GOBIERNO *de* GUATEMALA
DR. ALEJANDRO GIAMMATTEI

MINISTERIO DE ENERGÍA Y MINAS

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM

2022 - 2052

GOBIERNO de GUATEMALA
DR. ALEJANDRO GIAMMATTEI
MINISTERIO DE ENERGÍA Y MINAS

EXPANSION PLAN OF THE

GENERATION SYSTEM

2022-2052

PRESIDENT OF THE REPUBLIC
Alejandro Eduardo Giammattei Falla

VICE-PRESIDENT OF THE REPUBLIC
Cesar Guillermo Castillo Reyes

MINISTRY OF ENERGY AND MINES
MINISTER
Alberto Pimentel Mata

VICE-MINISTER OF THE ENERGY AREA
Manuel Eduardo Arita Sagastume

GENERAL DIRECTOR OF ENERGY
Edward Enrique Fuentes López

TABLE OF CONTENTS

LIST OF GRAPHICS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

LIST OF SYMBOLS

	MEASUREMENT UNITS	Magnitude
BTU	British Thermal Unit	Energy
CO_2	Carbon Dioxide	Mass
GWh	Gigawatt hour	Energy
Kg	Kilogram	Mass
kV	Kilovolt	Electric Voltage
MVA	Mega volt-ampere	Apparent Power
MW	Megawatt	Active Electric Power
TJ	Terajoule	Energy

GLOSSARY

	ACRONYMS
MEM	Ministry of Energy and Mines
UPEM	Unit of Mining Energy Planning
DGE	General Direction of Energy
DGH	General Direction of Hydrocarbons
AMM	Wholesale Market Administrator
CNEE	National Commission of Electric Energy
INDE	National Electrification Institute
EGEE	Electric Power Generation Company
AGER	Renewable Generators Association
AC	Co-generators Association
NDC's	National Determined Contributions

PRESENTATION

The Ministry of Energy and Mines of Guatemala, with the clear objectives of prioritizing renewable and clean energies, diversifying its electricity generation matrix, reducing greenhouse gases, providing security of electricity supply at competitive prices, in its fourth edition through the specialized technical body of the Ministry, the Unit of Mining Energy Planning - UPEM -, presents the Indicative Expansion Plan of the Generation System 2022-2052.

This plan performs an evaluation by means of efficient hydrothermal dispatch scenarios of the generation system with specialized programs for a 30-year horizon, through a series of premises that impact primary energy sources, such as the price of fuels and the copiousness of water seasons, considerations that in the opinion of this Ministry must be considered, especially under uncertain future conditions due to climate change.

UPEM carries out this expansion plan biannually, also considering the energy and power demand projections for the study horizon, with the objective of supplying this demand in an economically efficient manner and guaranteeing the supply of the Interconnected National System. Likewise, the projects under construction and the contributions made by the different associations of generators are considered to determine the portfolio of projects to be evaluated in the scenarios performed.

In this edition of the plan, the ten most probable scenarios in occurrence were analyzed in relation to demand growth, fuel prices and hydrology, as well as five contingency scenarios, which sought to supply demand in an optimal manner in situations in which certain capacity was lost in the generation park. Among the most probable scenarios, five of them took into consideration the fulfillment of public policies, specifically the fulfillment of 80% of renewable generation by the year 2027, derived from which a comparative analysis of investment costs, installed capacity, deficit and marginal costs can be made, for a total of fifteen scenarios.

The Ministry presents this indicative expansion plan for the generation system 2022-2052 in compliance with Article 15 Bis of the Regulations of the Wholesale Market Administrator, 25 years after the enactment of the General Law on Electricity, considering the observations of economic and technical aspects made by the National Electric Energy Commission and the Wholesale Market Administrator, and with a national vision of sector efficiency for the integral development of Guatemala.

Lic. Alberto Pimentel Mata
Minister of Energy and Mines

EXECUTIVE SUMMARY

UPEM has developed the Indicative Expansion Plan for the Generation System for a period from 2022 to 2052, which has been performed by evaluating fifteen scenarios that consider several premises, among them the Energy Policy 2013 - 2027, which seeks to comply with 80% of renewable generation by 2027, evaluated in five of these scenarios.

This Expansion Plan for the Generation System is based on article 15 BIS of the Wholesale Market Administrator's Regulations, as established by the Specialized Technical Body.

This document consists of twelve chapters and was prepared based on information provided by the different agents and participants of the electricity sub-sector, as well as governmental and private entities. The first seven chapters contain the technical and economic context of the country, analysis of the generation system, historical energy and power demand, the country's electric power generation potential, national electric coverage index, historical energy prices in present value and greenhouse gas emissions -GHG-, expressed in tons of Carbon Dioxide Equivalent (Ton CO_2e), produced by the generation park.

Chapter 8 presents the planning premises and the scenarios proposed to comply with the energy policy and the commitments acquired by the country, using the hydro-thermal optimization and dispatch software, SDDP, evaluating fifteen generation scenarios, which reveal interesting results for the electric sub-sector.

Legal and Political Basis in Guatemala

CHAPTER 1

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

1. LEGAL AND POLITICAL BASIS IN GUATEMALA

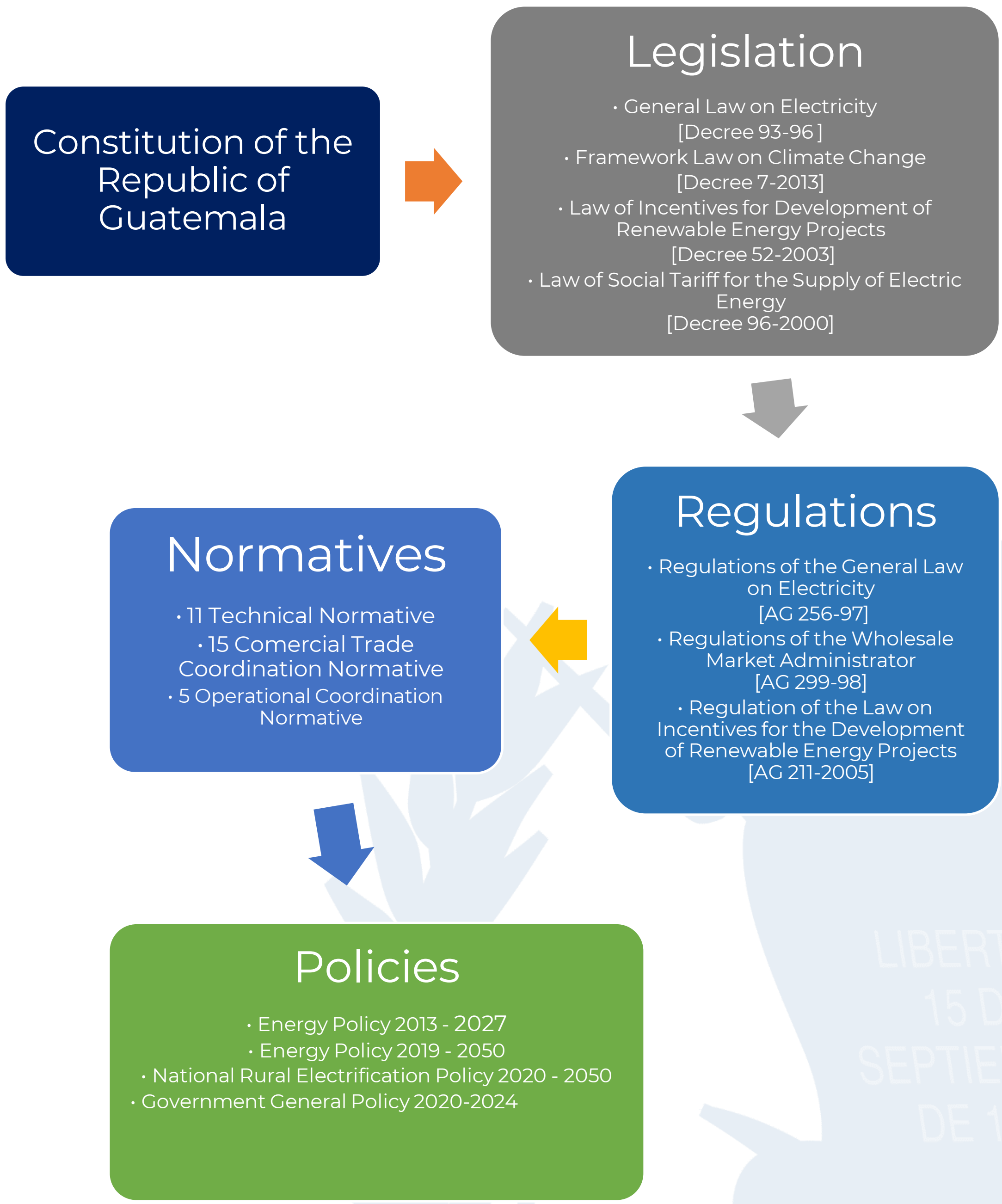
The Political Constitution of Guatemala establishes in its Article 2, Duties of the State, to guarantee to the inhabitants of the Republic, among other things, the integral development of the person. Likewise, the electrification of the country is declared of national urgency, based on the plans formulated by the State and the municipalities, in which the private initiative may participate (Article 129).
The reform of the Electric Sector in Guatemala began with the issuance of its Legal Framework established in the General Law on Electricity (Decree 93-96 of the Congress of the Republic of Guatemala) promulgated on November 15, 1996; subsequently, the Regulations of the General Law on Electricity (Agreement 256-97 of April 2, 1997) and the Regulations of the Wholesale Market Administrator -AMM- (Agreement 299-98 of June 1, 1998) were issued.

Since then, Transmission and Distribution Technical Standards, Commercial and Operational Coordination Standards and technical procedures have been issued to complement the Regulatory Framework.

1.1. LEGAL FRAMEWORK

The electric sub-sector is organized and operates under a political and legal framework composed of laws, regulations, norms and policies, the organization of which is graphically described in the following diagram:

Figure 1: Legal framework of the Electric Subsector.



Source: Ministry of Energy and Mines.

1.1.1. LEY GENERAL DE ELECTRICIDAD Y SUS REGLAMENTOS

The General Electricity on Law was approved through Decree No. 93-96 of the Congress of the Republic of Guatemala and was implemented for the development and assurance of the national electricity system.

This Law establishes the mechanisms that govern and monitor the activities of the electric power market, which is comprised of the activities of generation, commercialization, transmission, distribution, and electricity consumption.

Figure 2: Regulation of General Law on Electricity

Through Executive Order No. 256-97, the Regulation of General Law on Electricity (RLGE for its acronym in Spanish) were made official, in accordance with Article 4 of the transitory provisions of the General Law on Electricity. The purpose of the RLGE is to regulate the necessary norms for the adequate application of the General Law on Electricity.

Article 54 of these Regulations establishes the procedure for the preparation of the Expansion Plan of the Transportation System, the stakeholders involved and the submission dates.

Figure 3: Regulation of Wholesale Market Administrator.

Subsequently, the President of the Republic signs Executive Order No. 299-98, which allows the entry into force of the Regulations of the Wholesale Market Administrator (RAMM for its acronym in Spanish), in accordance with Article 38 of the RLGE, which instructs the Ministry of Energy and Mines to prepare the specific regulations governing the operation of the Wholesale Market Administrator.

Article 15 Bis of the RAMM instructs the respective procedure for the preparation of the Expansion Plan of Generation, which must be prepared every 2 years, with a minimum study horizon of 10 years; being submitted to the AMM and the Commission of Electric Energy (CNEE for its acronym in Spanish) before September 30th of each year of preparation, and officially published by the MEM before the end of the first fortnight of January of the respective year of its publication.

