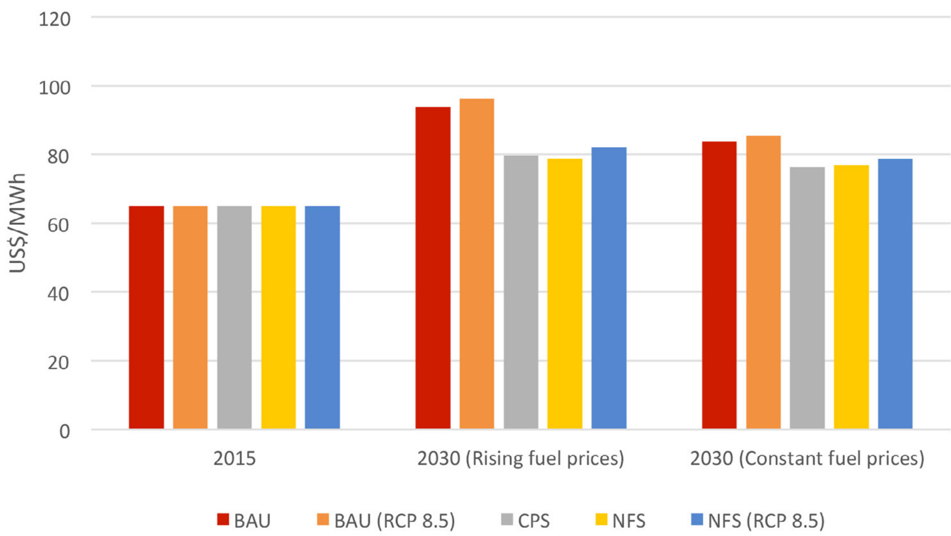
Source: simulation results

Table 11.12. Total LCOE in Brazil, constant fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r
BAU Scenario	65	71	78	84	1.7%
BAU (RCP 8.5) scenario	65	71	79	86	1.8%
CPS	65	66	71	76	1.1%
NFS	65	66	73	77	1.1%
NFS (RCP 8.5)	65	66	74	79	1.3%

Source: simulation results

Figure 11.4. Total LCOE in Brazil, according to the fuel price scenarios



Source: simulation results

In Tables 11.11 and 11.12, it can be seen that the leveled total cost of the energy generated in both the CPS and NFSs, for the year 2030, is reduced by 15% and 16%, respectively, with respect to the BAU scenario, a scenario of rising fuel prices; and by 9% and 8% for a scenario of constant fuel prices. This indicates that there is a slight benefit from the implementation of the NFS with respect to the CPS, in the case of rising prices, but a slight cost overrun in the case of constant prices.

11.3 Mexico

11.3.1 Unit costs of investment

Table 11.13. Projection of unit costs of investment in Mexico, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	2,200	2,429	2,682	2,961	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	1,700	1,700	1,600	1,600	-0.4%
Solar	2,000	2,000	1,800	1,800	-0.7%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

11.3.2 Projected LCOE

Table 11.14. LCOE for Mexico, scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	87	98	111	2.5%
Hydroelectric (RCP 8.5)	77	89	105	123	3.2%
Natural gas	51	63	77	95	4.2%
Diesel-Fuel Oil	159	198	246	306	4.5%
Coal	81	100	123	152	4.3%
Biomass	57	62	68	75	1.8%
Geothermal	88	93	99	106	1.3%
Wind	68	68	65	65	-0.3%
Solar	147	147	134	134	-0.6%
Nuclear	113	130	150	174	2.9%

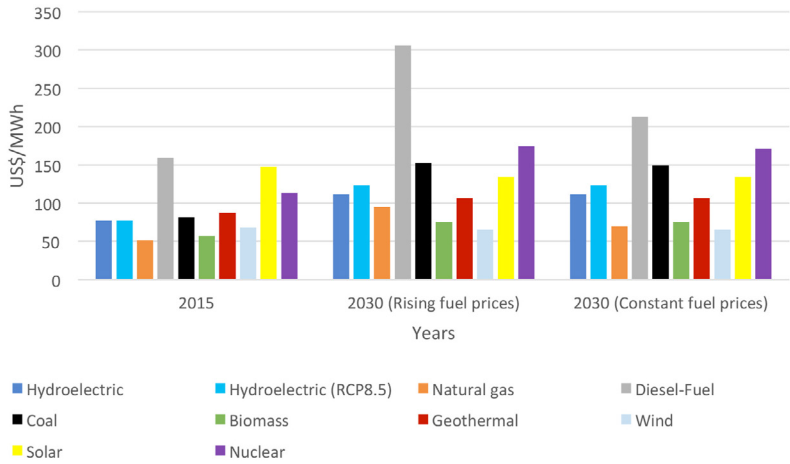
Source: simulation results

Table 11.15. LCOE for Mexico, scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	87	98	111	2.5%
Hydroelectric (RCP 8.5)	77	89	105	123	3.2%
Natural gas	51	56	62	70	2%
Diesel-Fuel Oil	159	173	191	213	2%
Coal	81	99	121	149	4.1%
Biomass	57	62	68	75	1.8%
Geothermal	88	93	99	106	1.3%
Wind	68	68	65	65	-0.3%
Solar	147	147	134	134	-0.6%
Nuclear	113	129	148	171	2.8%

Source: simulation results

Figure 11.5. Projected LCOE for Mexico, according to the fuel price scenarios



Source: simulation results

Mexico presents the unique feature that, due to the lower plant factor of its hydroelectric plants, NCRE like biomass, geothermal and wind power have lower LCOE than hydroenergy. It should also be noted that wind plants will be the cheapest technology by 2030, competing very closely with natural gas, for both fuel price scenarios (Figure 11.5).

It is also observed that although solar energy is the most expensive of the NCRE, it is cheaper than conventional technologies such as diesel-fuel and coal at the end of the projection period, due mainly to the restriction in the dispatch of the latter, for environmental reasons, which decreases its plant factor.

11.3.3 Projected total electricity generation costs

Table 11.16. Total electricity generation cost for Mexico, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	23,441	34,052	49,589	72,506	7.8%
BAU (RCP 8.5) scenario	23,441	34,211	50,122	73,708	7.9%
CPS	23,441	28,169	38,281	53,842	5.7%
NFS	23,441	27,445	36,989	59,843	6.4%
NFS (RCP 8.5)	23,441	27,558	37,349	60,632	6.5%

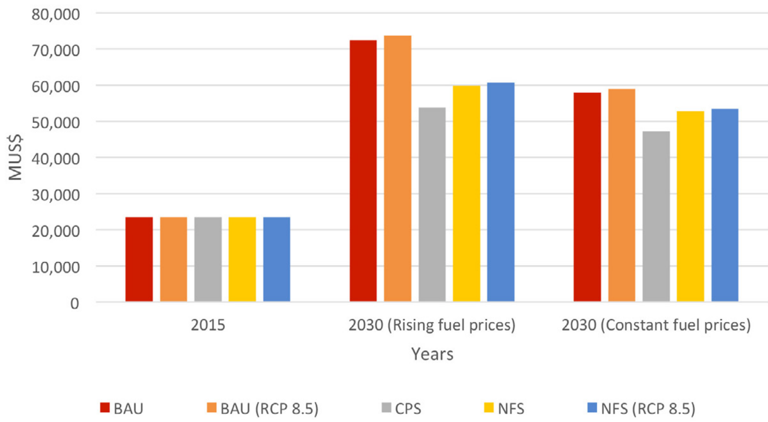
Source: simulation results

Table 11.17. Total electricity generation cost for Mexico, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	23,441	31,375	42,395	57,945	6.2%
BAU (RCP 8.5) scenario	23,441	31,527	42,889	59,028	6.4%
CPS	23,441	26,722	34,627	47,197	4.8%
NFS	23,441	26,066	33,687	52,867	5.6%
NFS (RCP 8.5)	23,441	26,166	33,972	53,431	5.6%

Source: simulation results

Figure 11.6. Projected total cost of electricity generation for Mexico, according to the fuel price scenarios

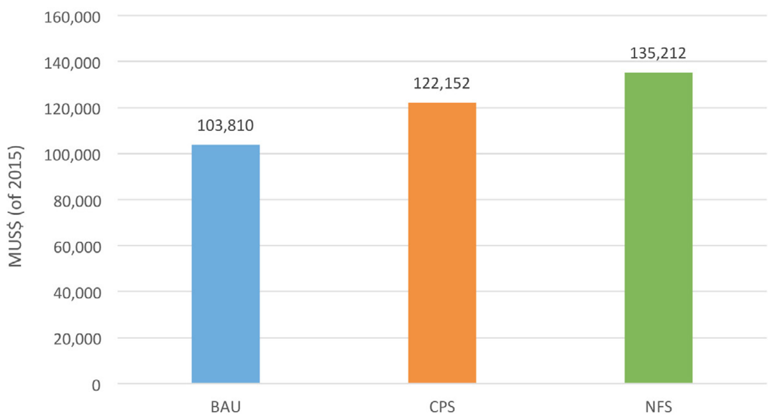


Source: simulation results

In Mexico the NFS generates 17% savings compared to the BAU scenario with rising fuel prices but the saving is reduced to 9% when said prices remain constant (Figure 11.6).

11.3.4 Total investment cost in electricity generation

Figure 11.7. Total investment cost in electricity generation for Mexico in the projection period



Source: simulation results

The CPS has a total investment cost overrun of 18% in the study period, while this overrun rises to 30% under the NFS due to the need for increased capacity and the proposed diversification of the electricity generation matrix (Figure 11.7).

11.3.5 Projected total LCOE by energy scenarios

Table 11.18. Total LCOE in Mexico, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	91	110	133	3.8%
BAU (RCP 8.5) scenario	75	91	110	134	3.9%
CPS	75	76	86	102	2%
NFS	75	76	86	100	1.9%
NFS (RCP 8.5)	75	76	87	101	1.9%

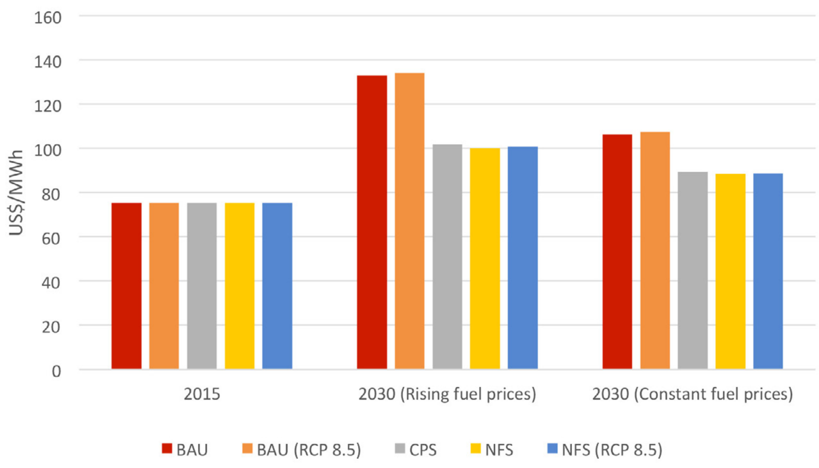
Source: simulation results

Table 11.19. Total LCOE in Mexico, constant fuel price sceanrio (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	84	94	106	2.3%
BAU (RCP 8.5) scenario	75	84	94	107	2.4%
CPS	75	72	78	89	1.1%
NFS	75	72	78	88	1.1%
NFS (RCP 8.5)	75	72	79	89	1.1%

Source: simulation results

Figure 11.8. Total LCOE in Mexico, according to the fuel price scenarios



Source: simulation results

In Mexico, the LCOE weighted by scenario, experienced a decrease of 25% in the NFS with respect to the BAU scenario and 2% with respect to the CPS, for a scenario of rising fuel prices, while for the constant price scenario of Fuels, these percentages are 17 and 1% respectively (see Tables 11.18 and 11.19).

11.4 Central America

11.4.1 Unit costs of investment

Table 11.20. Projection of unit costs of investment in Central America, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	2,800	3,091	3,413	3,768	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	2,200	2,200	2,100	2,100	-0.3%
Solar	2,500	2,500	2,300	2,300	-0.6%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

11.4.2 Projected LCOE

Table 11.21. LCOE for Central America, scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	86	97	110	2.4%
Hydroelectric (RCP 8.5)	77	87	100	115	2.8%
Natural gas	57	70	86	105	4.1%
Diesel-Fuel Oil	220	273	340	424	4.5%
Coal	81	100	123	152	4.3%
Biomass	142	153	167	183	1.7%
Geothermal	78	83	88	95	1.3%
Wind	85	85	82	82	-0.3%
Solar	181	181	168	168	-0.5%
Nuclear	112	129	149	172	2.9%

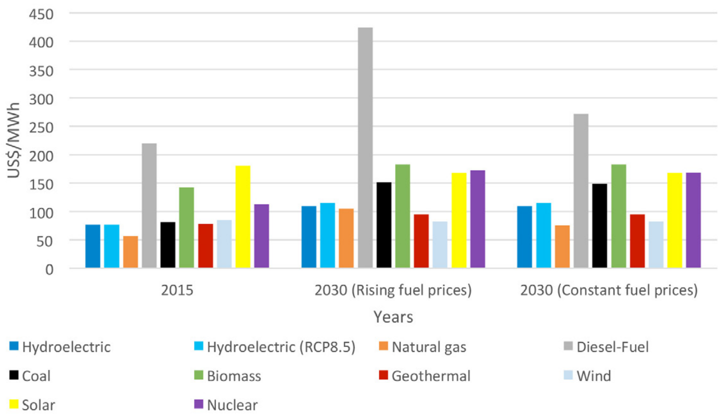
Source: simulation results

Table 11.22. LCOE for Central America, scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	86	97	110	2.4%
Hydroelectric (RCP 8.5)	77	87	100	115	2.8%
Natural gas	57	62	68	75	1.9%
Diesel-Fuel Oil	220	233	251	272	1.4%
Coal	81	99	121	149	4.1%
Biomass	142	153	167	183	1.7%
Geothermal	78	83	88	95	1.3%
Wind	85	85	82	82	-0.3%
Solar	181	181	168	168	-0.5%
Nuclear	112	128	147	169	2.8%

Source: simulation results

Figure 11.9. Projected LCOE for Central America, according to the fuel price scenarios



Source: simulation results

With regard to the LCOE in Central America, it should be noted that photovoltaic solar power is less competitive than coal in both fuel price scenarios. This is due to the technology's lower plant factor and relatively high investment cost.