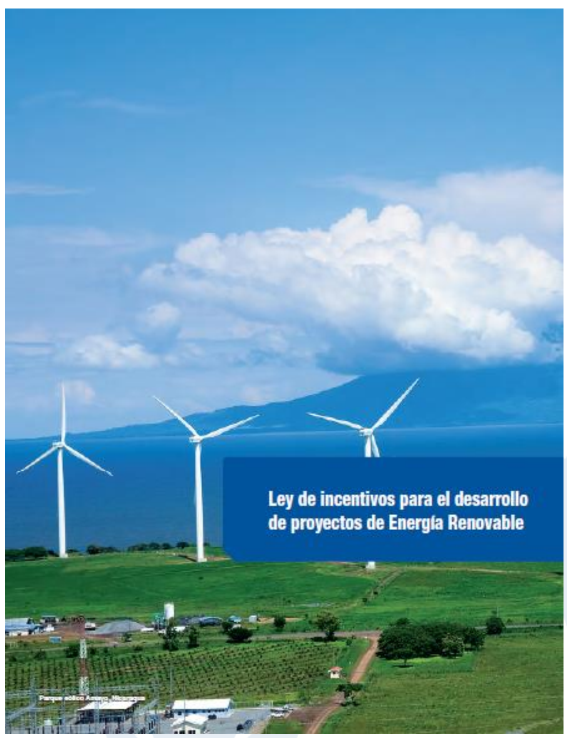
1.1.2. LAW OF INCENTIVES FOR DEVELOPMENT OF RENEWABLE ENERGY PROJECTS AND ITS REGULATIONS

The purpose of the Incentives Law (Decree No. 52-2003) is to promote the development of renewable energy projects and to establish fiscal, economic and administrative incentives for this purpose.

In which renewable energy resources are defined as those resources whose common characteristic is that they do not end or are renewable by nature. They include Solar energy, wind energy, hydro energy, geothermal energy, biomass, tidal energy, and others that are qualified by the Ministry of Energy and Mines.

It determines that Municipalities, the National Electrification Institute - INDE- for its acronym in Spanish, Mixed Companies, and individuals and legal entities that execute energy projects with renewable energy resources will benefit from the incentives established in said Law.

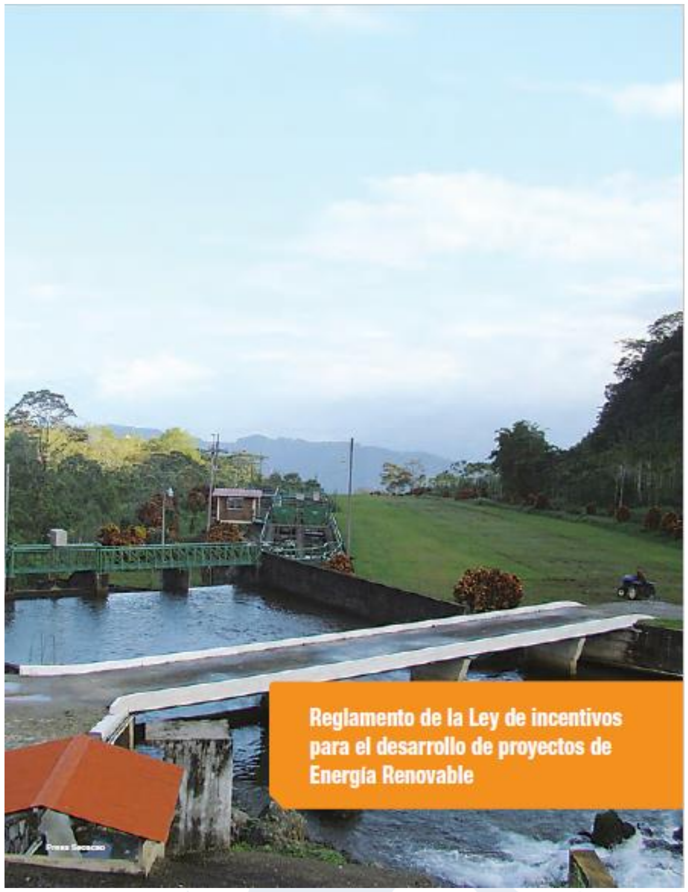
Figure 4: Cover of the Incentives Law for the development of Renewable Energy projects.



Source: Law of incentives for the development of Renewable Energy Projects, CNEE.

Likewise, the Regulations of the Incentives Law (Governmental Agreement No. 211-2005) were issued to allow the qualification and concrete application of the corresponding incentives.

Figure 5: Cover of the Regulation of the Law of Incentives for the Development of Renewable Energy Projects.



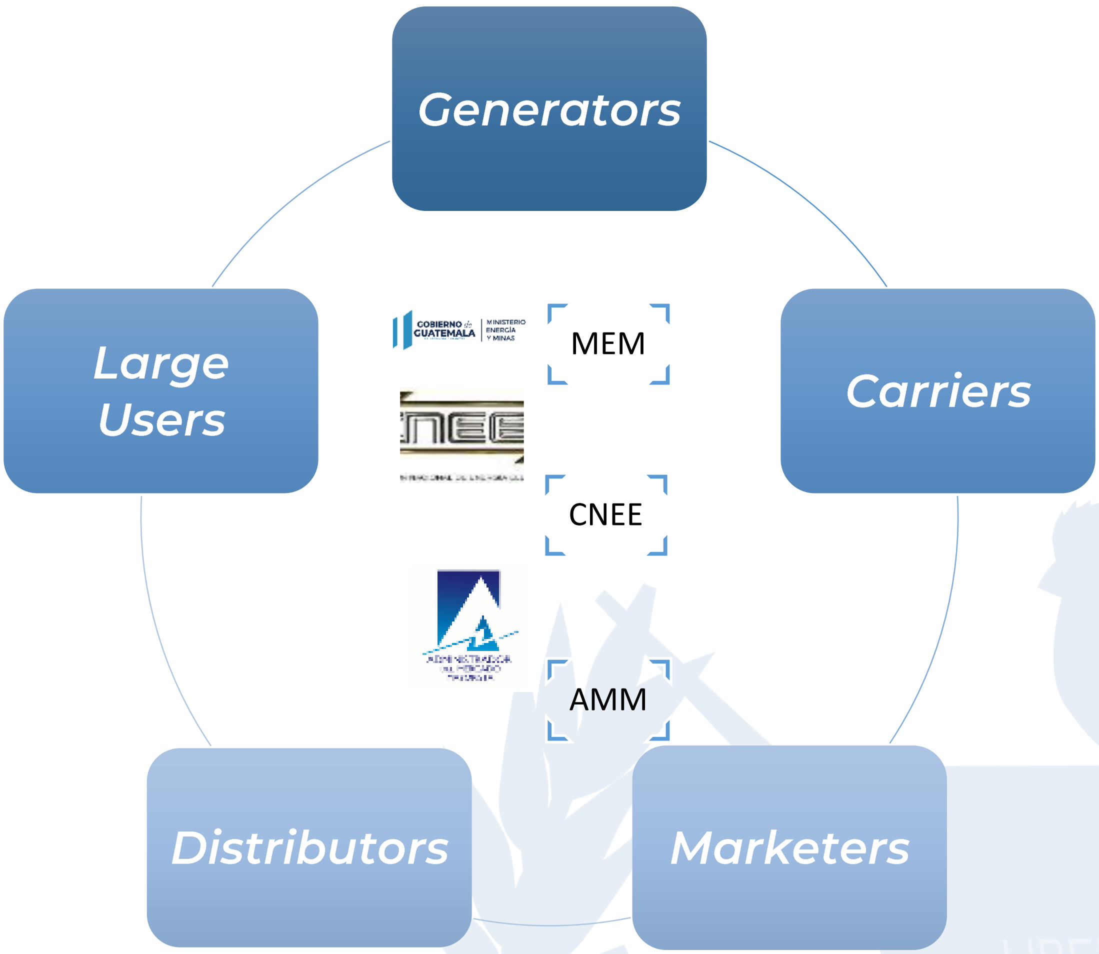
Source: Regulation of the Law of Incentives for the Development of Renewable Energy Projects, CNEE.

1.2. INSTITUTIONAL FRAMEWORK OF THE ELECTRIC SUB-SECTOR

Figure 6 shows the agents participating in the national electricity sub-sector, at the central level the Ministry of Energy and Mines, as the governing entity; the National Commission of Electric Energy, as the regulating entity; and the Wholesale Market Administrator, as the operating entity.

The following sections describe the functions of each of these entities.

Figure 6: Agents participating in the electric sub-sector.



Source: Ministry of Energy and Mines.

1.2.1. Ministry of Energy and Mines

It is the State body responsible for applying the General Electricity Law and its regulations to comply with its obligations. Likewise, it oversees setting forth and organizing the policies, state plans and indicative programs related to the electricity subsector and the hydrocarbons subsector, as well as the exploitation of mining resources.

In the electric sub-sector, the Ministry's functions include the following:

- To grant authorizations for the use of public property for the installation of generating plants and to provide electricity transmission and final distribution services.
- Preparation of socioeconomic evaluation reports, which is a prerequisite for managing the partial or total financing of rural electrification projects, from the institutions executing the projects.
- Registration and update of Large Users and Wholesale Market Agents.
- Promoting the development of renewable energy projects and qualifying renewable energy projects under the incentive law.
Perform the functions and regulations and control and supervision in electric energy assigned by law.

1.2.2. National Commission of Electric Energy [CNEE]

The National Commission of Electric Energy was created by the General Law on Electricity, contained in Decree No. 93-96 of the Congress of the Republic of Guatemala, published in the Official Gazette on November 21, 1996, as a technical body of the Ministry of Energy and Mines, with functional independence for the exercise of its attributions and the following functions described in Article 4:

- Fulfill and enforce the Law and its regulations, in matters within its competence and impose penalties on infringers, ensure compliance with the obligations of licensees and concessionaires, protect the rights of users and prevent conduct that infringes on free enterprise, as well as abusive or discriminatory practices.

- Define transmission and distribution tariffs, in accordance with the General Law on Electricity, as well as the methodology for their calculation.

- Arbitrate disputes between the agents of the electric sub-sector, acting as mediator between the parties when they have not reached an agreement.

- To issue technical standards related to the electric sub-sector and oversee compliance with them in accordance with accepted international practices, as well as to issue provisions and regulations to guarantee free access to and use of transmission lines and distribution networks, in accordance with the provisions of the law and its regulations.

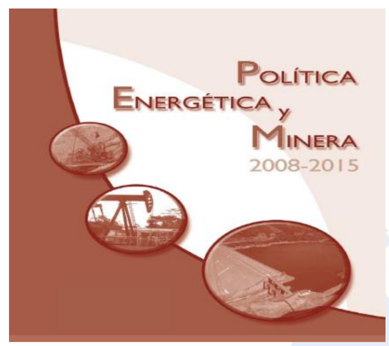
1.2.3. WHOLESALE MARKET ADMINISTRATOR [AMM]

The Wholesale Market Administrator is a private non-profit entity, which coordinates transactions between Wholesale Market participants, whose main functions are:

- The coordination of the operation of generating plants, international interconnections, and transmission lines, at the minimum cost for all wholesale market operations, within a framework of free contracting between generators, marketers, including importers and exporters, large users, and distributors.
- Establish short-term market prices for power and energy transfers between its agents when these do not correspond to freely agreed long-term contracts.
- Guarantee the security and supply of electricity in the country, as well as to create the general provisions for the operation of wholesale market agents.