11.4.3 Projected total electricity generation costs

Table 11.23. Total electricity generation cost for Central America, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	5,854	8,000	10,982	15,229	6.6%
BAU (RCP 8.5) scenario	5,854	8,051	11,144	15,577	6.7%
CPS	5,854	7,028	7,495	9,776	3.5%
NFS	5,854	5,893	7,239	11,579	4.7%
NFS (RCP 8.5)	5,854	6,024	7,361	11,889	4.8%

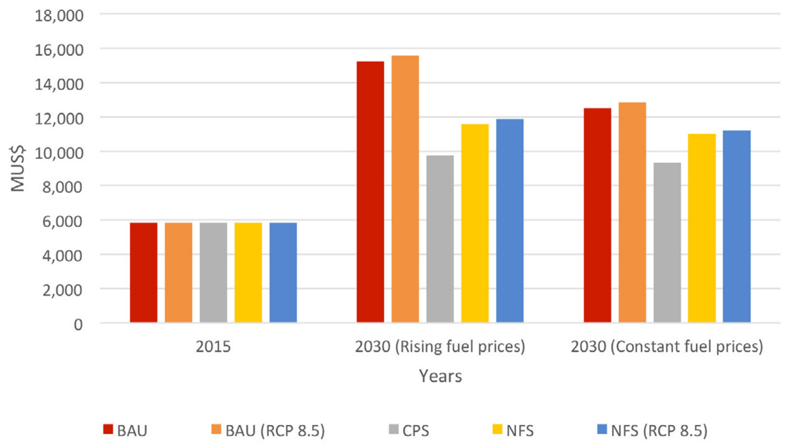
Source: simulation results

Table 11.24. Total electricity generation cost for Central America, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	5,854	7,480	9,612	12,512	5.2%
BAU (RCP 8.5) scenario	5,854	7,529	9,766	12,836	5.4%
CPS	5,854	6,763	7,274	9,333	3.2%
NFS	5,854	5,814	7,144	11,007	4.3%
NFS (RCP 8.5)	5,854	5,928	7,238	11,222	4.4%

Source: simulation results

Figure 11.10. Projected total cost of electricity generation for Central America, according to the fuel price scenarios

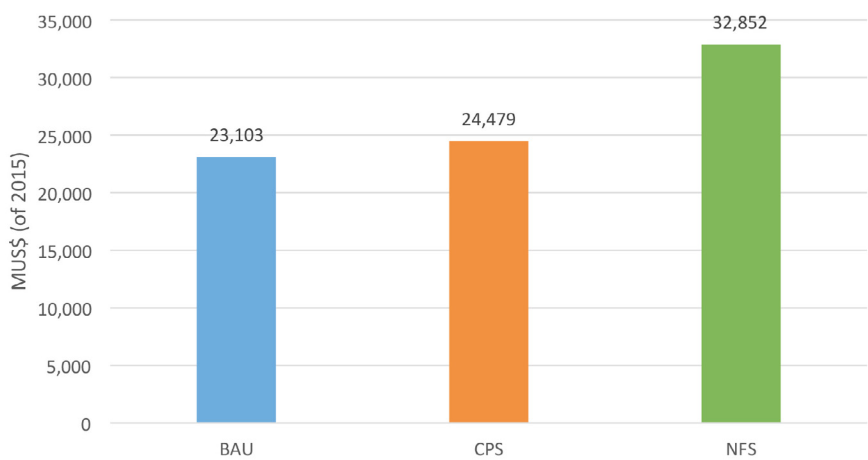


Source: simulation results

Despite the increase in electricity generation required, the NFS and allows a 24% economic savings in annual generation costs by 2030 for the rising fuel price scenario and 12% for the constant price scenario.

11.4.4 Total investment cost in electricity generation

Figure 11.11. Total investment cost in electricity generation for Central America in the projection period



Source: simulation results

The investment cost overrun in Central America under the CPS is just 6% compared to the BAU scenario, while under the NFS there would be a 42% investment cost overrun, mainly thanks to the significant increase in electricity generation under the latter scenario.

11.4.5 Projected total LCOE by energy scenarios

Table 11.25. Total LCOE in Central America, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	113	132	154	183	3.3%
BAU (RCP 8.5) scenario	113	132	156	185	3.4%
CPS	113	116	107	121	0.4%
NFS	113	101	108	119	0.3%
NFS (RCP 8.5)	113	98	105	117	0.2%

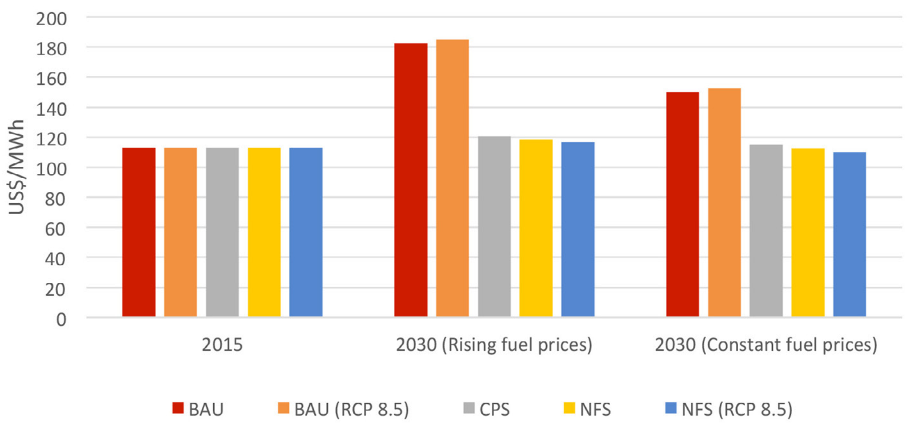
Source: simulation results

Table 11.26. Total LCOE in Central America, constant fuel price sceanrio (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	113	123	135	150	1.9%
BAU (RCP 8.5) scenario	113	124	137	153	2.0%
CPS	113	111	104	115	0.1%
NFS	113	99	107	113	0.0%
NFS (RCP 8.5)	113	97	103	110	-0.2%

Source: simulation results

Figure 11.12. Total LCOE in Central America, according to the fuel price scenarios



Source: simulation results

By 2030, the LCOE of the CPS and NFSs, recorded a decrease with respect to the BAU scenario of 34% and 35% respectively, in the scenario of rising fuel prices; and 23% and 25% respectively, in the scenario of constant fuel prices (see Tables 11.25 and 11.26).

11.5 Andean Subregion

11.5.1 Unit costs of investment

Table 11.27. Projection of unit costs of investment in the Andean Subregion, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	1,800	1,987	2,194	2,423	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	1,750	1,750	1,650	1,650	-0.4%
Solar	2,000	2,000	1,800	1,800	-0.7%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

11.5.2 Projected LCOE

Table 11.28. LCOE for the Andean Subregion scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	44	50	57	65	2.7%
Hydroelectric (RCP 8.5)	44	51	59	68	3.0%
Natural gas	57	70	86	106	4.1%
Diesel-Fuel Oil	234	290	359	445	4.4%
Coal	73	90	111	136	4.2%
Biomass	134	144	157	172	1.7%
Geothermal	78	83	88	95	1.3%
Wind	70	70	67	67	-0.3%
Solar	147	147	134	134	-0.6%
Nuclear	112	129	149	172	2.9%

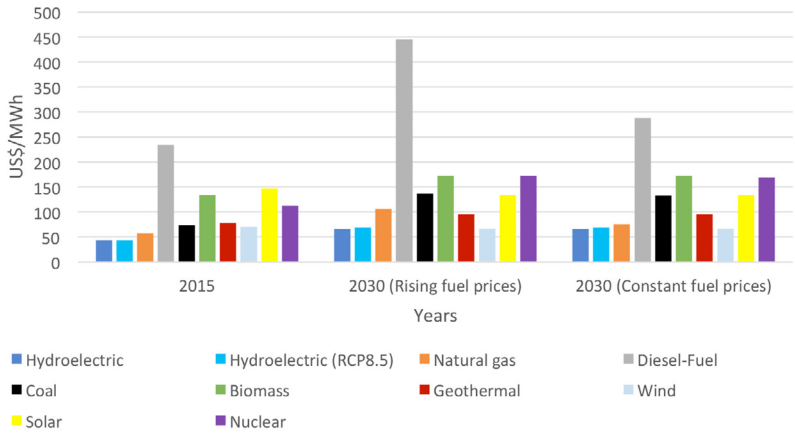
Source: simulation results

Table 11.29. LCOE for the Andean Subregion scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	44	50	57	65	2.7%
Hydroelectric (RCP 8.5)	44	51	59	68	3.0%
Natural gas	57	62	68	76	1.8%
Diesel-Fuel Oil	234	249	266	288	1.4%
Coal	73	89	109	133	4.0%
Biomass	134	144	157	172	1.7%
Geothermal	78	83	88	95	1.3%
Wind	70	70	67	67	-0.3%
Solar	147	147	134	134	-0.6%
Nuclear	112	128	147	169	2.8%

Source: simulation results

Figure 11.13. Projected LCOE for the Andean Subregion, according to the fuel price scenarios



Source: simulation results

One can see that NCRE, especially wind, are competitive compared to fossil fuels under both fuel price scenarios in the Andean Subregion (Figure 11.10).

11.5.3 Projected total electricity generation costs

Table 11.30. Total electricity generation cost for the Andean Subregion, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	21,596	31,308	45,824	67,772	7.9%
BAU (RCP 8.5) scenario	21,596	31,450	46,315	68,885	8.0%
CPS	21,596	21,770	29,450	40,798	4.3%
NFS	21,596	18,672	23,859	45,719	5.1%
NFS (RCP 8.5)	21,596	18,841	24,538	47,488	5.4%

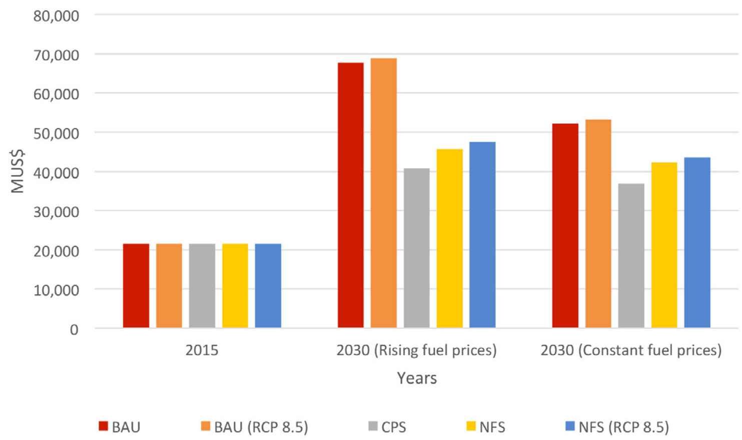
Source: simulation results

Table 11.31. Total electricity generation cost for the Andean Subregion, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	21,596	28,535	38,275	52,181	6.1%
BAU (RCP 8.5) scenario	21,596	28,673	38,743	53,223	6.2%
CPS	21,596	20,647	26,930	36,888	3.6%
NFS	21,596	17,966	22,994	42,344	4.6%
NFS (RCP 8.5)	21,596	18,114	23,518	43,561	4.8%

Source: simulation results

Figure 11.14. Projected total cost of electricity generation for the Andean Subregion, according to the fuel price scenarios

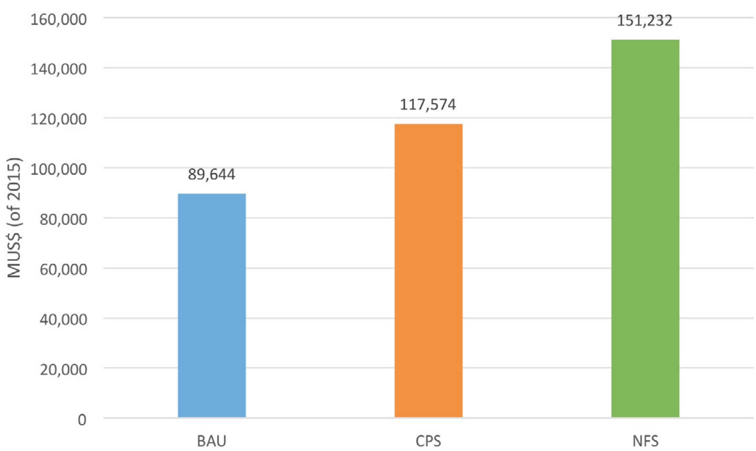


Source: simulation results

Despite the fact that it has a greater annual generation cost than the CPS, the NFS represents a 33% savings with rising fuel prices and 19% at constant prices in the Andean Subregion (Figure 11.11).

11.5.4 Total investment cost in electricity generation

Figure 11.15. Total investment cost in electricity generation for the Andean Subregion in the projection period



Source: simulation results

The overruns in total investment on electricity generation capacity for the Andean Subregion represent 31% under the CPS and 69% under the NFS when when compared to the BAU scenario.