1.3. POLITICAL AND SOCIO-ENVIRONMENTAL FRAMEWORK

Figure 7: Cover of the Energy and Mining Policy 2008 - 2015.



Source: Energy and Mining Policy 2008 - 2015, MEM.

The plans and policies formulated within the energy sector in general respond to the promotion of actions that seek national development with low Greenhouse Gas (GHG) emissions, thus complying with the international commitments acquired on the mitigation of climate change worldwide.

The GHG emission factors produced by the generation, transmission and distribution of electric energy within the SIN are calculated annually based on the accounting of the fuels used and the electric energy loss factors of the transmission and distribution networks.

1.3.1. ENERGY AND MINING POLICY 2008 - 2015

By means of Governmental Agreement Number 481-2007, in compliance with the provisions of the Law of the Executive Organism regarding what corresponds to the Ministry of Energy and Mines, in Council of Ministers, it was agreed: To approve the Mining Energy Policy, formulated by the Ministry of Energy and Mines.

The 2008 - 2015 energy policy was formulated because of a work process under the leadership of the Ministry of Energy and Mines, which was based on a diagnosis of the evolution of the Energy Sector over the last five years (2003 -

2007), as well as a participatory and consultative process, through several workshops with the participation of about 130 representatives related to energy matters.
The general objective of this policy was to contribute to sustainable energy development in the country, ensuring a timely, continuous and quality supply at competitive prices.

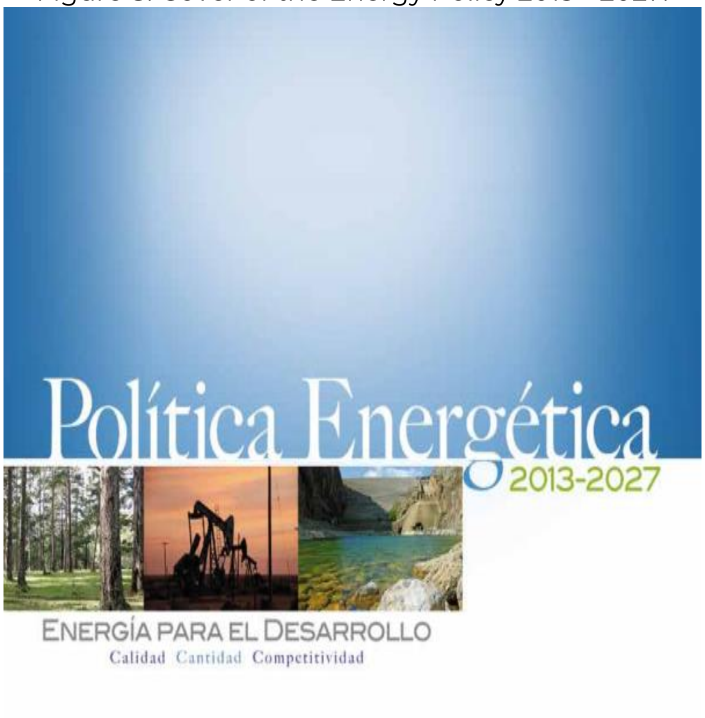
The specific objectives:

- Increase the country's energy supply at competitive prices.
- Diversify the country's energy matrix, prioritizing renewable energies.
- Promote competition and investments.
- Promote sustainable and sustainable development based on the country's renewable and non-renewable resources.
- Increase energy efficiency.
- Promote energy integration.

1.3.2. ENERGY POLICY 2013 - 2027

In response to Article 3 of the General Electricity Law, on February 15, 2013, through Governmental Agreement 80-2013, the Energy Policy 2013-2027 was made official. Its efforts are focused on strengthening the country's conditions to make it more competitive, efficient, and sustainable in the use and exploitation of resources, directed towards the conservation of national strategic reserves, the satisfaction of needs and technological development.

Figure 8: Cover of the Energy Policy 2013 - 2027.



Source: Energy Policy 2013 - 2027, MEM.

In addition, the promotion of spaces for inter-institutional dialogue that will allow for the democratic implementation of social and economic development initiatives, with the aim of guaranteeing an integral vision in their implementation, follow-up, and evaluation, as well as prioritizing the use of clean, environmentally friendly energies for national consumption.

To comply with the general objective of the Policy, the lines of intervention have been considered and detailed, which will guide the actions of the MEM and the public institutions related to the sector, these are listed below.

Figure 9: Core Concepts Energy Policy 2013 – 2027.

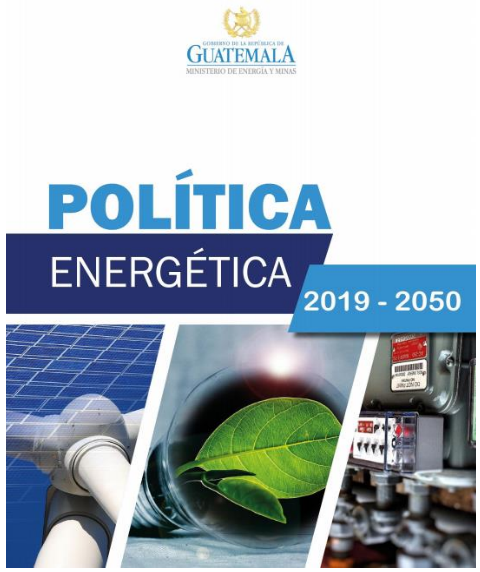
Source: Energy Policy 2013 - 2027, MEM.

For the purposes of this plan, the objectives, actions, and goals formulated within the first core concept "Electricity security supply with competitive prices", and the fourth core concept " Energy Saving and efficient use" are taken into consideration.

1.3.3. ENERGY POLICY 2019 - 2050

The Energy Policy 2019 - 2050 presents the ratification of the goals in the process of fulfillment of the energy policy 2013 - 2027, as well as the formulation of new sectorial objectives and goals to be developed by the Ministry.

Figure 10: Cover of the Energy Policy 2019 - 2050.



Source: Energy Policy 2019 - 2050, MEM.

The structure of this policy has been formulated as follows:

Table 1: Composition of consumption sectors and transversal core concepts, Energy Policy 2019 – 2050.

<table>
<tr><th>Consumer Sectors</th><th colspan="5">Transversal Core Concepts</th></tr>
<tr><td>Residential</td><td rowspan="5">Supply and end use of electricity</td><td rowspan="5">Supply and end use of fuels</td><td rowspan="5">Energy Efficiency</td><td rowspan="5">Sustainable Development</td><td rowspan="5">Firewood Consumption</td></tr>
<tr><td>Industry</td></tr>
<tr><td>Mobility and Transportation</td></tr>
<tr><td>Trade, services and Institutionality</td></tr>
<tr><td>Energy Industry</td></tr>
</table>

Source: Proprietary production, with information from Energy Policy 2019 - 2050, MEM.

It is important to emphasize that this Policy has a total of 66 actions promoted in the matrix of consumption sectors (rows) and transversal core concepts (columns).

1.3.4. Government General Policy 2020-2024

The current Government General Policy (PGG, for its acronym in Spanish) proposes five strategic pillars, which are:

1. Economy, Competitiveness and Prosperity: seeks to achieve the objective of higher economic growth and a significant increase in sustainable sources of employment.

2. Social Development: to achieve the objective of directly and effectively serving the poorest, promoting effective and focused social compensators;

3. Governance and Security in Development: seeks to improve the country's governance for a peaceful and harmonious coexistence, allowing adequate investment conditions;

4. Accountable, Transparent and Effective State: aims to effectively and transparently manage state institutions to put them at the service of citizens;

5. Relations with the World: with the purpose of ensuring that international relations are taken advantage of, so that in addition to good diplomatic relations, international trade, tourism, investment and the treatment of our migrants are improved.

Figure 11: Cover of the Government General Policy 2020 - 2024.

Source: Government General Policy 2020-2024, Government of Guatemala.

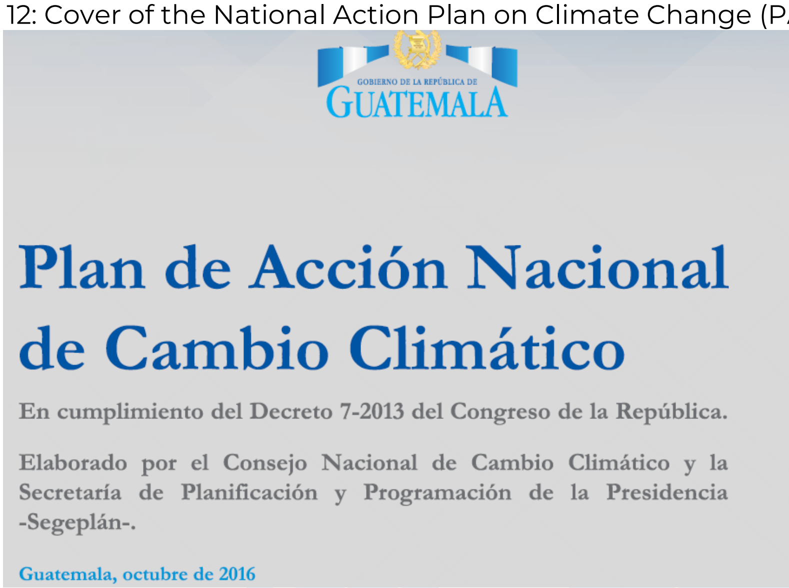
In addition to these five pillars, the PGG takes into account the environmental aspect in a cross-cutting manner to solve the problems of sustainable management of the environment, natural resources, land use planning and climate change.

1.3.5. NATIONAL ACTION PLAN ON CLIMATE CHANGE (PANCC)

During 2016, the National Council on Climate Change (CNCC for its acronym in Spanish) and the Secretariat of Planning and Programming of the Presidency of the Republic of Guatemala (SEGEPLAN for its acronym in Spanish), comply with Article 11 of the Framework Law to Regulate the Reduction of Vulnerability, Mandatory Adaptation to the Effects of Climate Change and Mitigation of Greenhouse Gases, which is endorsed by Decree 7-2013 of the Congress of the Republic; In said article, the aforementioned institutions are instructed to prepare a National Action Plan for Adaptation and Mitigation to Climate Change.

For the preparation of the Plan, each of the entities that make up the CNCC, developed the themes and lines of action concerning their portfolio of responsibilities; the Ministry of Energy and Mines was kind enough to develop the section on energy.

Figure 12: Cover of the National Action Plan on Climate Change (PANCC).



GOBIERNO DE LA REPÚBLICA DE GUATEMALA

Plan de Acción Nacional de Cambio Climático

En cumplimiento del Decreto 7-2013 del Congreso de la República.

Elaborado por el Consejo Nacional de Cambio Climático y la Secretaría de Planificación y Programación de la Presidencia -Segeplán-.

Guatemala, octubre de 2016

Source: National Action Plan on Climate Change

Within the energy section, five main topics were considered:

- Transportation
- Energy Industry.
- Manufacturing and construction industry
- Residential and commercial
- Country-level efforts

From the energy industry subsector, result 1 is taken into consideration: Carbon dioxide equivalent emissions per megawatt generated (tCO2/MW) reduced[1]. For the result indicator "MW generated with renewable and non-renewable energy", the goal "Increase the percentage of renewable energy in the electricity generation matrix" is presented.

1.3.6. AGENDA 2030 AND SUSTAINABLE DEVELOPMENT GOALS (SDGS)

The 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDGs), which was approved in September 2015 by the United Nations General Assembly, establishes a transformative vision towards economic, social and environmental sustainability of the 193 Member States, in which Guatemala belongs. Specifically in SDG 7 "Affordable and clean energy" determines that sustainable energy is an opportunity that transforms lives, economies, and the planet.