11.5.5 Projected total LCOE by energy scenarios

Table 11.32. Total LCOE in Andean Subregion, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	77	92	110	133	3.8%
BAU (RCP 8.5) scenario	77	92	111	135	3.8%
CPS	77	65	73	83	0.5%
NFS	77	60	68	81	0.4%
NFS (RCP 8.5)	77	60	70	84	0.6%

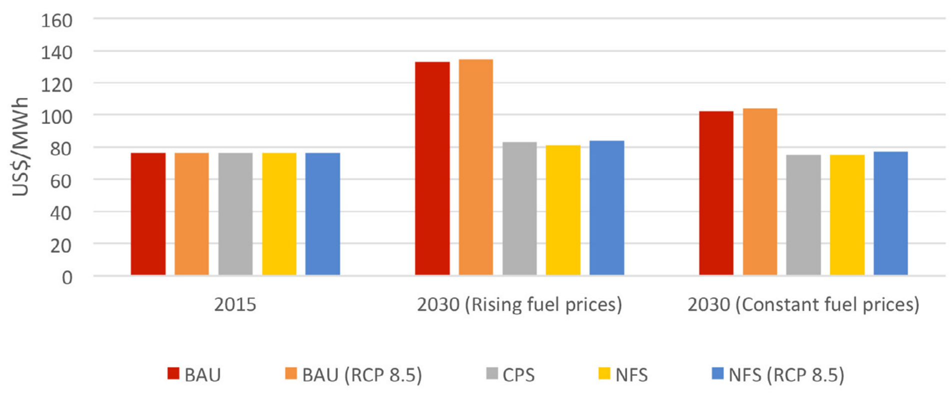
Source: simulation results

Table 11.33. Total LCOE in Andean Subregion, constant fuel price sceanrio es (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	77	84	92	102	2.0%
BAU (RCP 8.5) scenario	77	84	93	104	2.1%
CPS	77	61	66	75	-0.1%
NFS	77	58	65	75	-0.1%
NFS (RCP 8.5)	77	58	67	77	0.0%

Source: simulation results

Figure 11.16. Total LCOE in Andean Subregion, according to the fuel price scenarios



Source: simulation results

The LCOE of the scenarios CPS and NFS, in 2030, recorded a decrease of 38% and 39% respectively, compared with the BAU for that same year, for a scenario of rising fuel prices and 27% in both cases for a scenario of constant fuel prices (see tables 11.32 and 11.33).

11.6 Southern Cone

11.6.1 Unit costs of investment

Table 11.34. Projection of unit costs of investment in the Southern Cone, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	1,800	1,987	2,194	2,423	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	1,750	1,750	1,650	1,650	-0.4%
Solar	2,000	2,000	1,800	1,800	-0.7%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

11.6.2 Projected LCOE

Table 11.35. LCOE for the Southern Cone, scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	54	61	69	79	2.6%
Hydroelectric (RCP 8.5)	54	62	73	86	3.2%
Natural gas	56	69	85	104	4.1%
Diesel-Fuel Oil	228	284	354	441	4.5%
Coal	79	98	121	149	4.3%
Biomass	67	73	79	88	1.8%
Geothermal	78	83	88	95	1.3%
Wind	70	70	67	67	-0.3%
Solar	98	98	89	89	-0.6%
Nuclear	125	144	166	192	2.9%

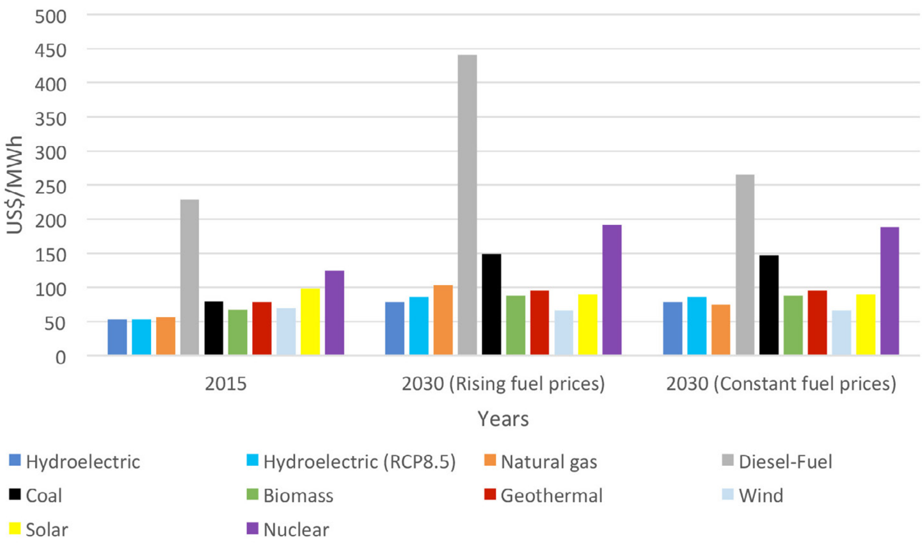
Source: simulation results

Table 11.36. LCOE for the Southern Cone, scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	54	61	69	79	2.6%
Hydroelectric (RCP 8.5)	54	62	73	86	3.2%
Natural gas	56	61	67	74	1.9%
Diesel-Fuel Oil	228	238	250	265	1.0%
Coal	79	97	119	147	4.2%
Biomass	67	73	79	88	1.8%
Geothermal	78	83	88	95	1.3%
Wind	70	70	67	67	-0.3%
Solar	98	98	89	89	-0.6%
Nuclear	125	143	164	188	2.8%

Source: simulation results

Figure 11.17. Projected LCOE for the Southern Cone, according to the fuel price scenarios



Source: simulation results

In the Southern Cone, NCRE become very competitive against nonrenewable energies by 2030. One can see that even photovoltaic solar power has an LCOE that is comparable to that of hydroenergy. This is due to the high plant factor of considered for photovoltaic energy in this subregion (Figure 11.13).

11.6.3 Projected total electricity generation costs

Table 11.37. Total electricity generation cost for the Southern Cone, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	21,272	31,342	44,852	64,614	7.7%
BAU (RCP 8.5) scenario	21,272	31,525	45,539	66,189	7.9%
CPS	21,272	26,624	36,193	49,515	5.8%
NFS	21,272	26,229	34,783	48,734	5.7%
NFS (RCP 8.5)	21,272	26,431	35,549	50,667	6.0%

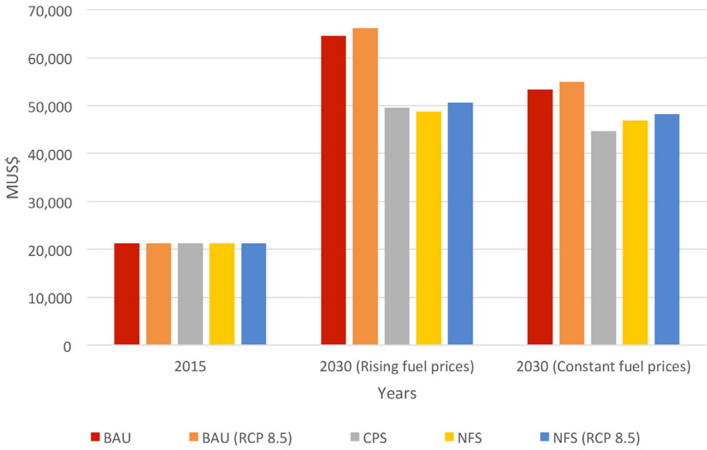
Source: simulation results

Table 11.38. Total electricity generation cost for the Southern Cone, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	21,272	29,260	39,280	53,371	6.3%
BAU (RCP 8.5) scenario	21,272	29,444	39,967	54,946	6.5%
CPS	21,272	25,741	33,606	44,644	5.1%
NFS	21,272	25,454	33,480	46,916	5.4%
NFS (RCP 8.5)	21,272	25,630	34,070	48,245	5.6%

Source: simulation results

Figure 11.18. Projected total cost of electricity generation for the Southern Cone, according to the fuel price scenarios

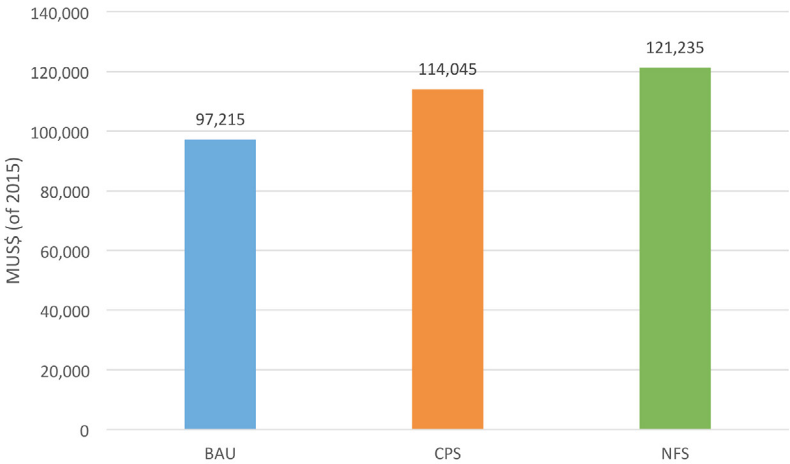


Source: simulation results

It is important to note that in the Southern Cone the NFS in the rising fuel price scenario has a lower annual generation cost in 2030 than the CPS despite the higher level of generation. However, its annual generation cost is higher under the constant price scenario (Figure 11.14).

11.6.4 Total investment cost in electricity generation

Figure 11.19. Total investment cost in electricity generation for the Southern Cone in the projection period



Source: simulation results

The cost overrun in electricity generation investment in the Southern Cone during the projection period is 17% for the CPS and 25% under the NFS compared the BAU scenario (Figure 11.15).

11.6.5 Projected total LCOE by energy scenarios

Table 11.39. Total LCOE in the Southern Cone, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	89	106	127	3.6%
BAU (RCP 8.5) scenario	75	90	108	131	3.8%
CPS	75	74	85	98	1.8%
NFS	75	74	83	91	1.3%
NFS (RCP 8.5)	75	75	85	94	1.5%

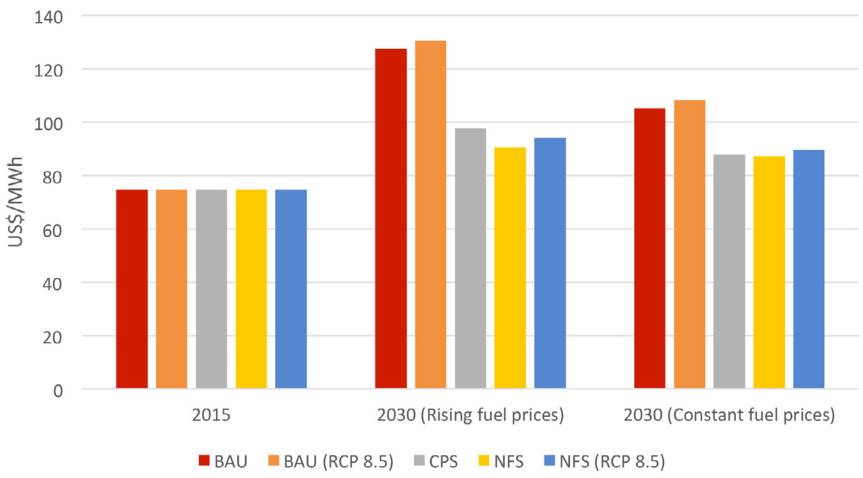
Source: simulation results

Table 11.40 Total LCOE in the Southern Cone, constant fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	83	93	105	2.3%
BAU (RCP 8.5) scenario	75	84	95	108	2.5%
CPS	75	72	79	88	1.1%
NFS	75	72	80	87	1.0%
NFS (RCP 8.5)	75	73	81	90	1.2%

Source: simulation results

Figure 11.20. Total LCOE in the Southern Cone, according to the fuel price scenarios



Source: simulation results

By 2030, the LCOE of the CPS and NFSs recorded a decrease of 23% and 29%, with respect to the BAU, for a scenario of rising fuel prices and of 16 and 17%, for a scenario of constant prices of the fuels (see Tables 11.39 and 11.40).

11.7 The Caribbean

11.7.1 Unit costs of investment

Table 11.41. Projection of unit costs of investment in the Caribbean, (US$/kW)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	2,800	3,091	3,413	3,768	2.0%
Natural gas	978	1,213	1,504	1,866	4.4%
Diesel-Fuel Oil	1,342	1,664	2,064	2,560	4.4%
Coal	3,636	4,509	5,593	6,936	4.4%
Biomass	2,500	2,500	2,500	2,500	0.0%
Geothermal	4,000	4,000	4,000	4,000	0.0%
Wind	2,200	2,200	2,100	2,100	-0.3%
Solar	2,500	2,500	2,300	2,300	-0.6%
Nuclear	6,000	6,956	8,064	9,348	3.0%

Source: by authors, based on data from the "2017 Annual Energy Outlook," EIA, USA

11.7.2 Projected LCOE

Table 11.42. LCOE for the Caribbean, scenario of rising fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	86	97	110	2.4%
Hydroelectric (RCP 8.5)	77	87	100	115	2.8%
Natural gas	53	65	79	97	4.2%
Diesel-Fuel Oil	207	258	321	400	4.5%
Coal	81	100	123	152	4.3%
Biomass	60	65	71	79	1.8%
Geothermal	78	83	88	95	1.3%
Wind	85	85	82	82	-0.3%
Solar	181	181	168	168	-0.5%
Nuclear	112	129	149	172	2.9%

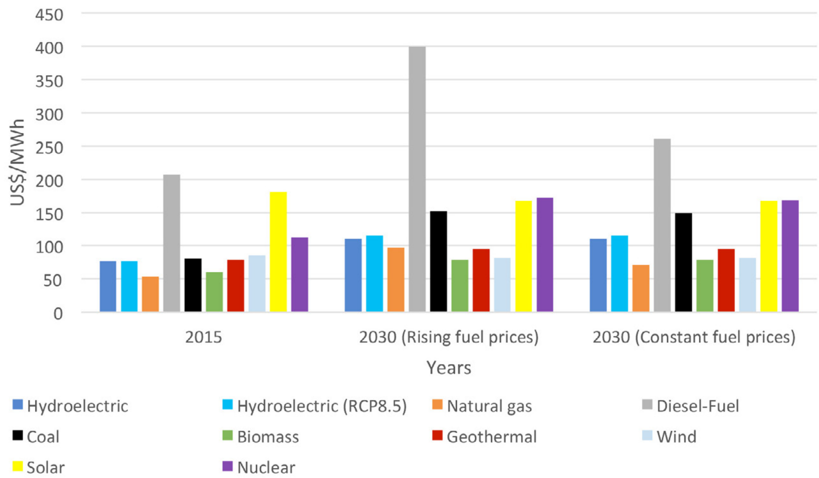
Source: simulation results

Table 11.43. LCOE for the Caribbean, scenario of constant fuel prices (US$/MWh)

Technology	2015	2020	2025	2030	a.a.r.
Hydroelectric	77	86	97	110	2.4%
Hydroelectric (RCP 8.5)	77	87	100	115	2.8%
Natural gas	53	58	64	71	2%
Diesel-Fuel Oil	207	222	239	261	1.6%
Coal	81	99	121	149	4.1%
Biomass	60	65	71	79	1.8%
Geothermal	78	83	88	95	1.3%
Wind	85	85	82	82	-0.3%
Solar	181	181	168	168	-0.5%
Nuclear	112	128	147	169	2.8%

Source: simulation results

Figure 11.21. Projected LCOE for the Caribbean, according to the fuel price scenarios



Source: simulation results

While electricity generation using NCRE like wind and biomass are very competitive compared to other technologies in the Caribbean, photovoltaic solar power has a relatively high LCOE due to its higher investment cost and lower plant factor of when compared to the other subregions (Figure 11.16).