Therefore, in Guatemala, the lack of access to energy supply in some regions is an obstacle to human and economic development, which is why, if households did not have access to electricity, there would be a great backwardness in terms of development.

Taking into account the considerations indicated in SDG 7, energy can be generated in different ways, but it is advisable to responsibly and consciously use renewable resources to reduce the impacts of climate change, because if energy is generated through the burning of fuels with high carbon content, high amounts of greenhouse gases (GHG) are produced, which favor climate change and have harmful effects on the well-being of the population and the environment.

[1] National Action Plan on Climate Change, page 119.

Figure 13: Agenda 2030 and the Sustainable Development Goals, PNUD.

Source: United Nations Development Programme.

1.3.7. Plan for National Development K’atun 2032

The National Development Plan K'atun, Our Guatemala 2032, proposes a common vision of the country, with confidence in a different and better future, in which it considers improving the quality of life of the inhabitants by efficiently providing basic services, among which energy is considered, and that such services have good quality, and help contribute to the development of the country.

It is established that energy is a central component of the sustainability of the country's development over the next twenty years.

Therefore, by the year 2032, it is considered that the established actions of the State in the energy issue through government policies will be conceived in the context of comprehensive development proposals for the generation of electricity through renewable resources, is related to the social, economic and environmental dimensions of the development of sustainable livelihoods.

Figure 14: Plan for National Development K’atun 2032

Source: Secretary of Planning and Programming of the Office of the President - SEGEPLAN-.

1.3.8. NATIONAL STRATEGY FOR LOW GREENHOUSE GAS EMISSION DEVELOPMENT

The U.S. Agency for International Development -USAID-, formulated a project known as the National Low GHG Emissions Development Strategy, which has been developed with the coordination of multiple governmental organizations, with the main objective of creating multiple public policy options that contribute to GHG mitigation. During each working session, the opinions of the various actors invited to the roundtables were taken into consideration, which addressed specific topics, including the following: energy, agriculture and livestock, transportation, urban development, waste, industry and forestry.

The Strategy presents options for reducing GHG emissions in the following sectors: Energy, Transportation, Industry, Solid and Liquid Waste, Agriculture and Livestock, and Forestry and other land uses.

Table 2: GHG emission reduction options for the energy sector.

ENERGY SECTOR		
Leading Ministry	Prioritized Options	Mediated Name
Ministry of Energy and Mines (MEM)	SE-9/E-1. Permitting and siting management to increase the potential of existing hydropower plants	SE-9/E-1. Increasing the potential of existing hydropower plants
	SE-10/E-2. Extending the use of solar generation potential	SE-10/E-2. Increasing solar generation
	SE-13/E-3. Expanding the use of geothermal power generation potential and geothermal energy development	SE-13/E-3. Increasing geothermal energy generation
	SE-16/E-4. New renewable generators to support the transmission system and reduce generation losses	SE-16/E-4. Reduction of losses through renewable energy
	SE-21/E-5. Development of mini and micro hydroelectric plants	SE-21/E-5. Development of mini and micro hydroelectric plants
	RCI-7/E-6. Energy Conservation Guidelines for Existing Buildings	RCI-7/E-6. Energy Efficiency in Existing Buildings
	RCI-3/E-7. Labeling Standards for Energy-Efficient Products	RCI-3/E-7. Labeling Standards for Household Appliances
	RCI-10/E-8. Energy Audits	RCI-10/E-8. Energy Audits
	RCI-15/E-9. Use of fuel-efficient wood-burning stoves	RCI-15/E-9. Energy efficient wood stoves
	U-3. Changeover to LED technology of the street lighting system as part of a Smart City vision of the AMCG.	U-3. Changeover to LED technology of the public lighting system
	U-4. Incorporate energy efficiency parameters in the National Building Code.	U-4. Energy efficiency in new buildings

Source: National Low Greenhouse Gas Emissions Development Strategy. USAID

1.3.9. NATIONAL PLAN OF ENERGY 2017 - 2032

Figure 15: National Plan of Energy 2017 - 2032.

Source: National Plan of Energy 2017-2032, MEM.

The main objective of the National Energy Plan is to support the country's efforts to reduce greenhouse gases, promoting the use of technologies for energy efficiency and savings; prioritizing renewable energy sources in a sustainable manner to diversify the electricity generation matrix, as well as the substitution of firewood use for new energy and technological sources, to obtain benefits to improve environmental conditions by using sources with low GHG emissions.

In order to comply with the emission reduction goals, within the energy sector, the National Energy Plan proposes three strategic axes:

1. Sustainable use of natural resources.
2. Energy Efficiency and Saving.
3. Reduction of Greenhouse Gas Emissions.

The National Plan of Energy is consistent with the objectives of the Energy Policy 2013-2027, the actions and with the mitigation options prioritized by the Energy Roundtable, within the framework of the formulation process of the Low Emission Development Strategy of the USAID/Low Emission Development Project.

1.3.10. NATIONAL ENERGY EFFICIENCY PLAN 2019 - 2032

Figure 16: National Energy Efficiency Plan 2019 - 2032.

Source: National Energy Efficiency Plan 2019 - 2032, MEM.

In accordance with the fourth axis of the Energy Policy 2013 - 2027, the National Energy Efficiency Plan 2019 - 2032 is presented, which seeks to demonstrate the points of greatest energy demand within the energy consumption sectors of the country; and to identify the highest growth rates of such demand.

The avoided energy goal projected for the Plan is 69,790 TJ [Tera-Joules] for the year 2032, with respect to the baseline scenario -BAU-. This reduction represents a 15.1% reduction in the country's energy consumption.

1.4. GOALS IN THE ENERGY SECTOR

There are goals for the energy sector, which have been generated based on energy policies and plans, in accordance with the strategic axes proposed in each one of them. The goals related to the energy sector are listed below:

Table 3: Goals in the country's energy sector of the plans and policies developed.

SOURCE	GOAL	CORE CONCEPT TO WHICH IT BELONGS
National Plan of Energy 2017 - 2032	Expand geothermal energy participation by 3.34 GWh by 2032.	Core concept 1 "Sustainable Use of Natural Resources".
National Plan of Energy 2017 - 2032	Incorporation of 128.38 MW from GDR plants and Non-Conventional Plants to the energy matrix by 2032.	
National Plan of Energy 2017 - 2032	Incorporation of 12.52 MW of power for self-generation with energy surplus by 2032.	
National Plan of Energy 2017 - 2032	Reduction of 15,766,996 tons of GHG emissions from the use of firewood as energy source..	
National Plan of Energy 2017 - 2032	Participation of 4,447 units of electric vehicles in the country's vehicle fleet.	Core Concept 2 "Energy Efficiency and Savings".
National Plan of Energy 2017 - 2032	Reduction of electricity consumption in the residential sector by 18%, equivalent to 684.16 GWh by 2032.	
RURAL ELECTRIFICATION POLICY 2019 - 2032	Reach 99% national electricity coverage by 2032.	Rural Electrification
Energy Policy 2013 - 2027	Achieve 80% of electricity generation from renewable energy sources	First Core Concept “Electricity security supply with competitive prices”.
Energy Policy 2013 - 2027	Promote investment in the generation of 500 MW of renewable energy.	
Energy Policy 2013 - 2027	Increase the network by 1,500 km of transmission lines of different voltage levels that facilitate the supply of demand and allow taking advantage of renewable resources.	

Energy Policy 2013 - 2027	To reach 95% of the electricity coverage index.	
Energy Policy 2013 - 2027	Within the framework of the MER, to turn Guatemala into the regional plant that will export at least 300 MW to the region.	
Energy Policy 2013 - 2027	Take advantage of the interconnection with Mexico to import energy at competitive prices for at least 200 MW and export surplus capacity for at least 150 MW.	
Energy Policy 2013 - 2027	To make an inventory of the country's probable or potential natural gas reserves.	Second Core Concept “Security of fuel supply at competitive prices”.
Energy Policy 2013 - 2027	Having at least one natural gas storage terminal.	
Energy Policy 2013 - 2027	Promote the utilization of natural gas reserves by 25%.	Third Core Concept “Exploration and exploitation of oil reserves looking towards national self-supply”.
Energy Policy 2013 - 2027	Promote energy consumption and energy savings of 25% in the industrial and commercial sector.	Fourth Core Concept “Energy Saving and efficient use.”
Energy Policy 2013 - 2027	Increase the country's energy forests by 10%.	Fifth Core Concept “Reduction of firewood use in the country.”
ENERGY EFFICIENCY NATIONAL PLAN 2019-2032	30% efficiency reduction in Utilities {Electricity, Diesel, LPG, Gasoline}.	This plan comes in fulfillment of what is described in the energy policy 2013 - 2027, indicated in one of the actions of the fourth core concept "Saving and efficient use of energy".
Energy Efficiency National Plan 2019-2032	25% efficiency reduction in Industry {Electricity, Diesel, LPG, Gasoline}.	
Energy Efficiency National Plan 2019-2032	30% efficiency reduction in Commerce and Services {Electricity, Diesel, LPG, Gasoline}.	
Energy Efficiency National Plan 2019-2032	2% efficiency reduction in Transportation {Electricity, Diesel, LPG, Firewood}.	
Energy Efficiency National Plan 2019-2032	18% efficiency reduction in Residential {Electricity, LPG, Firewood}.	

Source: Policies and Plans MEM.

Macroeconomic Context

CHAPTER 2

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

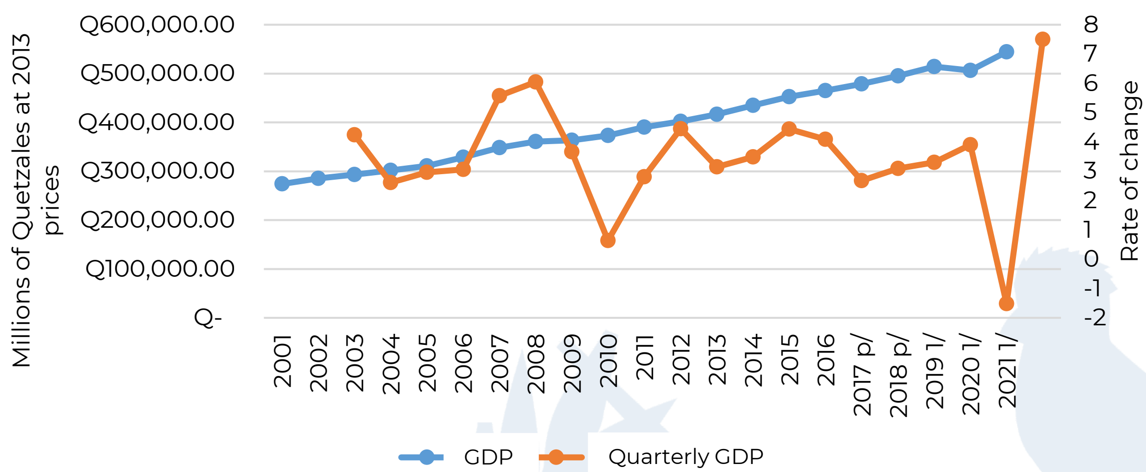
2. MACROECONOMIC CONTEXT

Guatemala has made progress in macroeconomic stability and democratic consolidation after a bloody 36-year war. Since the signing of the Peace Accords in 1996, it has also improved its access to foreign markets through various trade agreements. Guatemala's economic production and circulation activities are heavily concentrated in agriculture, commerce, and services.