11.7.3 Projected total electricity generation costs

Table 11.44. Total electricity generation cost for the Caribbean, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	7,026	10,424	15,561	23,381	8.3%
BAU (RCP 8.5) scenario	7,026	10,455	15,657	23,598	8.4%
CPS	7,026	7,905	11,815	17,355	6.2%
NFS	7,026	7,808	10,135	11,877	3.6%
NFS (RCP 8.5)	7,026	7,849	10,296	12,318	3.8%

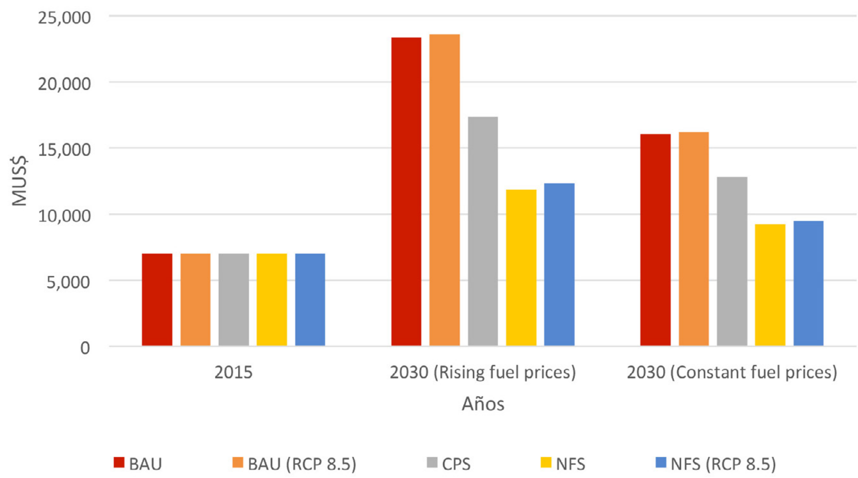
Source: simulation results

Table 11.45. Total electricity generation cost for the Caribbean, constant rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	7,026	9,108	11,997	16,070	5.7%
BAU (RCP 8.5) scenario	7,026	9,136	12,074	16,226	5.7%
CPS	7,026	7,085	9,543	12,802	4.1%
NFS	7,026	6,944	8,205	9,231	1.8%
NFS (RCP 8.5)	7,026	6,979	8,325	9,517	2.0%

Source: simulation results

Figure 11.22. Projected total cost of electricity generation for the Caribbean, according to the fuel price scenarios

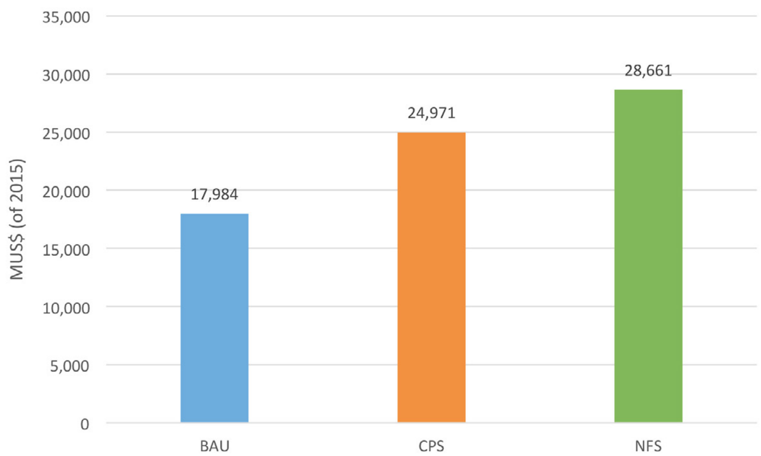


Source: simulation results

There is a very marked difference in annual electricity generation costs by 2030 in the Caribbean when comparing the BAU, CPS and NFSs. The cost under the NFS and is lower in this subregion than under CPS due to the lower need for generation and the diversification of technologies. The NFS allows a 49% savings compared to the BAU scenario with rising fuel prices and 43% with constant fuel prices (Figure 11.17).

11.7.4 Total investment cost in electricity generation

Figure 11.23. Total investment cost in electricity generation for the Caribbean in the projection period



Source: simulation results

Despite the lower generation levels under the CPS and NFS compared to the BAU scenario, there are investment cost overruns due to the diversification of the electricity generation matrix. These cost overruns are 39% and 59%, respectively, compared to the BAU scenario.

11.7.5 Projected total LCOE by energy scenarios

Table 11.46. Total LCOE in the Caribbean, rising fuel price scenario (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	128	158	196	242	4.3%
BAU (RCP 8.5) scenario	128	158	196	242	4.3%
CPS	128	122	152	186	2.5%
NFS	128	126	142	140	0.6%
NFS (RCP 8.5)	128	126	144	144	0.8%

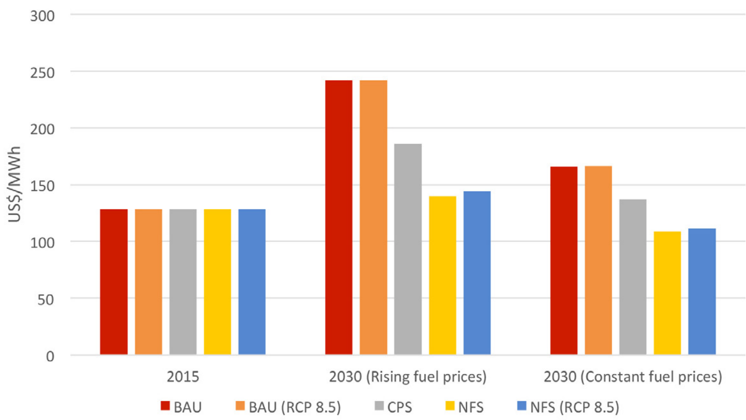
Source: simulation results

Table 11.47. Total LCOE in the Caribbean, constant fuel price sceanrio (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	128	138	151	166	1.7%
BAU (RCP 8.5) scenario	128	138	151	166	1.7%
CPS	128	109	123	137	0.5%
NFS	128	112	115	109	-1.1%
NFS (RCP 8.5)	128	112	116	111	-1.0%

Source: simulation results

Figure 11.24. Total LCOE in the Caribbean, according to the fuel price scenarios



Source: simulation results

By 2030, the LCOE of the CPS and NFSs recorded a decrease of 23% and 42%, with respect to the BAU, for a scenario of rising fuel prices and of 17 and 35% for the constant price scenario of the fuels (see Tables 11.46 and 11.47).

11.8 Latin America and the Caribbean (LAC)

11.8.1 Projected total electricity generation costs

Table 11.48. Total electricity generation cost for LAC, rising fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	117,055	166,893	237,802	339,818	7.4%
BAU (RCP 8.5) scenario	117,055	167,914	241,267	347,375	7.5%
CPS	117,055	137,572	183,558	249,303	5.2%
NFS	117,055	131,009	172,093	263,054	5.5%
NFS (RCP 8.5)	117,055	132,096	175,748	272,206	5.8%

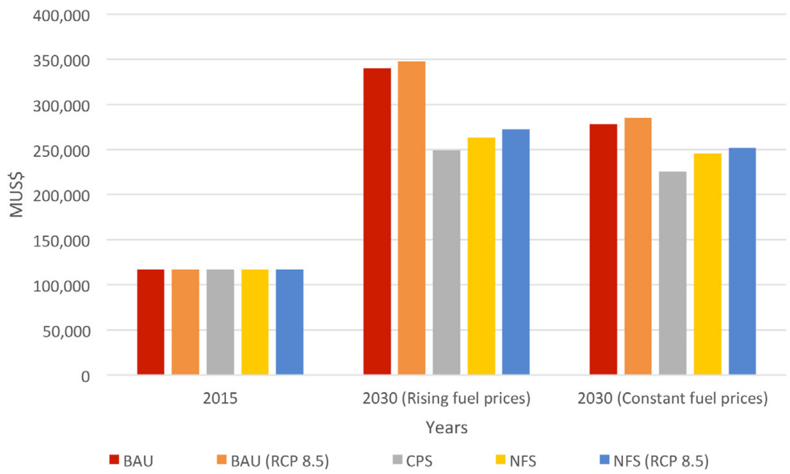
Source: simulation results

Table 11.49. Total electricity generation cost for LAC, constant fuel price scenario (MUS$)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	117,055	155,628	207,437	278,008	5.9%
BAU (RCP 8.5) scenario	117,055	156,553	210,529	284,633	6.1%
CPS	117,055	132,547	170,548	225,735	4.5%
NFS	117,055	126,856	163,748	245,493	5.1%
NFS (RCP 8.5)	117,055	127,800	166,540	251,697	5.2%

Source: simulation results

Figure 11.25. Projected total cost of electricity generation for LAC, according to the fuel price scenarios



Source: simulation results

For the integral region of LAC, in 2030, the savings in electricity generation costs, associated with the NFS, with respect to the BAU scenario, turns out to be 23%, for the scenario of rising fuel prices and 12%, for the scenario of constant prices of fuels, while throughout the projection period, the NFS, would allow an accumulated saving of MUS$ 75,524 for the scenario of increasing prices of fuels and MUS$ 27,782 for the scenario of precise constant, with respect to the CPS. It should also be noted that the cost of generation in the NFS is greater than that of the CPS, at the end of the projection period due to the greater amount of energy generated.

11.8.2 Total LCOE values, weighted by scenario for LAC.

Table 11.50. LCOE for LAC, scenario of rising fuel prices (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	88	104	123	3.4%
BAU (RCP 8.5) scenario	75	88	105	125	3.5%
CPS	75	73	82	93	1.5%
NFS	75	72	80	89	1.2%
NFS (RCP 8.5)	75	72	82	91	1.3%

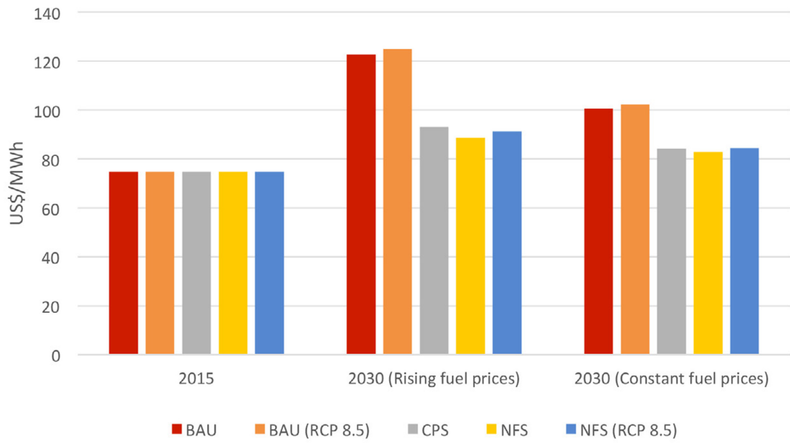
Source: simulation results

Table 11.51. LCOE for LAC, scenario of constant fuel prices (US$/MWh)

Scenario	2015	2020	2025	2030	a.a.r.
BAU Scenario	75	82	91	100	2.0%
BAU (RCP 8.5) scenario	75	82	92	102	2.1%
CPS	75	70	76	84	0.8%
NFS	75	70	76	83	0.7%
NFS (RCP 8.5)	75	70	77	84	0.8%

Source: simulation results

Figure 11.26. Projected LCOE for LAC, according to the fuel price scenarios

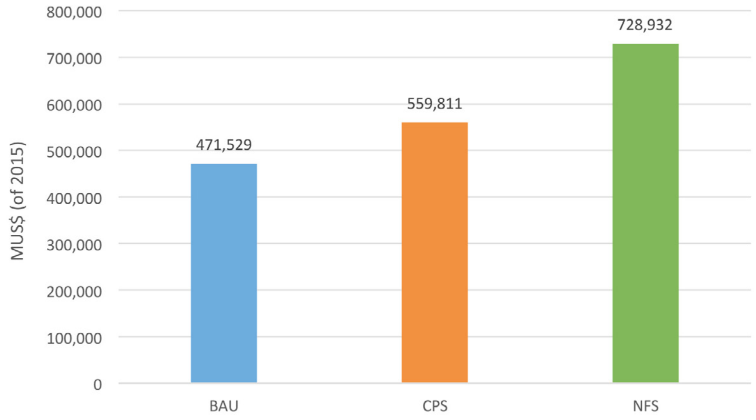


Source: simulation results

By 2030, the level of electricity production costs (LCOE) of the LAC region in the scenarios CPS and NFS, are reduced by 27% and 19% respectively, in relation to those of the BAU scenario, for a scenario of increasing international prices of fuels; and 23% and 12% respectively, for a scenario of constant fuel prices.

11.8.3 Total investment cost in electricity generation

Figure 11.27. Total investment cost in electricity generation for LAC in the projection period



Source: simulation results

As in all the subregions analyzed, for the LAC integral region, the scenarios CPS and NFS, present total cost overruns in the projection period (19% for the CPS and 55% for the NFS), with respect to the BAU scenario. These cost overruns include: the cost of increasing the electricity generation capacity needed to supply the highest electrification of the final consumption, considered within the energy efficiency measures; and the cost of diversification of the electricity generation matrix aimed at the greater participation of NCREs.

It is important to note that at the regional and subregional levels, in terms of LCOE, wind energy is the most competitive source in relation to conventional sources and other NCREs, remaining by the year 2030, in most subregions at approximately the same level of natural gas.

These results, in short, show that the adoption of the premises of the NFS has a positive impact not only on GHG emissions but also on electricity production costs. However, the above can not be ignored the fact that the incremental investments in the production of electricity, both in the NFS and in the CPS, exceed those of the BAU scenario. In particular, these incremental investments in the NFS exceed the respective investments of the BAU and CPSs by more than 55% and 30%, which in some countries may imply a restriction in the promotion of a more accelerated development. of renewables in the power generation matrix.

12. Conclusions

12. Conclusions

12.1 Conclusions by subregion

12.1.1 Brazil

As it can be seen in chapters 7 and 10, Brazil obtained, through the simulation of the CPS scenario, a reduction of GHG emissions of approximately 10% by 2030, with respect to the BAU scenario, which, as noted in said chapters, would be below the targets set by most countries and the regional reference target; and also, the average annual growth rate of said emissions during the projection period (2).6%) would be above the maximum estimated by the Ministry of Mines and Energy - MME, for the energy sector (1.8%), in order to comply with the goals established in the NDCs of Brazil (see table 7.1).

On the other hand, with the NFS scenario, a reduction of around 35% with respect to the BAU scenario was achieved, which is above the general targets of most countries and the regional target taken as a reference (25 to 30%), and also, the average annual growth rate of said emissions (0.5%), is lower than the maximum expected by the MME for the energy sector (1.8%), which could be considered a successful contribution to the fulfillment of its NDCs. This is mainly due to a reduction in energy demand of 11% with respect to the CPS and 14% with respect to the BAU, the decrease in the share of petroleum products in final consumption (40% NFS vs 47% CPS and 47% BAU), greater renewability of the electricity generation matrix (92% NFS vs 85% CPS and 74% BAU) and greater renewability of the total supply matrix (49% NFS vs 41% CPS and 41% BAU). It is important to highlight that of the total reduction of emissions observed when comparing the NFS and BAU energy scenarios in the year 2030, the contribution of the electricity sector is 36%.

In Chapter 11, it can be seen that, by 2030, the LCOE of the CPS and NFSs recorded a decrease of 15% and 16% respectively, in relation to the BAU, for a scenario of rising fuel prices; and 9% and 8% for a scenario of constant fuel prices.

12.1.2 Mexico

GHG emissions under the CPS decline by 14% over those of the BAU scenario in 2030, which is substantially less assuming a similar target for the energy sector as what is established in its NDCs (25%). This reduction would be around 24% under the proposed NFS, which means practically fulfilling the target. This would mainly come from a 13% decline in demand compared to the CPS and 16% over the BAU scenario, an increased proportion of renewable electricity generation compared to the BAU scenario (34% NFS vs 18% BAU), and a decline in the importance of oil products and derivatives in total energy supply (25% NFS vs 33% CPS and 38% BAU), with increased renewability in this matrix (18% NFS vs 14% CPS and 8% BAU). It should be noted that the emissions reduction target is achieved despite the continued predominance of natural gas in the Mexican energy matrix.

Regarding the economic analysis, NCRE are observed to be more competitive than oil products and coal in terms of LCOE by 2030 and in the case of wind power, it competes very closely with natural gas. The NFS also allows a 17% and 9% savings in the total cost of electricity generation compared to the BAU for the scenarios of rising and constant fuel prices, respectively.

12.1.3 Central America

Though a significant percentage reduction in GHG emissions (17.5%) is achieved by 2030 compared to the BAU scenario, some conditional NDCs for countries in the subregion propose more ambitious targets (for example: Guatemala 22.5%). However, a 30% reduction in GHG emissions would be achieved under the NFS. This would mainly be thanks to a 27% decline in demand compared to the CPS and 29% compared to BAU, driven by a vigorous policy to replace firewood with modern energy sources. Under the NFS this subregion shows a decline in the renewability of total energy supply with regard to the CPS (45% NFS vs 49% CPS) due to fact that the significant decline in the use of biomass (especially firewood) that is registered under the NFS is not compensated by the policies to foster penetration by modern renewable energies.

Under the NFS, a rise in the share of oil and its derivatives in the final consumption matrix can be observed with regard to the CPS (52% NFS vs 47% CPS), due to the substitution of biomass with LPG, but there is also a significant increase in the share represented by electricity (25% NFS vs 14% CPS and 15% BAU). When it comes to electricity generation, renewables maintain levels of around 76%, inasmuch as natural gas shows a slight increase to the detriment of coal and oil products (22% NFS vs 19% CPS). It is also noted that of the total emissions observed when contrasting the NFS and BAU energy scenarios in 2030, the electricity sector's contribution is about 41%. For their part, by 2030 the LCOE in the CPS and NFS fall by 34% and 35%, respectively, with regard to the BAU in a scenario of rising fuel prices, and 23% and 25%, respectively, in a scenario with constant fuel prices.

12.1.4 Andean Subregion

GHG emissions under the CPS are cut by 7.4% by 2030 compared to the BAU scenario, far from the reference target of between 20% and 25% and according to the NDCs declared by the countries in this subregion. However, a 32% reduction in GHG emissions would be achieved if the assumptions of the NFS are fulfilled. This would mainly come from a 12% decline in demand compared to the CPS and 15% over the BAU, increased penetration by renewables in the total energy supply (29% NFS vs 17% CPS and 14% BAU) and a decline in the importance of oil products and derivatives (37% NFS vs 44% CPS and 51% BAU). The most significant thing in the electricity generation matrix's evolution is the strong increase in the share of renewables (78% NFS vs 66% CPS and 65% BAU), replacing coal and oil products. The electricity sector's contribution to the total reduction in emissions achieved under the NFS when compared to the BAU scenario is 34% in 2030. For their part, by 2030 the LCOE in the CPS and NFS falls by 38% and 39%, respectively, compared to the BAU in a scenario of rising fuel prices, and 27% in both cases for a scenario with constant fuel prices.

12.1.5 Southern Cone

There is an 8.5% reduction in GHG emissions under the CPS when compared to BAU, clearly lower than the reference target of the 20% for the subregion's energy sector as considered in the NDCs of the countries that belong to it. For its part, the NFS energy scenario achieves a reduction in GHG emissions of close to 26%, mainly the result of a 15% decline in demand compared to the BAU scenario and 12% over the CPS, increased participation by renewables in the total energy supply (30% NFS vs 22% CPS and 20% BAU), and a substantial decline in the supply of oil products (23% NFS vs 29% CPS and 33% BAU). With regard to the final consumption matrix, the increased share of electricity stands out (28% NFS vs 22% CPS and BAU). In electricity generation there is a significant increase in the share of renewables (60% NFS vs 54% CPS and 46% BAU), to the detriment of the use of coal and mainly of oil products. Of the total emissions observed when contrasting the NFS and BAU energy scenarios in 2030, the electricity sector's contribution is 39%. One can also see that by 2030 the LCOE in the CPS and NFS fall by 23% and 29%with regard to the BAU in a scenario of rising fuel prices, and 16% and 17% in a scenario with constant fuel prices.

12.1.6 The Caribbean

GHG emissions by 2030 under the CPS energy scenario are down by 10.4% compared to the BAU scenario. This decline is significantly lower than the reference target of 15% established for the subregion's energy sector, according to the NDCs of the countries that belong to it. However, the reduction in GHG emissions that would be achieved under the NFS is around 27%, which would mainly be thanks to a 9% decline in demand compared to the BAU scenario and an increase in the renewability of the total energy supply (23% NFS vs 18% CPS and 13% BAU), in addition to increased participation by natural gas (50% NFS vs 45% CPS and 43% BAU), to the detriment of oil and its derivatives. For its part, the electricity generation matrix under the NFS shows a significant increase in the share of renewable sources (45% NFS vs 26% CPS and 8% BAU) and natural gas (51% NFS vs 44% CPS and 40% BAU), significantly displacing the use of goal and oil-based products. The electricity sector's observed contribution to the reduction in total emissions when contrasting the NFS and BAU energy scenarios in 2030 is particularly important in this subregion, where it reaches approximately 83%. For their part, by 2030 the LCOE in the CPS and NFS fall by 23% and 42%, with regard to BAU in a scenario of rising fuel prices, and 17% and 35% in a scenario with constant fuel prices.

12.1.7 Latin America and the Caribbean

Given that the decline in the energy sector's CO2e emissions is just 10% by 2030 under CPS when compared to BAU and considering the magnitude of the proportional reductions expressed in the individual countries' NDCs, one can conclude that current policies are not enough to achieve the goals proposed in these NDCs. For this reason, under the assumptions of the NFS, in which policies to incentivize energy efficiency are deepened, more progress is made with the penetration of renewable energies and consumption of natural gas is encouraged as an alternative to oil products, the GHG emission's reduction for the energy sector would be close to 30% by 2030 compared to the BAU scenario, which would be satisfactory when considering the reference target defined in the NFS (from 25% to 30% for LAC).

The renewability of total energy supply by 2030 increases under the NFS (34% NFS vs 27% CPS and 24% BAU). Together with the above, a decline in the proportion of oil and its derivatives is also detected (32% NFS vs 38% CPS and 41% BAU). For their part, the additional measures to promote energy efficiency that were implemented under the NFS made it possible to reduce demand for energy by 12% compared to CPS and 15% over BAU. The results in terms of the final consumption matrix reveal a decline in the share of oil and derivatives (42% NFS vs 50% CPS and 50% BAU) and an increased share of electricity (26% NFS vs. 20% CPS and 20% BAU). In electricity generation there is a significant increase in the share of renewable energies when comparing both scenarios (70% NFS vs 63% CPS and 52% BAU), substituting coal and oil products.

It is important to highlight that electricity generation's contribution by to the total reduction in energy matrix GHG emissions under the NFS is 37% in 2030 compared to the BAU scenario.

Regarding the economic dimension, the results show that by 2030 the leveled costs of electricity (LCOE - U$S/MWh) in the LAC region under the CPS and NFS would fall by 27% and 19%, respectively compared to the BAU scenario in a context or rising fuel prices and 23% and 12%, respectively, with constant fuel prices. The BAU, CPS and NFSs were modeled on the premise that by 2030, the effects of climate change on both energy supply as well as demand will be of little significance. Given the prevailing uncertainty regarding the evolution of this phenomenon and its effects, a sensitivity analysis was performed to consider an extreme climate change scenario, for which the RCP 8.5 climate scenario was considered. The results of this analysis for LAC show moderate effects on both energy supply (particularly due to hydrological variations in different watersheds) as well as demand (essentially due to the effect of rising temperatures on the use of heating and air-conditioning) by 2030. Inclusion of these impacts on the modeling of the BAU and NFSs allows one to extract the robustness of the NFS, regarding the effects of a more drastic climate change scenario, as a significant conclusion. Thus, in such circumstances, the emissions differential between the two energy scenarios shows a 27.8% reduction by 2030, an amount that surpasses the minimum regional reference target of the 25% defined for the sector. Nevertheless, it is important to note that in the event of a climate scenario of such characteristics, emissions in absolute terms under the NFS would increase slightly, by 2.6%, without this jeopardizing the robustness of the NFS, since it would simply point to the need to slightly adapt the renewable energy promotion measures foreseen in this scenario to the challenges that could be posed by the effects of climate change in each area, be it applying adaptation measures in hydroelectric systems or increasing the use of other renewable sources. In terms of the impact of CC on the LCOE by 2030, it is 3% under the NFS for a context of rising fuel prices and just 2% for a scenario of constant fuel prices.

The analysis of sensitivity to the intensity of climate change in the subregions reveals the same results with regard to the robustness of the respective NFSs, as the emission reductions achieved by 2030 in all subregions in an extreme climate change scenario (NFS (RCP 8.5) vs BAU (RCP 8.5)) surpass the respective reference targets for each subregion. However, it should be noted that in all cases these reductions are slightly lower than those achieved under in scenarios with a negligible CC effect. In addition, by 2030 every subregion can be observed to have substantially lower LCOE under the respective NFSs than under the BAU scenarios and moderately lower ones compared to the CPS.

The hypotheses on the evolution of the price of energy sources and their associated technologies were built based on reference price scenarios taken from well-known international publications on the subject. For the purpose of this study it was considered appropriate to undertake a sensitivity analysis for the occurrence of a scenario with prices more unfavorable to the development of renewable energies and energy efficiency. Thus, fossil fuel prices were frozen at 2015 levels and their impact on LOCE was analyzed. The results show that, even under these assumptions, for the region as a whole the LCOE for the CPS and the NFS were 16% and 18% less in 2030, respectively, when compared to the BAU scenario.

When the above sensitivity analysis is extended to the subregional level one can see that in all cases the LCOE for the CPS and NFS are lower than under the BAU scenario, though to a lesser degree than those registered with rising fuel prices. The Andean, Central American and Caribbean subregions are the ones to achieve the greatest reductions, while in the latter of these the difference between the LCOE under the NFS and the CPS is the highest, at 35% and 17%, respectively.