2.1. GROSS DOMESTIC PRODUCT

According to the Bank of Guatemala, for the year 2021, taking as a reference the price of the quetzal in 2013, the estimated GDP was 544,485 million quetzals, with a growth of 7.5% over the previous year. This increase was due to the reactivation after the covid-19 pandemic.

Graph 1: Gross domestic product, at 2013 prices.

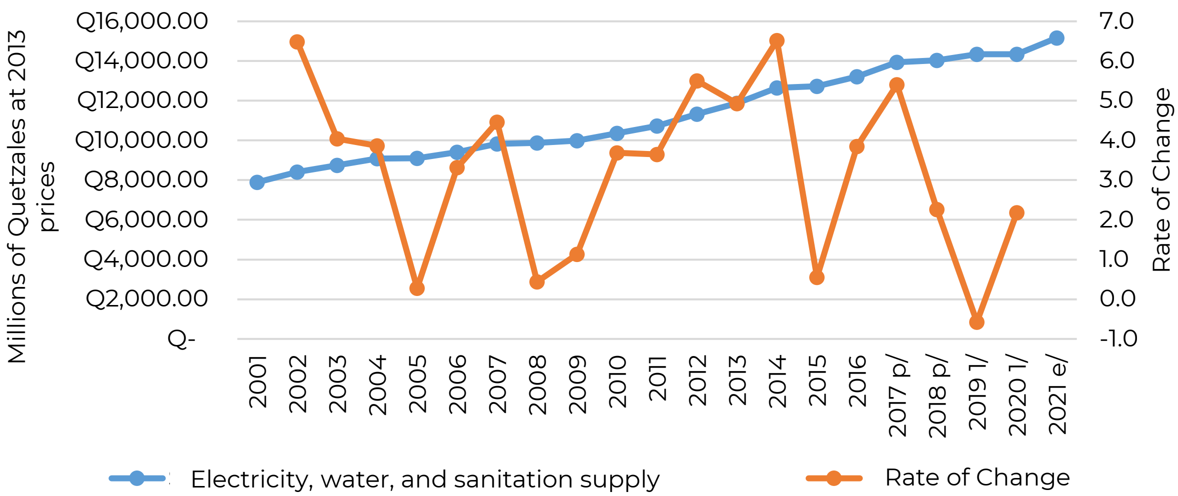


P/ Preliminary data
1/ Preliminary data not harmonized with the annual accounts.
*/ Data from 2001 to 2012 are spliced.

Source: Proprietary production with information from Bank of Guatemala, www.banguat.gob.gt.

When analyzing the GDP by production activity, the growth of the electricity and water supply sector, for 2021, had a value of 15,167.10 million quetzals, at 2013 prices. This behavior is shown in the following graph.

Graph 2: GDP at 2013 prices, of the electricity and water supply sector.



p/ Preliminary data

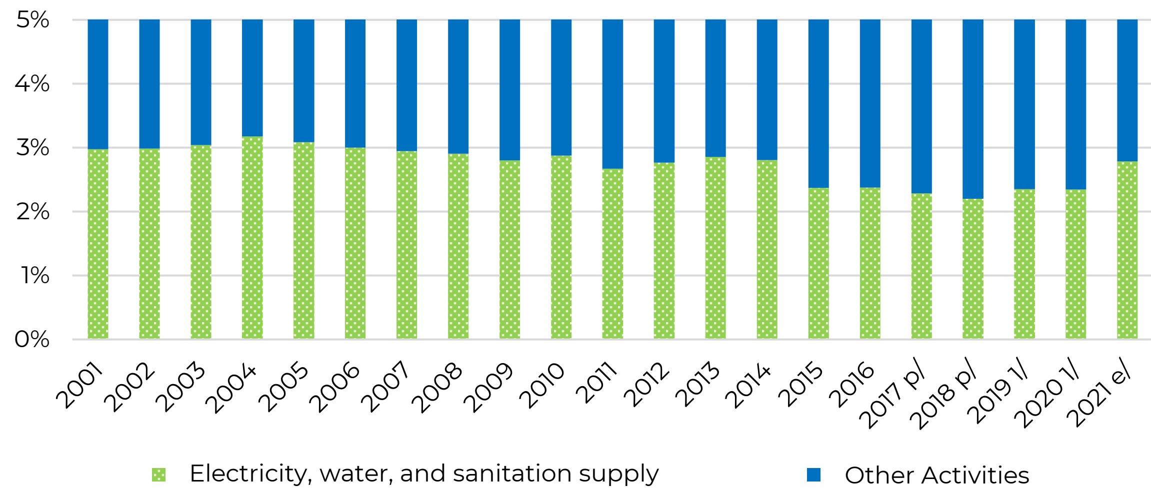
1/ Preliminary data not harmonized with the annual accounts.

*/ Data from 2001 to 2012 are spliced.

Source: Proprietary production with information from Bank of Guatemala, www.banguat.gob.gt.

The participation of this sector in the overall GDP of the nation decreased slightly in 2021, with respect to the previous year, to 0.23%, considering the GDP at 2013 prices, as shown in the following graph.

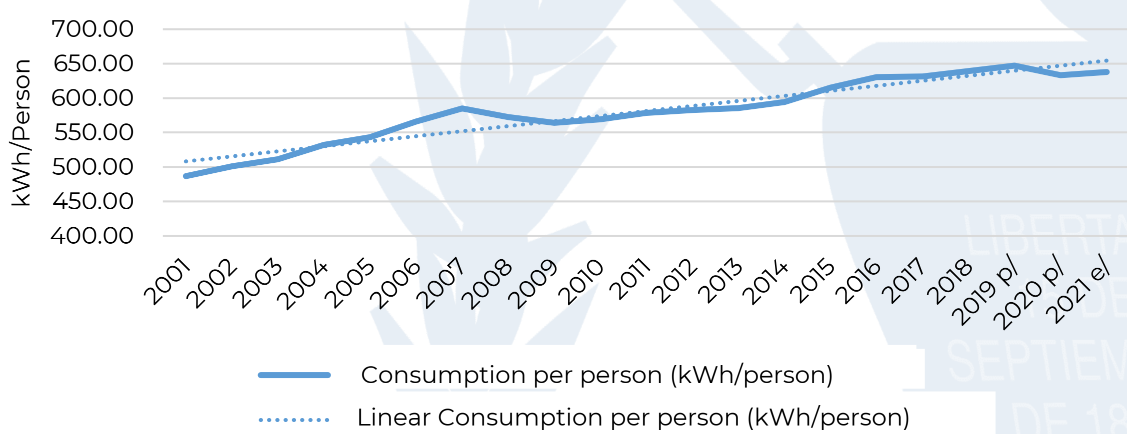
Graph 3: Percentage participation in Guatemala's GDP.



p/ Preliminary data
1/ Preliminary data not harmonized with the annual accounts.
*/ Data from 2001 to 2012 are spliced

Source: Proprietary production with information from Bank of Guatemala, www.banguat.gob.gt.

Graph 4: Net electricity consumption per capita (annual).

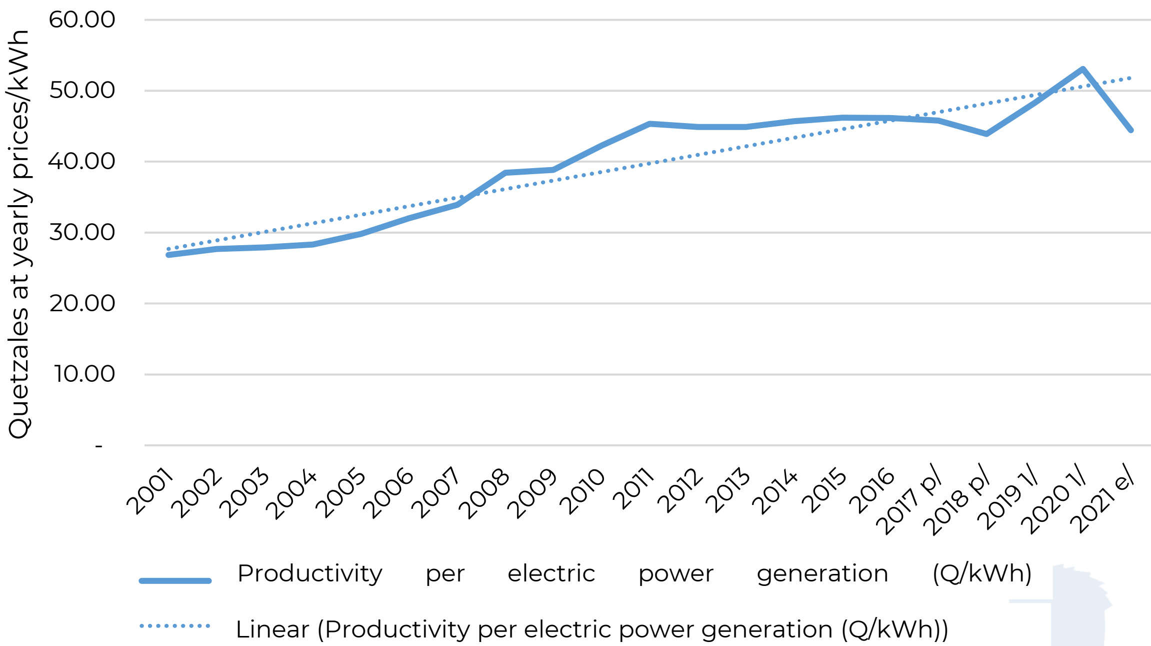


p/ CEPAL Projection
Source: AMM, INE, MEM.

The estimate of electricity consumption per person, Graph 4, is an annual indicator resulting from relating electricity demand to the population of Guatemala, which has been growing steadily since 2001.

For 2021, there was a slight decrease compared to the previous year, but the estimated per capita electricity consumption in that year is 637.75 kWh/person.

Graph 5: Productivity per electric power generation.



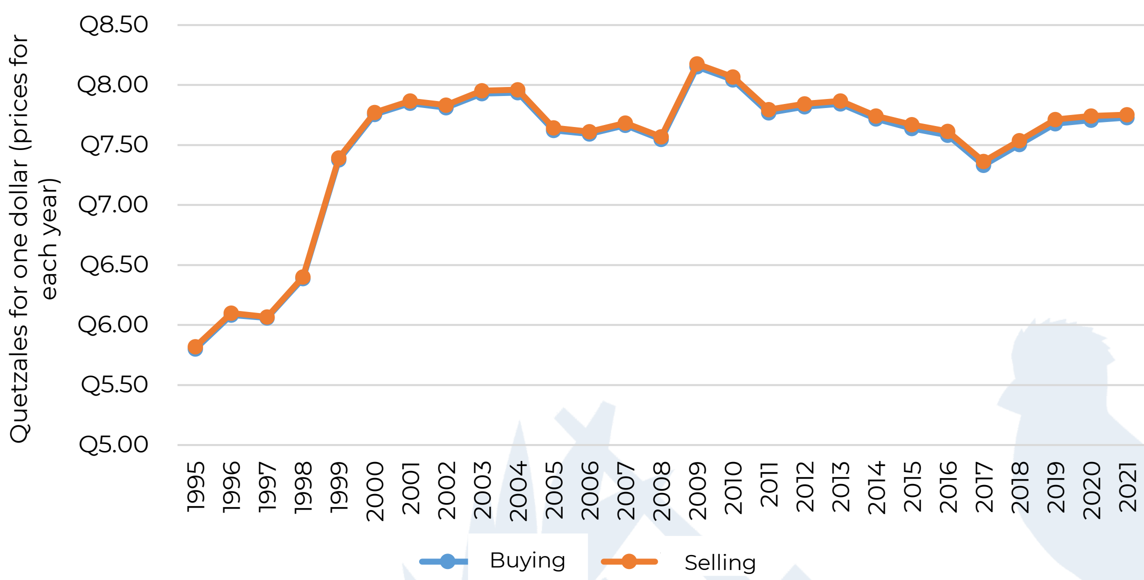
Source: AMM, BANGUAT, MEM.