12.2 General conclusions

In sum, and as a general conclusion for the LAC region as a whole, it is worth noting that if current the policies in force remain (CPS assumptions), the reduction in GHG emissions achieved by 2030 compared to those projected under the BAU scenario would be considerably below the minimum reference target of 25% set for the sector for the purposes of this study. In contrast, if the assumptions of the NFS are fulfilled, significant additional reductions in the energy sector's GHG emissions could be achieved that would allow that reference target to be achieved. The study's results show that such reductions are driven by an increase in the proportion of renewable energies in the total energy supply (mainly to the detriment of oil and its derivatives) and by a greater stimulus of energy efficiency, with the consequential impact on energy demand.

With regard to the final consumption matrix, the significant increase in the penetration of electricity and the significant decline in the proportion of oil and its derivatives (though both continue to maintain significant weight in both scenarios) stand out. As far as the electricity generation matrix is concerned, consistent with the increased incentive to the development of renewables under the NFS, their share will expand significantly by 2030, reaching levels of close to 70%. The electricity sector's significant contribution to the reduction of GHG emissions under the NFS versus BAU is also worth noting (37% of total emissions by 2030).

In addition, the study's results show that by 2030 the LCOE for the NFS register slightly lower levels than the CPS. Regarding the comparative analysis of the accumulated costs for the period 2015-2030, one can also infer that the former scenario represents a savings of 75,524 MUS$ compared to the latter for the scenario of rising fuel prices and 27,782 MUS$ for the constant price scenario. This ultimately means that adopting the assumptions of the NFS has a positive impact not just on GHG emissions, but also on the production costs of electricity. Notwithstanding the above, one cannot ignore the fact that the incremental investment in electricity production, both under the NFS as well as in the CPS, surpasses that of the BAU scenario. In particular, said incremental investments under the NFS are over 55% higher and 30% more than the respective investments under the BAU scenario and CPS, which in some countries could imply a restriction in the promotion of swifter development of renewables in the electricity generation matrix.

As pointed out in the introduction, this study aims to promote a debate that OLADE considers necessary and for this it offers a first approximation to the analyzed topics. A detailed analysis of whether the goals established in the NDCs are adequate and sufficient, that it also offers concrete proposals by country on how to achieve compliance, as well as a rigorous estimate of the investments needed to do so, would require sufficient resources to be able to carry out a larger study.

13. General proposal of OLADE to reach the NDCs

13. General proposal of OLADE to reach the NDCs

This study analyzes the energy sector's contribution and the effectiveness of existing energy development policies in Latin American and Caribbean (LAC) countries in meeting the targets proposed in their NDCs for GHG emissions cuts by 2030. An energy forecasting exercise was performed taking 2015 as the base year and with a horizon of 2030 for the LAC region, in turn subdivided into 2 countries and 4 subregions: Brazil, Mexico, Central America, Andean Subregion, Southern Cone and the Caribbean.

The regional energy sector's main contribution to fulfillment of the GHG emissions reductions will clearly come from promoting of incorporation of renewable energies and energy efficiency programs. Thus, to conclude we present a series of recommendations below that are worth considering when it comes to improving and/or deepening the policy actions under way.

13.1 Proposal on policies of energy efficiency

Energy efficiency is achieved in the relationship between a series of behaviors and practices that require energy for their implementation and the rational actions that allow the amount of energy consumed to ultimately obtain the products and services to be optimized. This is valid both for the case seeking to maintain the level of comfort or production, as well as the case seeking to increase them, with energy consumption possibly even increasing in the latter case, but with a more than proportional improvement in the energy services provided (lighting, heating, driving force, etc.). It is therefore important to insist that the promotion of energy efficiency cannot be to the detriment of people's qualify of life or negatively affect the productivity of sectors that dynamize economies.

If we assume that, to a certain degree, there is a significant correlation between per capita energy consumption and the standard of living of a country's population, and that it is understandable for the inhabitants of LAC to aspire to achieving more satisfactory living standards, then there is no doubt that the region must increase the amount of energy available to it. In this context, it should also be noted that per capita energy consumption in OECD countries is four times higher than in LAC.

In countries that have satisfied their basic needs, any improvement in the way that energy is used is translated into a direct reduction in consumption. However, as development indicators deteriorate, there is an energy gap that must be closed before energy efficiency actions can result in direct energy savings. Improvements in the energy efficiency of emerging economies are often not translated into energy savings, but rather are an additional tool to provide and improve access to energy resources, increase production and as a mechanism to reduce energy poverty. In this context, energy efficiency has a central role to play by helping to decouple economic growth from energy consumption and increasing the population's level of comfort with the minimum energy consumption possible

LAC must prepare itself to deal with rising energy consumption, but in an efficient way, reducing unnecessary consumption and providing more and better services.

Institutional capacity and continuity, and the sectoral policy decisions made are key elements to having at the very least an expectation of success in the creation development and implementation of energy efficiency programs. Of course, the existence of an energy efficiency law assumes its compliance and therefore, that the state has adequate oversight, in addition to mechanisms to promote and incentivize energy savings. For this reason the OLADE seeks to assist the region's countries with the proposal of a Framework Law for Regional Energy Efficiency and a Model Institutional Framework, both broad and general enough to allow their adaptation to the unique conditions in each country.

In addition, it is critical that participation by trained human resources be guaranteed, along with their continuity in their functions. Local capacities need to be created among technical workers and energy managers, with training programs that offer regional certifications. For this reason, participation by universities and technical training centers will play an important role in catalyzing knowledges through research programs and offering increasingly specialized diploma and master's degree programs.

The use of useful energy balances gives a clearer idea of the state of affairs in the energy efficiency context and provides the basis analyzing energy substitution possibilities and the price and tariff competitiveness of different energy sources. OLADE recently published its Manual of Useful Energy Balances. The use of useful energy balances facilitates the -post evaluation of the programs, allowing those subsectors with the greatest potential to reduce energy intensity to be identified. Today it is possible, like never before, to leverage the potential of information technologies and Big Data to measure (even in real time) energy uses in certain sectors, such as transportation

In the area of public policy, there is a need to overcome the idea of energy efficiency exclusively focused on public sector action. Likewise, it is important to avoid the intermittence of programs so they can become consolidated as true state policies that do not depend on the actors of the moment. This would allow the sectoral approach to be consolidated and create stable frameworks to facilitate incentives and break down the barriers that prevent the development and dynamization of market mechanisms to facilitate the private sector's participation, such as in the area of ESCOs. To achieve these objectives, methodologies based on the formulation of roadmaps with multisector participation can be used.

International organizations, multilateral banks and institutions that promote development cooperation have an essential responsibility to close development gaps between countries. To this end, increased coordination is needed that integrates the technical support provided with financing needs, allowing the projects and programs that are promoted to be designed and implemented and for them to achieve results that can be sustained and consolidated over the medium and long term. It is also important to encourage the possibility of south-south cooperation by systematizing exchange of technical knowledge and existing expert networks. The human talent capacities of the region as a whole can be taken advantage of by all countries with the existence of dynamic communication mechanisms. Along these lines, it is important to have regional professional certification systems for energy managers.

When considering that the transportation sector is the largest energy consumer in LAC, specifically of fossil fuels, and that internal combustion vehicles show relatively low efficiency levels, there is a clear need to prioritize the implementation of improvement measures in this sector. Thus, it is essential that the energy and public transport areas coordinate their actions.

In major urban centers, the sum of energy inefficiency and economic unproductiveness, the decline in the quality of life and the sudden rise in local contamination levels from urban traffic should motivate the formulation of policies to promote a modal shift in the use of transport. These policies should promote public transportation, encourage carpooling, promote the use of bicycles with exclusive lanes and foster penetration by electric vehicles, in addition to encouraging distance work systems and, in some cases, implementing times for restricting vehicular traffic, including considering the charging of fees for entering central areas with a high concentration of activity. In addition, it is possible to make progress, as several countries have done, on the implementation of technical review systems for vehicles, training public transportation drivers to promote efficient driving and providing information to consumers by implementing labeling systems for cars and cargo vehicles.

Some countries have ambitious goals for penetration of electric vehicles in the automobile fleet. However, significant investments will be required in distribution networks and the technological improvement it achieves must reduce costs and significantly increase autonomy for this type of vehicle to attain a significant share of the ground transportation sector (especially private). Therefore, it is considered more feasible in the implementation of mass public transportation systems in major urban centers, such as metro lines, cable cars and trams.

While energy efficiency measures in transportation, as in other sectors, have been represented in as simplified way in this study, the specific analysis of an efficiency program in this sector requires a large volume of information to characterize the vehicle fleet. Said information must at the very least cover indicators such as: specific consumptions by mode of transport, kilometers traveled, passengers carried, tons displaced and usage factors, etc., both for the freight as well as passenger transport sectors. For this reason it is once again recommended that useful energy balances be developed and that this type information be monitored and collected, if possible by a centralized institution.

On the other hand, a significant share of electric power in a country's final energy consumption is an indicator not only of socioeconomic development, but also of efficiency, since electricity is the source with the highest exergy. However, there is a need to extend the analysis to the entire chain of production and consumption to examine whether the processes have been optimized in terms of efficiency and environmental purity.

In this context, it is important to make progress in the implementation of labeling programs for domestic appliances and other commonly used devices, in addition to the implementation of minimum energy performance standards, MEPS, for high-consumption devices. Where possible, it is recommended that a regional perspective be taken, with increased integration among importers associations, customs services, regulatory bodies, and quality infrastructure measurement and certification systems, encouraging the joint creation of metrology laboratories in countries whose markets do not have sufficient scale.

National energy efficiency targets must be defined in each country by the state institution with access to a holistic picture, both of the energy sector as well as the country's economic and social context. A comprehensive view of intersectoral relationships will help to ensure that all national policies contribute to energy efficiency programs. In particular, special attention should be paid to the implementation of generalized subsidies for energy sources, as they can discourage consumers' investment in technological upgrades. Though subsidy programs may be necessary in many cases - to guarantee access to modern energy services for the most disadvantaged sectors - it is recommended that they be targeted.

The quest for increased penetration by electricity or other sources in end uses traditionally supplied by fossil fuels could entail a decline in revenues for the hydrocarbons sector in a given country. The search for compensation options to mitigate the impact should not be ruled out should such situation arise. However, this is generally a fairly complicated issue. Some producing countries, for example, allocate their oil and/or natural gas to their domestic markets to promote industrial and residential uses (subsidized with regard to their opportunity costs), to the detriment of maximizing value through exports. In this case, one goal to be set would be to have larger exportable balances and the displacement of domestic hydrocarbons consumption would have a positive effect (obviously depending on the cost of alternatives).

Countries should fine-tune their specific energy efficiency and GHG emissions mitigation programs toward the achievement of goals that are consistent and in line with the reality of their available natural and economic resources. They are also responsible for the permanent monitoring of the effect of these programs in identifying the needs for reinforcement or even their reformulation.

13.2 Proposal on policies of renewable energy sources

This study's analysis shows that all of the region's countries have goals to increase the share of renewable energies in their energy planning by incorporating them in the energy mix for electric power supplies, which would represent between 20% and 85% by 2030 depending on the case, diversifying toward nonconventional renewable energies but with hydroelectric power predominating due to the availability of water resources in the region, as in 2015 it did not represent even 25% of the usable hydroelectric potential.

If the countries in the region have the will to consolidate a diversified energy mix with large proportion of renewable energies, the energy sector must be accompanied by receiving appropriate conditions that make the adequate and sustainable incorporation of renewable energies viable.

Regarding diversification of the electricity generation matrix, aimed at increased participation by renewable energy sources, aspects such as the economically recoverable potentials of each country must be taken into account, along with the firm backup energy, competitiveness of leveled costs of energy to avoid a negative effect on electricity rates and, above all, to find the most adequate financing mechanisms to cover investment costs without it having an economic impact on the country.

In fact, financing of investments is a fundamental issue. The maturity and size of the financial systems in the majority of countries in the region is deficient. There are few financial instruments available and funds are limited. Each country has different priorities toward which it focuses its investments to finance development and given the limited financing capacity that they tend to have, the allocation of resources to capital-intensive generation technologies like wind and solar power sources may not be a priority. For this reason, facilitation of financing mechanisms through international cooperation can become an essential element. The diverse green funds and the facilities provided by diverse international lending agencies are an example of this.

Another important element is the possible formulation of power purchase agreements (PPA). These mechanisms establish diverse price and quantity commitments and the guarantees that allow the cash flows involved to be determined, in that way establishing a credit rating for generation projects under this modality. To facilitate financing of renewable energy projects, having other instruments available does not cease to be important, such as: green bonds, carbon taxes, focalized subsidies, emissions permit trading and the hybrid frameworks that might emerge in a given circumstance.

In addition, to attract both the public as well as private investments needed to increase the share of renewables, stable institutional and regulatory frameworks are needed with clear rules and transparent procedures.

On the other hand, to favor the productive knock-on effect and the creation of qualified employment as part of renewable energy development projects, especially when the surpass a given scale, the incorporation of local components in the installation of said projects must be considered, not relying just on equipment imports. For this to be possible, actions must be articulated among diverse stakeholders, such as companies that supply inputs, business associations, technical training centers and universities, which dynamize the necessary capacity-building; diverse public sector areas, etc. It is recommended that roadmaps (technology roadmapping) be drafted to catalyze these types of opportunities, based on which agreements are reached and actions for development by each stakeholder are determined, with the corresponding timeline. On the governmental level, it is also recommended that a state vision be adopted, not just that of a government, so that all political actors can feel involved, which in turn facilitates the continuity of processes in the medium and long terms.

Everything indicates that traditional biomass will continue to occupy a prominent position for cooking, heating water and heating in several of the region's countries. This is why, in addition to continuing with efforts to improve access to modern energy sources for cooking, greater progress must be made in the implementation of national programs to promote the use of efficient and clean firewood-fuel stoves, with an emphasis on environmental protection, public health protection and taking families' sociocultural features into account. For their part, the programs with the highest probability of success are those which offer direct and conscious participation by their targets, are supported on the technical skills of communities, stimulate the innovative capacity of their organizations and incorporate the gender dimension in the processes of developing, designing and implementing the substitution of these technologies.