Electricity generation productivity estimates the participation in the gross domestic product in constant currency, at 2013 prices, of each kWh generated in the country, with an estimated 44.43 quetzals per kWh for 2021.

2.2. EXCHANGE RATE

Graph 6 shows the behavior of the exchange rate of the quetzal against the dollar, and it can be seen that it has remained at stable levels, except for the period 2008 to 2009 due to the global economic crisis. Recently the devaluation of the dollar in 2017 involved the monetary and fiscal policy adopted by the United States; however, considering the interests of the Guatemalan export sector, the Bank of Guatemala adopted monetary and exchange policies that allowed stabilizing the exchange rate around 7.5 quetzales for each dollar purchased in 2018 (exchange rate in current currency), for the year 2021 the purchase price of the dollar was on average 7.75 quetzales, which represents an increase of Q0.03 in the price of the year 2021.

Graph 6: Exchange rate of the Quetzal against the dollar (Period 1995-2021), at nominal values.



Source: Bank of Guatemala, www.banguat.gob.gt.

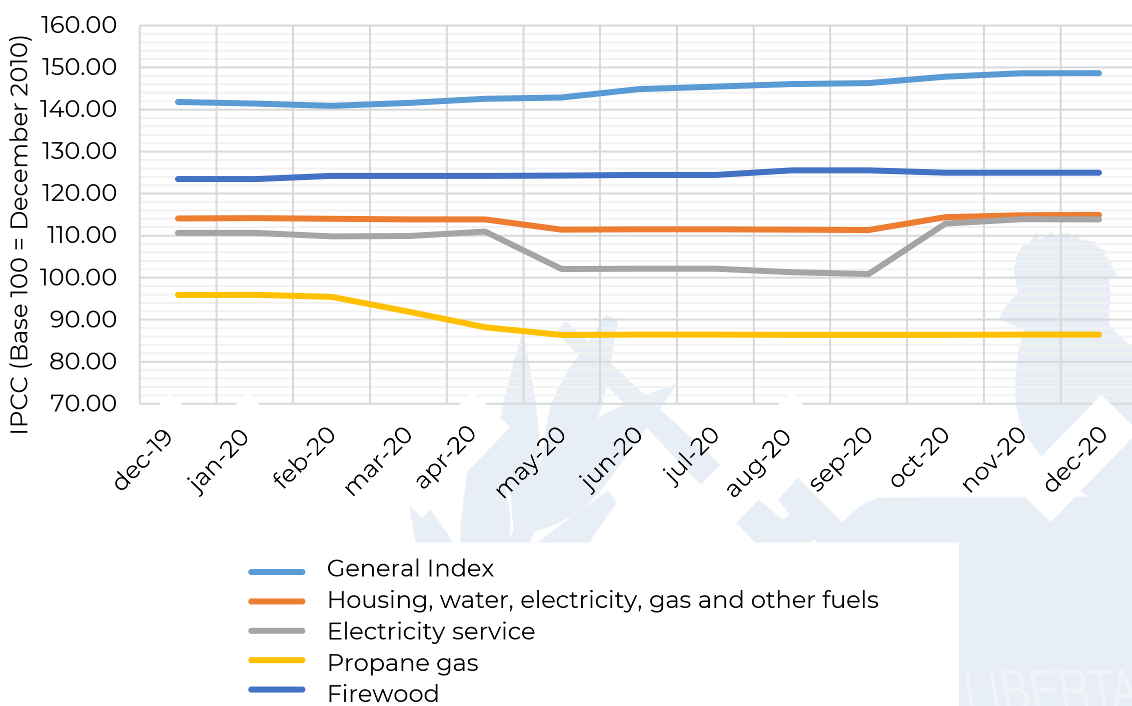
2.3. CONSUMER PRICE INDEX -IPC-

The National Institute of Statistics publishes the IPC (for its acronym in Spanish) monthly with base 100 taken as a reference in December 2010. Up to December 2020, in general, there was a growth of 7.18 points compared to January 2020. In the subsector of electricity, gas and other fuels, the growth was 0.77 points.

In the electricity sub-sector, the growth of the electricity tariff is lower than the general inflationary growth, therefore, a reduction in the tariff is still being obtained when considering constant currency.

The following graph shows how the IPC has behaved from December 2019 to December 2020 for electricity, gas, and other fuels. It can be noticeably observed, how the consumer price index in electricity service, decreased in the period from May to September 2020.

Graph 7: Consumer price index for electricity, gas, and other fuels 2020.



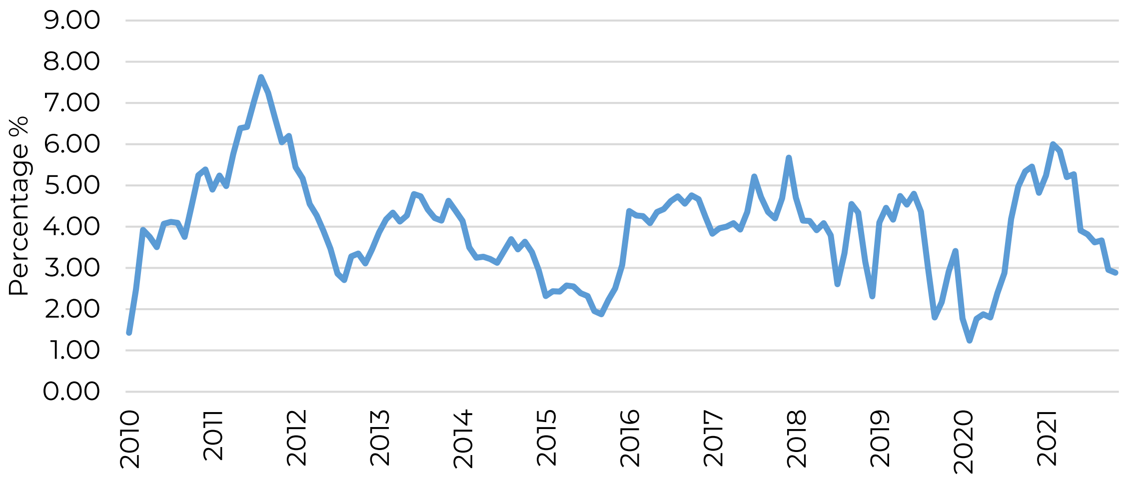
Source: According to INE data, www.ine.gob.gt.

2.4. INFLATION

According to the consumer price index -IPC-, the National Institute of Statistics calculates the percentage of inter-annual variation, which is known as inflation. This calculation is made taking as a base December 2010 = 100.

The maximum year-on-year percentage change, in the period 2017 to 2021, was recorded in February of the latter year, with a value of 6%.

Graph 8: Year-on-year inflation 2010 - 2021.



Source: Proprietary production with data published by BANGUAT.

Table 4: Year-on-year inflation, period 2017- 2021.

	2017	2018	2019	2020	2021
January	3.83	4.71	4.10	1.78	5.24
February	3.96	4.15	4.46	1.24	6.00
March	4.00	4.14	4.17	1.77	5.84
April	4.09	3.92	4.75	1.88	5.20
May	3.93	4.09	4.54	1.80	5.17
June	4.36	3.79	4.80	2.39	3.91
July	5.22	2.61	4.37	2.88	3.82
August	4.72	3.36	3.01	4.19	3.62
September	4.36	4.55	1.80	4.97	3.67
October	4.20	4.34	2.17	5.34	2.96
November	4.69	3.15	2.92	5.46	2.89
December	5.68	2.31	3.41	4.82	

Source: Proprietary production with data published by BANGUAT.

2.5. ELECTRICITY BILL COST HISTORY

- INDE - 1997

According to information in the files of the National Electrification Institute -INDE-, dated July 1997, regarding the tariffs for the electric energy service, which were applied to all its direct users; the GENERAL USE RATE WITHOUT DEMAND CHARGE (ITG-2) (REGULATED), was applicable to all INDE services that used single or three-phase energy for any use, with consumption of less than 300 kWh per month, whose connected load did not exceed 11 kW and which did not have more than 1HP in each motor or device controlled by a single switch.

Table 5: Tariff structure (ITG2) (REGULATED), -INDE- 1,997.

Q6.52	For the first 10 kWh
Q0.470	Per kWh, for the remaining kWh consumed.

Source: Proprietary production by the authors with data from INDE.

In addition to the tariff structure, additional concepts were applied for the final calculation, these were:

Minimum charge: As of January 1,998, the minimum charge was equivalent to 28 kWh calculated with the cuts of the structure of this tariff.

Charge for Fluctuating or intermittent equipment: If the consumer's installation included these characteristics, an additional charge of Q5.00 per KVA of rated capacity, or for any other data that reveals it, was made.

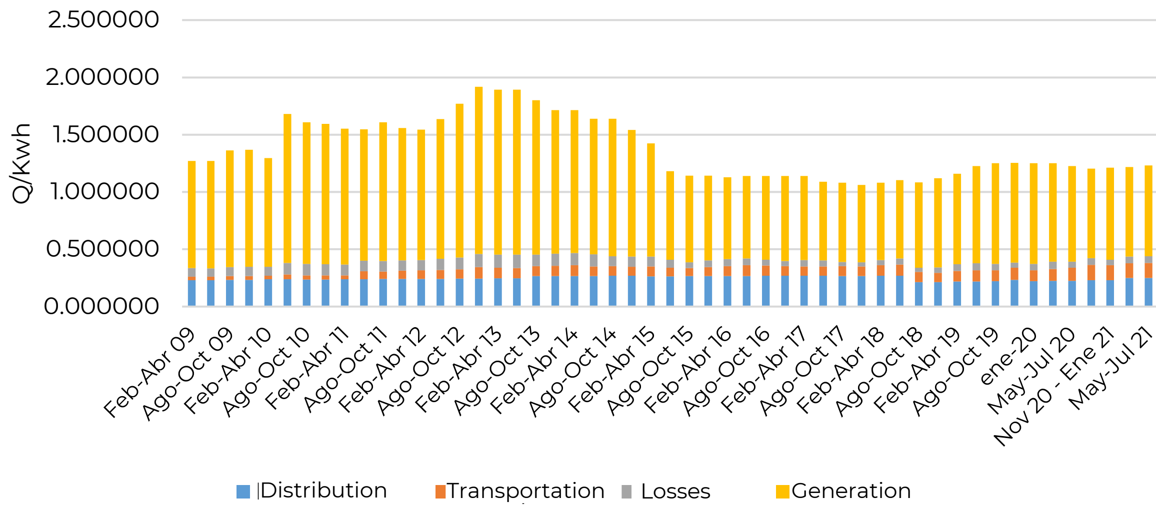
Discount sliding factors (FIT-3) (TRANSITIONAL): users with monthly consumption of up to 150 kWh enjoyed a direct discount through the application of the FIT-3 factor, which was applied until December 1997.

HISTORICAL TARIFFS BY DISTRIBUTOR 2009 - JULY 2021

Energy prices in Guatemala are defined according to the voltage and distribution power level received by the end user. Additionally, tariffs for end users connected to the distribution network are divided into social and non-social tariffs, which vary according to the monthly consumption of the end user.