Penetration by renewable energy sources in the transportation sector's final consumption matrix is directly associated with increased use of biofuels, with the possibility to displace fossil fuels like gasoline and diesel through their increase in blends or total substitution. Increased use of biofuels must consider the agro-energy potential of each country, the technological limitations of the vehicle fleet and, above all, the formulation of adequate market policies.

Both with regard to the particular issue of biofuels, as well as the promotion of hydropower and, partially, in the case of other water uses like the cooling of thermal and nuclear power plants, there is an additional complexity that is laid bare in the enunciation of the focus Connection: Water - Energy - Food. The way in which a society manages its water, food and energy resources must consider the interdependencies and specific complexities. The idea is to simultaneously ensure the achievement of the threefold objective of energy, water and food security, which requires increased levels of coordination between subsectors of government, which in the past had been isolated from each other. The cross-linking of planning agendas entails no small challenge when it comes to managing these 3 important sectors of economic activity. To deal with this issue, in addition to expanding financing opportunities, it is recommended that greater coordination between the environmental and energy authorities be encouraged, as well as with other cross-cutting areas.

An issue has emerged in recent years that LAC has begun to consider: that of distributed generation, which consists in producing electricity using many small energy sources, usually renewable, in places that are as close as possible to charges to facilitate emissions reductions and to optimize use of the grid. If a market for the installation of small renewable electricity generators in places of consumption is created and incentivized, investment in transportation and distribution would be reduced, emissions cut, fossil fuels reduced, the energy matrix would be diversified and, to a certain point, security of supplies would improve. The presence of this issue entails dealing with a certain complexity that must be incorporated into current legislation and regulation.

Another important matter that OLADE has historically tried to promote is that of regional energy integration. While the need for countries to achieve higher levels of energy self-sufficiency has been presented as a priority objective, regional electrical integration projects can also facilitate energy efficiency as well as the increase in sustainable energies in a country, to the extent that they increase security of supply, complement sustainable energy generation and allow energy to be acquired at a lower price.

In a context in which non-managed sources and technologies are introduced and where distributed generation begins to take hold, interconnection between countries becomes an appropriate means to complement variabilities efficiently. Taking advantage of the climatic differences and the different consumption patterns according to time zones would make it possible to facilitate complementarity in the use of these sustainable energies among some of the countries in our region. Thus, the integrated use of optimization and simulation tools to analyze the dispatch of electricity, incorporating energy exchanges among countries, would make it possible to optimize the use of these sustainable sources to the detriment of thermal generation, thus turning regional electrical integration into a useful device for promoting sustainable electricity generation.

Given the tremendous changes that have occurred over recent years, the future emerges as both challenging and promising. It will depend on (i) the targets set to promote increased penetration by sustainable sources, (ii) the formulation of public policies that leverage that penetration and at the same time provide adequate instruments and regulations, (iii) the financial incentives to facilitate the creation of markets, (iv) international cooperation to develop pilot projects and to support countries' work through technical assistance, (v) participation by the private sector, increasingly attuned and aware of the need for voluntary investment in the issue, (vi) the necessary capacity-building for energy managers with knowledge required to manage state-of-the-art technologies, and (vii) increased coordination among all social actors so we can make progress, to greater or lesser degrees, toward a clean and inclusive energy future that respects the environmental limits of our planet and the material needs of our peoples. It would be desirable for studies, like the one that concludes here, to contribute to providing knowledge that facilitates achievement of these highly necessary objectives.

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Annex

Annex I. Summarized description of the SAME model

The SAME is a simulation model of technical coefficients that allows different prospective energy supply and demand scenarios to be built for a given study horizon.

It is very versatile in the projection method and is very agile in the generation of baseline, evolutionary or rupture scenarios, allowing one to simulate policies for diversifying the final consumption and energy supply matrix, greenhouse gas (GHG) emissions reduction measures and energy efficiency programs.

It provides diverse energy, economic and environmental indictors as parameters for comparison among the scenarios developed, such as the following:

a) Energy supply renewability index
b) Energy autarchy or self-sufficiency indicator
c) Average GHG emissions factor for the energy matrix as a whole
d) Average GHG emissions factor for the electricity generation matrix
e) Leveled cost of electricity
f) Structure of energy consumption
g) Structure of total energy supply
h) Structure of the electricity generation matrix
i) Projected energy balances
j) Prospective GHG emissions
k) Prospective installed electricity generation capacity and other energy supply infrastructure
l) Scope of proven fossil fuel sources of reserves
m) Degree to which potential sources of renewable energy are taken advantage of
n) Projection of energy efficiency indexes by end use of energy.

Utility of the model. -

Among other applications of the SAME model, the following can be mentioned:

- It is ideal for designing and refining sustainable energy development policies
- It allows energy forecasting studies to be updated when there are changes in assumptions or in the exogenous and endogenous situation.
- For building future exploratory scenarios that are consistent with the energy sector
- For building roadmap-style or anticipatory scenarios
- For developing national energy development, integrated as well as sectoral

Annex II. Table summarizing the NDCs of LAC countries

Subregion	Country	General Goals		RE Goals		EE Goals	
		Unconditional	Conditional	Unconditional	Conditional	Unconditional	Conditional
	Brazil	To cut greenhouse gas emissions by 37% over 2005 levels in 2025 and 43% by 2030.		Approximately 18% increase in sustainable biofuels in the energy matrix, increasing consumption of ethanol and the proportion of biodiesel in the diesel blend. 45% RE by 2030. Use of RE sources other than hydroelectric power in the total energy mix between 28% and 33 % by 2030.		EE gains in electricity sector total 10% in 2030. Promotion of new clean energy standards and improving EE measures and low carbon infrastructure even more. Promote EE measures and improve infrastructure for transportation and public transport in urban areas.	
	Mexico	Cut GHG emissions and short life climate contaminants by 25% (below BAU) by 2030. This entails a 22% reduction in GHG and a 51% cut in black carbon. The BAU is: 2020: 906 MtCO2e (792 GHG and 114 BC); 2025: 1013 MtCO2e (888 GHG and 125 BC) ;2030: 1110 MtCO2e (973 GHG and 137 BC).	Conditionally reduce up to 40%. This means GHG reductions could increase to as much as 36% and black carbon reductions to 70% in 2030. The BAU is: 2020: 906 MtCO2e (792 GHG and 114 BC) ;2025: 1013 MtCO2e (888 GHG and 125 BC) ;2030: 1110 MtCO2e (973 GHG and 137 BC).				
	Bolivia			79% participation by RE 9% participation by alternative energies and other energies (Steam Combined Cycle). Increase in electricity sector's capacity to 13,387 MW Export electricity (8,930 MW).	81% participation by RE Consolidate the 9% share of alternative and other energies (SCC). Increase in electricity sector's capacity to 10,489 MW Export electricity (8,930 MW).		
	Colombia	Reduction of GHG emissions of 20% to 2030, with respect to the BAU scenario	Reduction of GHG emissions of 20% to 2030, with respect to the BAU scenario				
Andean Region	**Ecuador**	Reduction of 20.4 to 25% compared to the BAU scenario.	Reduction of 37.5 to 45.8% compared to the BAU scenario.	Introduction of 2,828 MW of hydroelectric power.	Introduction of 4,382 MW of additional hydroelectric power capacity on top of unconditional scenario.	Introduction of 1.5 million induction stoves. Construction of Trans-Amazon Electric Train Mass replacement of incandescent light bulbs with economical lighting (CFL)	Introduction of 3.4 million induction stoves.
	Peru	Reduction of GHG emissions of 20% to 2030, with respect to the BAU scenario	Reduction of GHG emissions of 20% to 2030, with respect to the BAU scenario				
	Venezuela	Reduction of GHG emissions of 20% to 2030, with respect to the BAU scenario		Construction of two high-capacity wind farms (Paraguana and La Guajira). Implementation of the Sembrando Luz program, which allows isolated communities to receive electricity services via hybrid wind and solar power systems.			
	Argentina	Cut GHG emissions to 483 MtCO2eq in 2030 compared to BAU, which is 592 MtCO2eq.	Cut GHG emissions to 369 MtCO2eq in 2030 compared to BAU, which is 592 MtCO2eq.				
	Chile	Cut CO2e emissions by unit of GDP by 30% below 2007 levels by 2030.	Cut CO2e emissions by unit of GDP in 2030 until achieving a 35%-45% reduction over 2007 levels.	20% of the energy matrix will consist in NCRE in 2025.			
Southern Cone	**Paraguay**	10% reduction in projected emissions in 2030. BAU base year 2011: 140 MtCO2e; 2020: 232 MtCO2e; 2030: 416 MtCO2e.	10% reduction in projected emissions in 2030 on top of those in the unconditioned target.	Paraguayan National Development Plan: Increase consumption of RE by 60%. Incorporate technologies for the exploitation of new sustainable energy sources, (including solar, wind, biomass).		Paraguayan National Development Plan: Increase the efficiency of agricultural production systems.	
	Uruguay	Reduce intensity by 25% in 2030 compared to 1990 levels. Achieve an 88% reduction in absolute emissions by 2017, with 40% participation by NCRE and 55% in hydropower.	Reduce intensity by 40% in 2030 compared to 1990 levels with additional means of implementation.	Incorporation of energy storage systems for managing surplus wind power. Increase the percentage of biofuels for gasoline and gasoil blends. Introduction of private and public vehicles that can use higher fuel blends with a higher		Introduction of private and public electric and hybrid vehicles. Upgrade vehicle fleet to higher energy efficiency standards and lower emissions. Implementation of BRT corridors for metropolitan public transport.	

Central America	**Belize**	Reduction of 2.4 MtCO2eq by 2033 (National Sustainable Energy Strategy)		Reduction of per capita energy intensity by at least 30% by 2033; reduce dependence on fuel imports by 50% in 2020 using RE. 85% participation by RE in 2030.		Achieve a reduction of at least 20% in the use of conventional transportation fuel by 2030 and promote EE in the transportation sector with appropriate policies and investments.	
	Costa Rica	Absolute maximum of 9,374,000 TCO2eq net emissions in 2030, with a proposed trajectory of per capita emissions of 1.73 tons net in 2030; 1.19 tonnes net per capita in 2050 and -0.27 tonnes net per capita in 2100.		Achieve and maintain 100% renewable electricity generation by 2030. Develop NAMA proposals for cattle farming and biomass.		Creation of an integrated public transportation system where bus routes are improved, the train is expanded, and non-motorized transport is incorporated. Electric inter-urban train project.	
	El Salvador						
	Guatemala	Projected 11.2% reduction in total GHG emissions over the base year 2005 by 2030; this means that emissions in a baseline scenario of 53.85 MtCO2e, by 2030 the will be reduced to 47.81 MtCO2e by that year.	Projected 22.6% reduction in total GHG emissions over the base year 2005 by 2030; this means that emissions in a baseline scenario of 53.85 MtCO2e, by 2030 the will be reduced to 41.66 MtCO2e by that year.	80% of electricity generation will be from renewable sources in 2030. Promotion of regulations to establish tax incentives and targeted subsidies for the use of clean energy in public and private transportation.		Implementation and improvement of Transmetro system currently operating in Guatemala City. Reduced use of firewood in the country through the National Strategy for the Efficient and sustainable use of Firewood.	
	Honduras		A 15% reduction in emissions by 2030 compared to the BAU scenario. The BAU scenario for emissions is as follows: Year 2012: 18,915 Gg of CO2eq; Year 2020: 22,027 Gg of CO2eq; Year 2030: 28,922 CO2eq			For its part, through the efficient stoves NAMA, domestic firewood consumption is expected to be cut by 39%.	
	Nicaragua						
	Panama			Increase the % of electricity generation using other RE sources such as solar, wind and biomass by 30% in 2050 compared to 2014. The share of RE in the electricity matrix will be 15% by 2030. Installation of wind turbines or solar panels, with help from the private sector. Tender for the installation of 1,184.1 MW of RE, such as solar and wind, equivalent to 41.8% of the installed capacity in 2014.		Promote the use of new technologies to make improvements in energy efficiency, generation, storage, transmission and distribution. Amend and create new regulatory frameworks to promote EE.	They say that they will need international support to achieve the targets, but do not differentiate between conditional or unconditional targets.

The Caribbean	**Barbados**	Reduction in GHG emissions of 44% compared to its (BAU) scenario by 2030. This is a reduction of 23% compared with the baseline year, 2008. As an interim target, the intention will be to achieve an economy-wide reduction of 37% compared to its BAU by 2025, equivalent to an absolute reduction of 21% compared to 2008.		Contributing 65% of total peak electrical demand by 2030 with RE. Other planned measures include WTE and biomass generation plants, wind, distributed and centralized solar PV and capture and use of landfill gas for energy generation.		22% reduction in electricity consumption compared to a BAU scenario in 2029. 'Public Sector EE and Conservation Programme', implementation of applicable recommendations through the Caribbean Hotel EE and RE Action-Advanced Program, EE measures in homes and various LED lighting initiatives. 29% reduction in non-electric energy consumption including transport, compared to a BAU scenario in 2029. Investing in alternative vehicles and fuels and encouraging their adoption through tax incentives.	
	Cuba			Installation of 2,144 MW of capacity; construction of: 19 bio-electrical plants with 755 MW capacity using sugarcane and forestry sector biomass. 13 wind farms with 633 MW. 700 MW photovoltaic and, 74 Small Hydro. Installation of 200,000 m2 of solar heaters in residential and industrial sectors. Installation of solar pumps for agriculture. Use of organic waste for the production of biogas and to obtain bio-fertilizers. Handling of waste from animal production, industry and urban solid waste.	They say that they will need international support to achieve the targets, but do not differentiate between conditional or unconditional targets.	Installation of LED technology lighting with the distribution of 13 million lamps in the residential sector and 250,000 for public lighting. Replacement of 2 million electricity resistance stoves for induction stoves.	
	Grenada	Grenada commits to reducing its Greenhouse gas emissions by 30% of 2010 by 2025, with an indicative reduction of 40% of 2010 by 2030.		Grenada plans a 30% reduction in emissions through electricity production by 2025 with 10% from renewables. This is 10MW from solar, 15MW from geothermal and 2 MW from wind. Plans to construct a controlled (or capped) to collect the methane gas generated for electricity production.		30% reduction in emissions through electricity production by 2025 with 20% from EE measures. EE actions to reduce emissions include retrofitting of all buildings (20% reduction), establishment of policies for EE building codes for all building sectors (30% reduction) and implementation of EE in hotels (20% reduction).	
	Guyana			Develop a mix of wind, solar, biomass and hydropower. Construction of small hydro systems at suitable locations. Power all of the six newly established townships using RE sources. Encourage independent power producers and suppliers to construct energy farms and sell energy to the national grid. Preliminary approvals have been given for a 26MW wind farm. Encourage the use of bio-digesters to reduce waste, produce biogas and provide affordable, healthy and efficient cooking means.	Committed to eliminating our near complete dependence on fossil fuels. Given the solar, wind and hydropower potential and relatively small national demand, with adequate and timely financial support, Guyana can develop a 100% renewable power supply by 2025.	Continue to conduct energy audits and replace inefficient lighting at public, residential and commercial buildings to reduce energy consumption. Implement other policies to encourage EE and the use of RE, including building codes and net-metering of residential renewable power.	
	Haiti	Reduce emissions by 5% compared to the reference scenario for the year 2030.	Reduction of emissions by an additional 26% in relation to a reference scenario for the year 2030.	Install by 2020, an additional 37.5 MW of hydroelectricity.	Install for 2030 (4 wind farms: 50 MW, hydroelectric energy: additional 60MW, solar parks: 30 MW, biomass: 20 MW). Increase the share of renewable energy in Haiti's electricity system by 47% in 2030 (24.5% hydro, 9.4% wind, 7.5% solar biomass 5.6%).	Control, regulate the import of used vehicles.	Promote the use of EE stoves instead of traditional stoves in homes (energy gain of 25-30% per stove). Distribute one million energy-saving lamps for replacing incandescent bulbs. Improving the EE of wood-burning ovens (obtaining yields of 10 to 15% to 30-45%).
	Jamaica	BAU = 2025: 13.443 MtCO2e; 2030: 14,492 MtCO2e. Goal: 7.8% below BAU by 2030. 2025:12.370 MtCO2e; 2030: 13,368 MtCO2e.	BAU = 2025: 13.443 MtCO2e; 2030: 14,492 MtCO2e. Goal: 10% below BAU by 2030. 2025:12.099 MtCO2e; 2030: 13,043 MtCO2e.	Increase the share of renewable sources of energy in its primary energy mix to 20% by 2030.			Jamaica seeks support for the expansion of EE initiatives in the electricity and transportation sectors, in line with sector action plans and policies currently under development.
	Dominican Republic		25% reduction over base year 2010 emissions by 2030.		Through existing efforts and with funding for implementation, Suriname is keen to continue to transition its energy sector to ensure it stays above 25% renewable by 2025.	A nation-wide EE program has commenced aimed at consumer awareness and usage of energy-saving light bulbs as well as promoting EE designs for buildings.	
	Suriname			Several initiatives are already in an advanced stage such as solar energy for communities in the hinterland, a study on waste-to-energy at the national landfill, and micro-hydro power projects in the Interior. Other forms of renewable energy to be explored are wind energy as well as biomass-to-energy.			
	Trinidad & Tobago	30% reduction in GHG emissions by end of 2030 in the public transportation sector compared to BAU scenario (reference year 2013).	Additional reduction achievable under certain conditions which would bring the total GHG reduction to 15% below BAU emission levels by end of 2030.				

Annex III. Relative efficiencies in final consumption

Sector	Transportation		Industrial		Residential		Comercial and Services		Agro, fishing and mining	Construction
Source \ Technology	Conventional	Efficient	Conventional	Efficient	Conventional	Efficient	Conventional	Efficient	Conventional	Conventional
Oil	0.50		0.50							0.50
Natural gas	0.75		0.75	0.85	0.75	0.80	0.75	0.80	0.75	0.75
Coal			0.40	0.50			0.40		0.40	
Solar					1.00					
Firewood			0.20	0.40	0.15	0.30	0.20		0.20	0.20
Sugarcane products			0.30	0.50					0.30	
Other Biomass			0.30		0.30		0.30		0.30	0.30
Electricity	1.00		0.85	1.00	0.85	1.00	0.85	1.00	1.00	1.00
LPG	0.70		0.70		0.70	0.75	0.70	0.75	0.70	0.70
Gasoline	0.60	0.70	0.60		0.60		0.60		0.60	0.60
Kerosene and Jet	0.60		0.60		0.60		0.60		0.60	0.60
Diesel Oil	0.65	0.75	0.65	0.75	0.65		0.65	0.70	0.65	0.65
Fuel Oil	0.50		0.50	0.60	0.50		0.50	0.55	0.50	0.50
Gases	0.70		0.70		0.70		0.70		0.70	0.70
Coke			0.40	0.50					0.40	
Charcoal			0.25		0.25		0.25		0.25	0.25
Ethanol	0.60									
Biodiesel	0.65									
Other secondary	0.40		0.40		0.40				0.40	

Source: Intrinsic coefficients of the SAME Model - OLADE. These values have been defined in consultation with OLADE experts.

Annex IV. Energy efficiency measures and diversification of final consumption considered under the NFS.

Subregion	Transportation	Industrial	Residential	Commercial
Brazil	20% of diesel with electricity 30% of gasoline with electricity 50% of diesel with efficient diesel 60% of gasoline with efficient gasoline 20% of gasoline with ethanol 10% of diesel with biodiesel	20% of natural gas with electricity 80% of natural gas with efficient natural gas. 20% of coke with natural gas 80% electricity with efficient electricity 60% of coke with efficient coke 50% of sugarcane products with efficient sugarcane products 60% of firewood with efficient firewood 50% of firewood with natural gas	50% of firewood with LPG 20% of firewood with natural gas 50% of LPG with electricity 20% of electricity with solar 20% of natural gas with solar 20% of LPG with solar 50% electricity with efficient electricity 50% of firewood with efficient firewood 50% of natural gas with efficient natural gas. 50% of LPG with efficient LPG	20% of firewood with LPG 20% of firewood with natural gas 80% electricity with efficient electricity 80% of LPG with efficient LPG 50% of firewood with efficient firewood
Mexico	20% of diesel with electricity 30% of gasoline with electricity 50% of diesel with efficient diesel 60% of gasoline with efficient gasoline 10% of gasoline with ethanol 5% of diesel with biodiesel	20% of diesel with electricity 20% of coke with natural gas 20% of coal with natural gas 80% of natural gas with efficient natural gas. 80% electricity with efficient electricity 50% of coke with efficient coke 50% of coal with efficient coal	30% of firewood with LPG 20% of firewood with natural gas 30% of LPG with electricity 20% of natural gas with electricity 20% of electricity with solar 20% of natural gas with solar 20% of LPG with solar 80% electricity with efficient electricity 80% of natural gas with efficient natural gas. 80% of LPG with efficient LPG 50% of firewood with efficient firewood	30% of other biomass with LPG 20% of other biomass with natural gas 80% of natural gas with efficient natural gas. 80% electricity with efficient electricity 80% of LPG with efficient LPG
Central America	20% of diesel with electricity 30% of gasoline with electricity 50% of diesel with efficient diesel 60% of gasoline with efficient gasoline 10% of gasoline with ethanol 5% of diesel with biodiesel	20% of diesel with electricity 30% of firewood with LPG 30% of other biomass with LPG 80% electricity with efficient electricity 60% of firewood with efficient firewood 50% of diesel with efficient diesel	50% of firewood with LPG 20% of firewood with electricity 20% of electricity with solar 20% of LPG with solar 50% of firewood with efficient firewood 60% electricity with efficient electricity 80% of LPG with efficient LPG	30% of firewood with LPG 20% of LPG with electricity 60% electricity with efficient electricity 60% of LPG with efficient LPG
Andean Subregion	20% of diesel with electricity 30% of gasoline with electricity 50% of diesel with efficient diesel 60% of gasoline with efficient gasoline 20% of gasoline with ethanol 10% of diesel with biodiesel	20% of diesel with electricity 50% of firewood with LPG 40% of firewood with natural gas 80% electricity with efficient electricity 80% of natural gas with efficient natural gas. 80% of diesel with efficient diesel 80% of coal with efficient coal 80% of LPG with efficient LPG	50% of firewood with LPG 40% of firewood with natural gas 20% of electricity with solar 20% of natural gas with solar 20% of LPG with solar 80% electricity with efficient electricity 80% of LPG with efficient LPG 80% of natural gas with efficient natural gas. 50% of firewood with efficient firewood	80% electricity with efficient electricity
Rest the Southern Cone	20% of diesel with electricity 30% of gasoline with electricity 10% of gasoline with ethanol 20% of diesel with biodiesel 50% of diesel with efficient diesel 60% of gasoline with efficient gasoline	20% of diesel with electricity 30% of firewood with natural gas 20% of firewood with LPG 20% of other biomass with natural gas 10% of other biomass with LPG 50% of firewood with efficient firewood 80% electricity with efficient electricity 80% of natural gas with efficient natural gas. 80% of diesel with efficient diesel	30% of firewood with LPG 20% of firewood with natural gas 30% of LPG with electricity 20% of natural gas with electricity 20% of LPG with solar 20% of natural gas with solar 20% of electricity with solar 50% of firewood with efficient firewood 80% electricity with efficient electricity 80% of NG with efficient NG	80% electricity with efficient electricity 80% of natural gas with efficient natural gas.
The Caribbean	10% of diesel with electricity 16% of gasoline with electricity 6% of gasoline with ethanol 4% of diesel with biodiesel 40% of diesel with efficient diesel 50% of gasoline with efficient gasoline 5% of gasoline with ethanol 5% of diesel with biodiesel	20% of diesel with electricity 20% of fuel oil with electricity 60% electricity with efficient electricity 60% of natural gas with efficient natural gas.	50% of firewood with natural gas 50% of firewood with efficient firewood 60% electricity with efficient electricity 60% of natural gas with efficient natural gas. 20% of LPG with solar 20% of natural gas with solar 20% of electricity with solar	20% of fuel oil with natural gas 30% of firewood with natural gas 60% electricity with efficient electricity 60% of natural gas with efficient natural gas.

Annex V. CO2e emissions factors by source and activity

Source \ Activity	Electricity generation	Final consumption						
		Transportation	Industrial	Residential	Commercial	Agro, fishing and mining	Construction and others	Own consumption
Crude Oil	455	441	444				444	444
Natural gas	288	369	289	310	310	289	369	289
Coal	548		548		548	548		548
LPG	389	393	391	341	391	391	393	391
Gasoline	276	423	276	292	276	276	423	276
Kerosene and Jet	420	428	402	406	406	406	402	402
Diesel Oil	406	445	406	438	436	445	445	406
Fuel Oil	431	441	430	444	441	430	441	430
Gases	288	369	286	310	310	289	289	289
Coke	630		630			630		526

Source: SieLAC, OLADE, 2017

Annex VI. Participation of the energy sector in the total emissions of CO_2e

	Number of the National Communication	Year of the National Communication	Last recorded year of emissions	Total emissions (kt CO2e)	Net emissions (including sinks) (kt CO2e)	Emissions of the energy sector (kt CO2e)	Participation of the energy sector in the total emissions (%)
Brazil	3rd	2010	2010		1,364,197	374,554	27.5
Mexico	5th	2012	2010		748,252	503,818	67.3
Bolivia	2nd	2009	2004		85,331	10,202	12.0
Colombia	3rd	2017	2012	258,797	185,640	78,015	30.1
Ecuador	3rd	2017	2012	100,397	80,627	37,594	37.4
Peru	3rd	2016	2012	187,534	171,310	44,638	23.8
Venezuela	1st	2005	1999	192,133	177,836	143,668	74.8
Argentina	3rd	2015	2012	429,437	338,922	183,378	42.7
Chile	3rd	2016	2013	109,909	70,054	85,075	77.4
Paraguay	3rd	2016	2012	183,607	167,377	5,709	3.1
Uruguay	4th	2016	2012	38,890	36,765	8,461	21.8
Belize	3rd	2016	2009	12,921	4,143	445	3.4
Costa Rica	3rd	2014	2010	9,262	8,789	7,081	76.5
El Salvador	2nd	2013	2005	14,627	14,453	5,910	40.4
Guatemala	2nd	2016	2005	31,446	6,954	12,166	38.7
Honduras	2nd	2012	2000	66,344	13,829	4,066	29.4
Nicaragua	2nd	2011	2000	11,981	59,477	3,922	32.7
Panama	2nd	2012	2000	26,402	-1,871	4,814	18.2
Barbados	1st	2001	1997	4,056	4,045	2,027	50.0
Cuba	2nd	2015	2002	36,340	23,835	26,113	71.9
Grenada	1st	2000	1994	1,606	1,514	136	8.5
Guyana	2nd	2012	2004	3,072	-51,572	1,657	53.9
Haiti	2nd	2013	2000	6,683	7,832	1,568	20.0
Jamaica	2nd	2011	1994	116,314	166,147	8,231	7.1
Dominican Republic	2nd	2009	2000	26,433	7,639	18,247	69.0
Suriname	2nd	2016	2003	3,330	4,871	2,404	72.2
Trinidad & Tobago	2nd	2013	1990	16,006	14,510	9,928	62.0

Source: http://di.unfccc.int/detailed_data_by_party

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