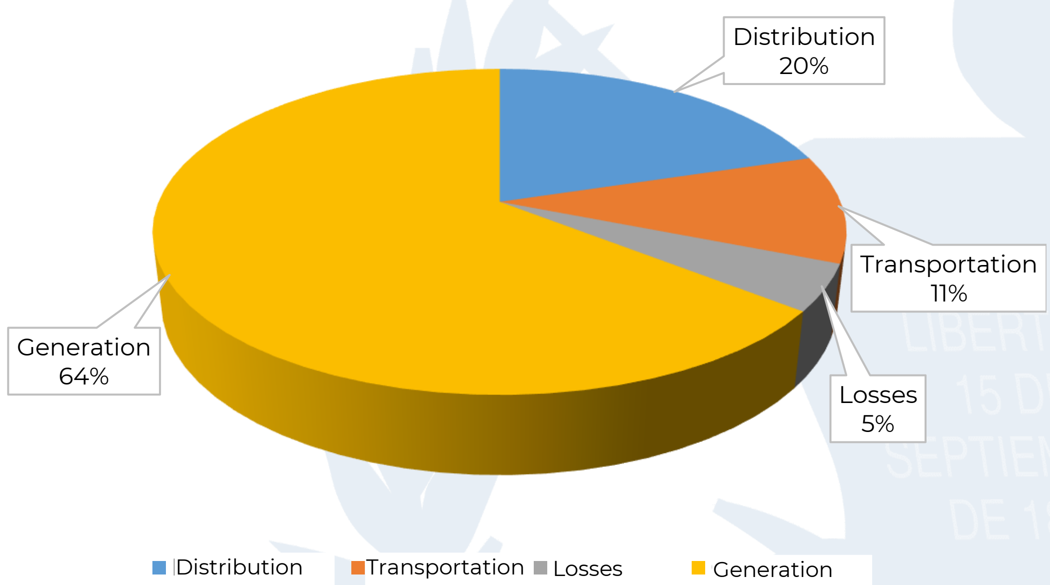
The following graphs show the breakdown of the social tariff -TS-, by price of Distribution, Transportation, Losses, and Generation, of the three most representative distributors in the country, which are EEGSA, DEOCSA and DEORSA:

Graph 9: Disaggregation of the price of the Social Tariff -TS- EEGSA.



Source: Proprietary production with CNEE data.

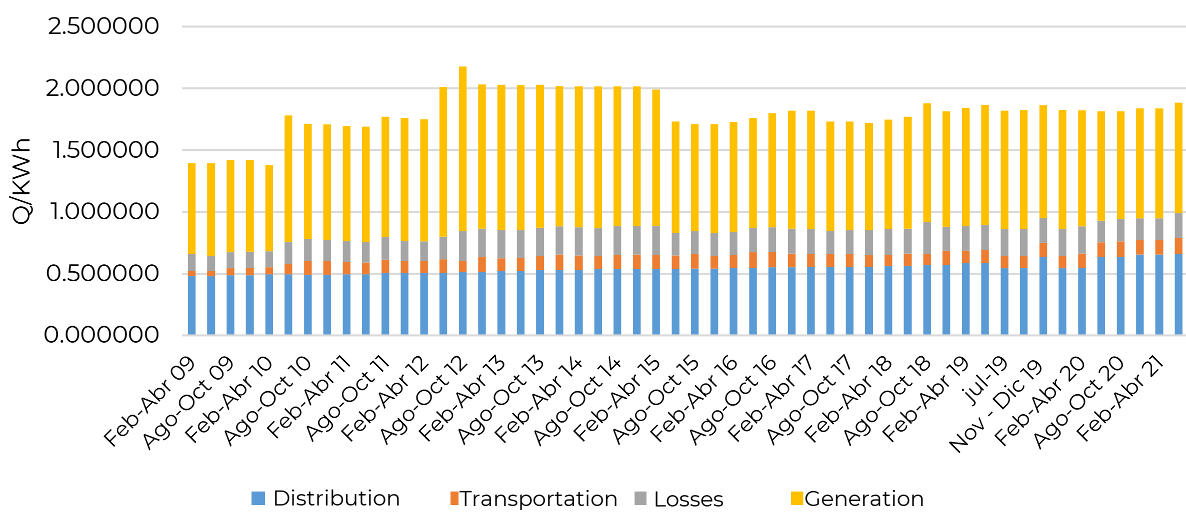
Graph 10: Distribution of the price of the Social Tariff -TS- EEGSA, in the period May-Jul 21.



Source: Proprietary production with data from the CNEE.

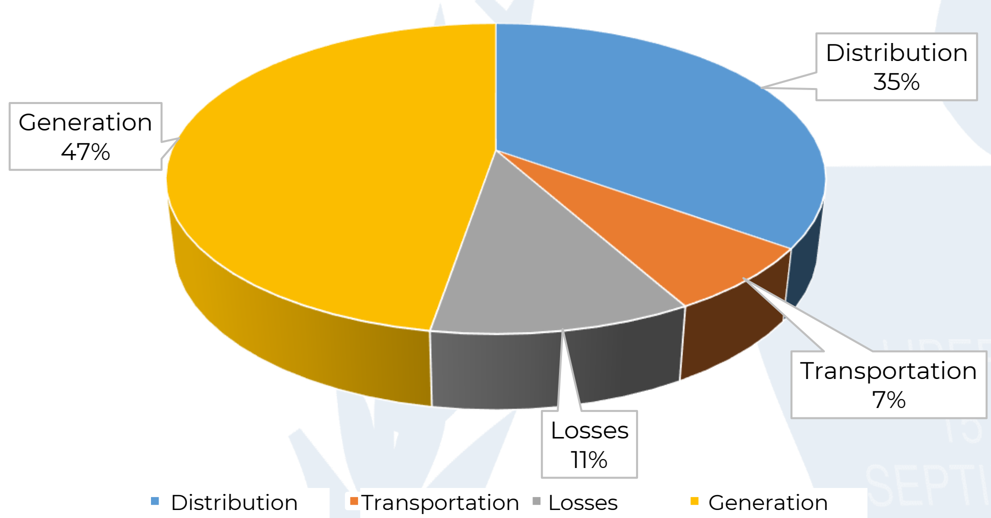
For the last period, May to July 2021, the price of the social tariff of the distribution company EEGSA, suffered a slight increase of 1.23% with respect to the previous period, reflecting a price in the current period of Q1.232760/KWh, of which most corresponds to Generation (64%) and only 5% corresponds to losses.

Graph 11: Disaggregation of the price of the Social Tariff -TS - DEOCSA.



Source: Proprietary production with data from CNEE.

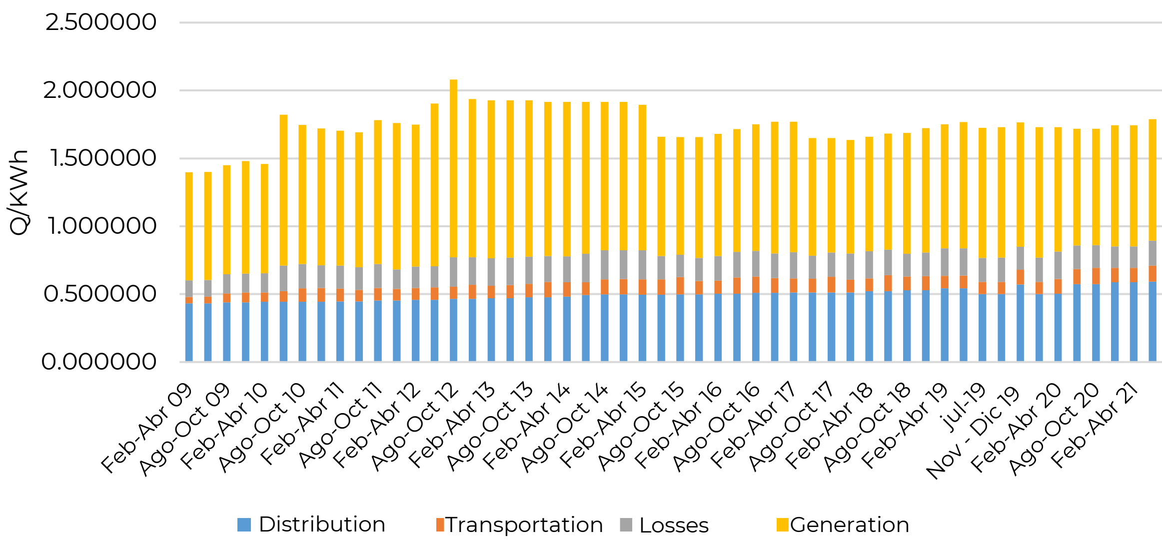
Graph 12: Distribution of the price of the Social Tariff -TS- DEOCSA, May-Jul 21.



Source: Proprietary production with data from CNEE.

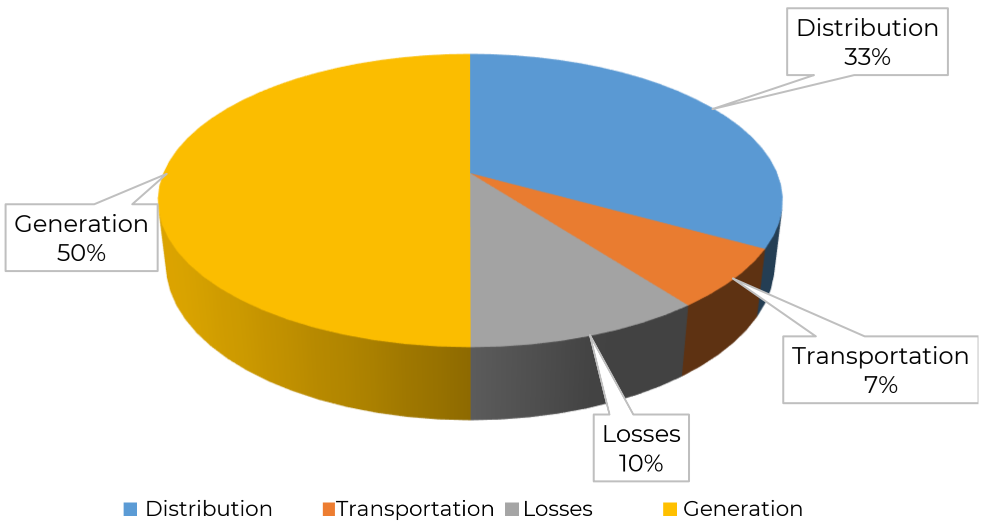
For the present period, the price of the Social Tariff of the distributor DEOCSA, presented a slight increase of 2.50% with respect to the price in the previous period, being for this period Q1.884034/kWh; of this price, 47% corresponds to generation, 35% to distribution and the rest corresponds to losses and transportation.

Graph 13: Disaggregation of the price of the Social Tariff -TS- DEORSA.



Source: Proprietary production with data from CNEE.

Graph 14: Distribution of the price of the Social Tariff -TS- DEORSA, May-Jul 21.



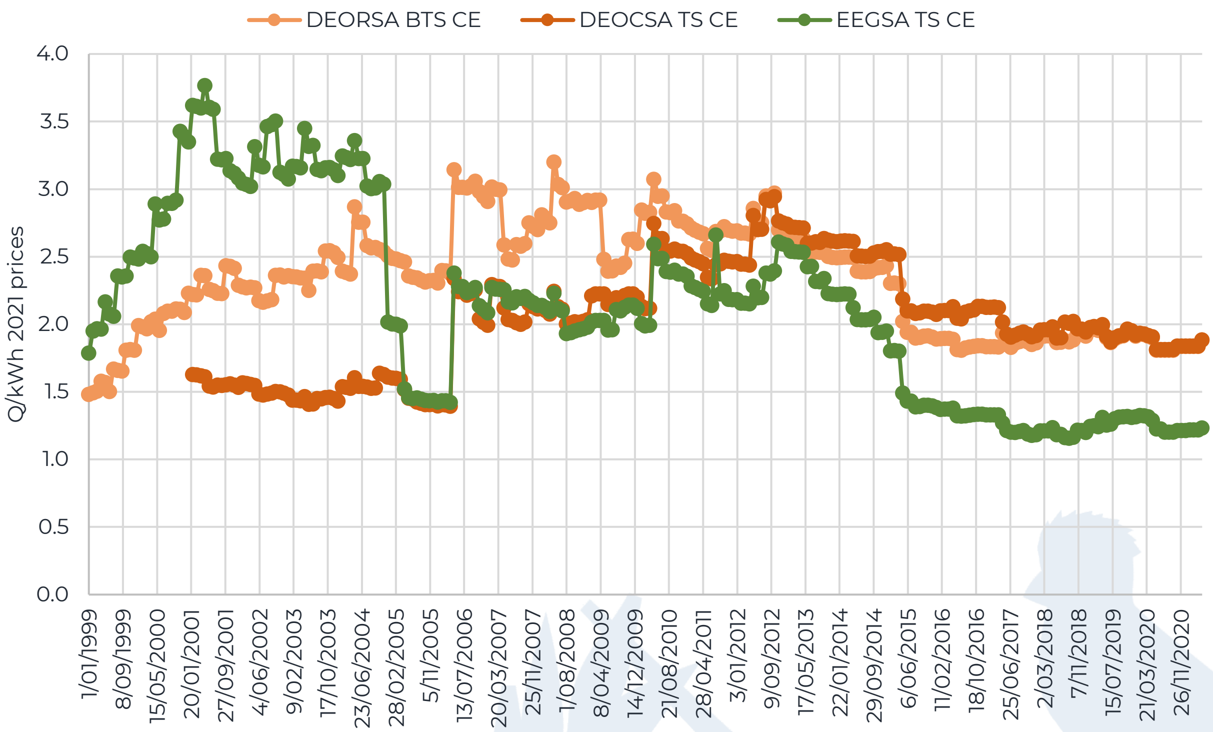
Source: Proprietary production with data from CNEE

The distribution company DEORSA, for the period from May to July 2021, has a social tariff price of Q1.789772, which is 2.64% higher than that of the previous period; of this price, 50% corresponds to generation, 33% to distribution and the rest to losses and transportation.

HISTORICAL TARIFFS, AT 2021 PRICES, BY DISTRIBUTION COMPANY

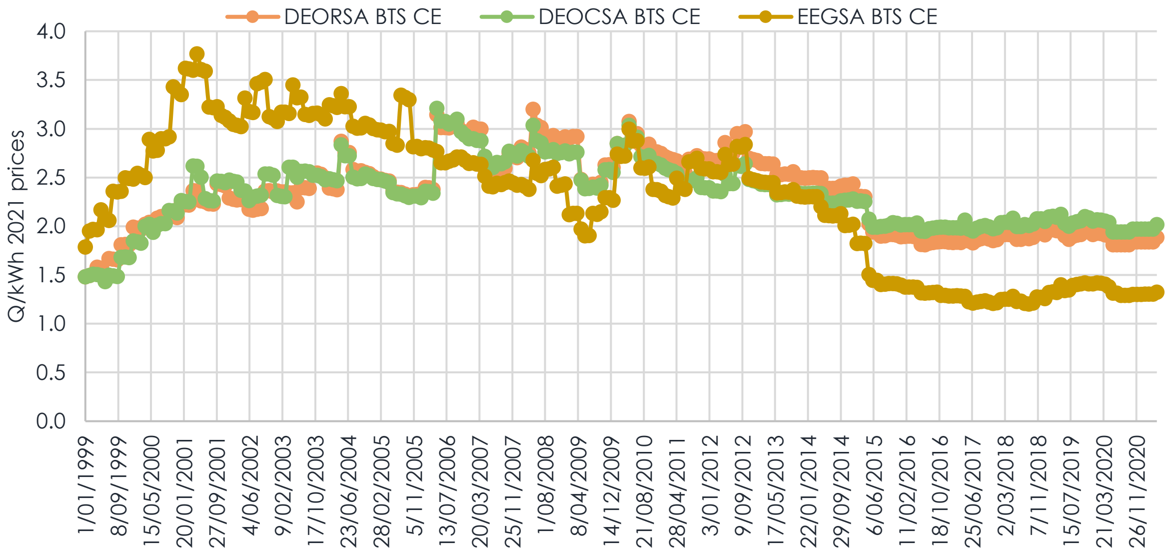
The behavior of the evolution of the social and non-social tariffs by distribution company is shown below. These prices have been converted to present value in order to obtain a reference parameter that allows price comparisons with previous years.

Graph 15: Evolution of the Social Tariff at constant values.



Source: Unit of Mining Energy Planning, MEM.

Graph 16: Evolution of the Non-Social Tariff at constant values.



Source: Unit of Mining Energy Planning, MEM.

Graph 15 represents the evolution of the Social Tariff for the three largest electricity distributors operating in the country; when analyzing the prices for each one by transferring their amounts to the net present value, it is observed that it has tended to decrease from 2012 to the present.

Graph 16 represents the evolution of the cost of the Non-Social Tariff transferred to the net present value, as in the Social Tariff, a significant decrease in the overall amount for each distributor is observed; this continues to be an important benefit for electricity consumers with values lower than 300 kWh/month.

Socioeconomic Characteristics

CHAPTER 3

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

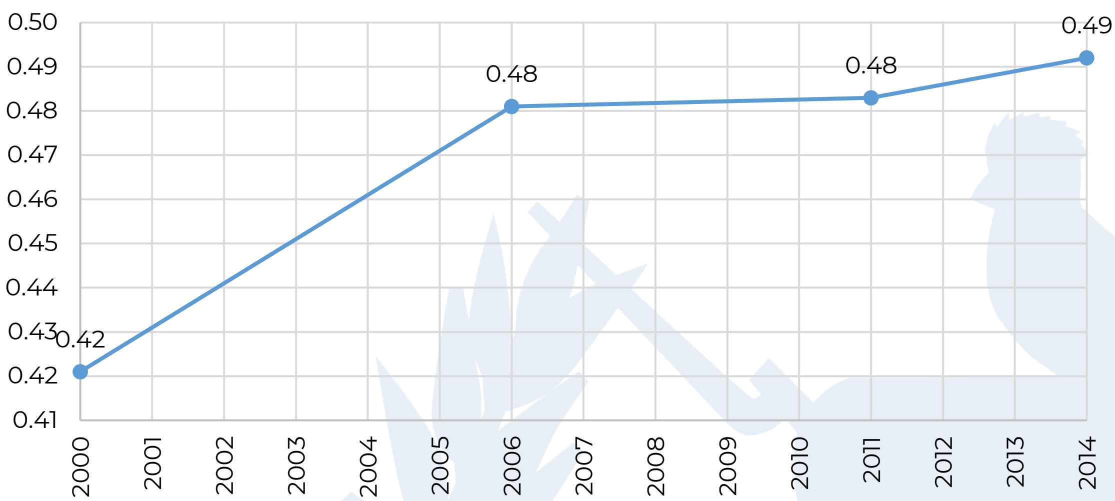
3. SOCIOECONOMIC CHARACTERISTICS

Based on the estimate and projection of the 2018 National Census, there are 16 million 858 thousand 333 inhabitants in Guatemala, for which there is a GDP per capita of Q30,036.66, with GDP at 2013 prices; below are more details on the socioeconomic characteristics that describe the national context.

3.1. HUMAN DEVELOPMENT INDEX

The human development index is defined within three basic dimensions: health, education and income. It is based on measuring development in terms of increased opportunities for human development. For Guatemala, the Human Development Index increased by 17% from 2000 to 2014, however, from 2011 to 2014 it increased by only 2%, the largest increase is between 2000 and 2006 with an increase of approximately 14%. The evolution of the human development index can be seen in Graph 17.

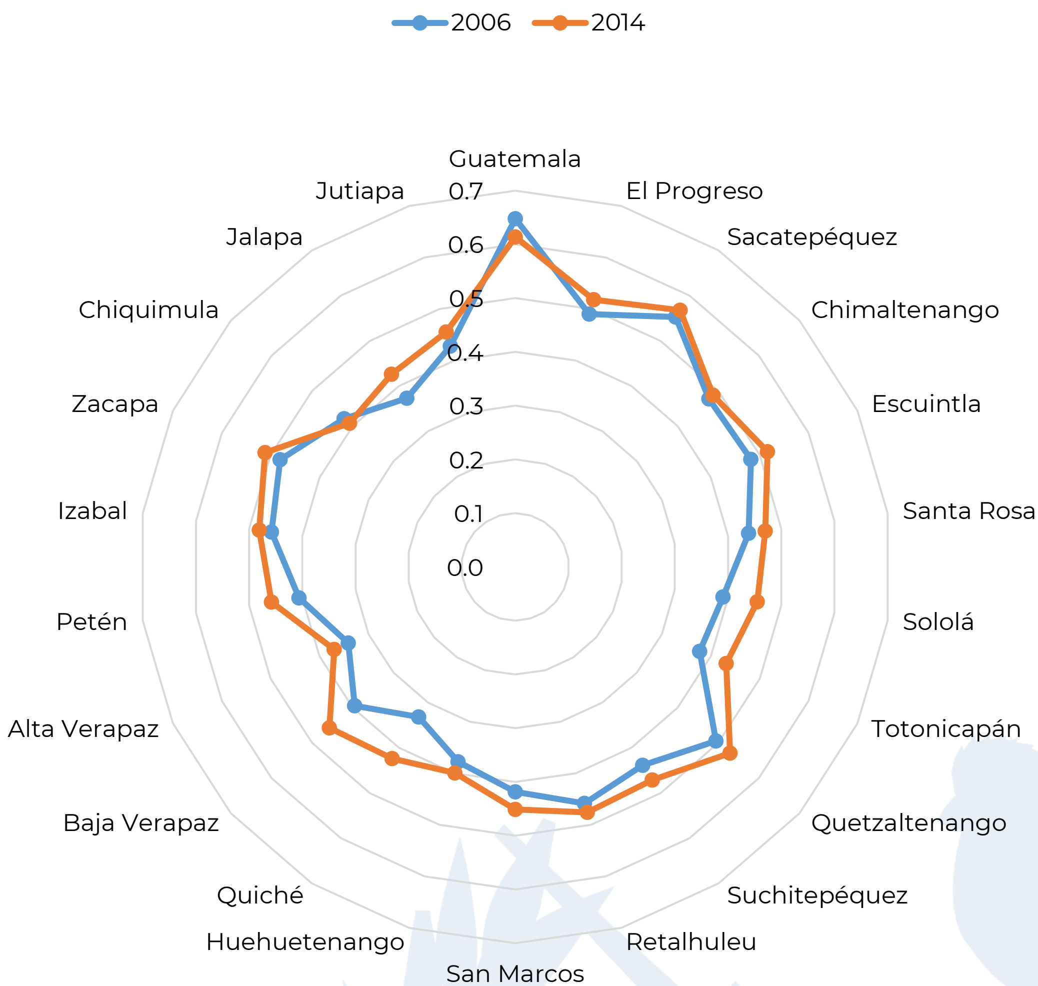
Graph 17: Human Development Index.



Source: National Human Development Report Guatemala, PNUD.

Graph 18 shows the human development indexes broken down by department for 2006 and 2014. This graph shows the evolution of the HDI of each department, it can be seen that Guatemala is the department with the highest HDI for both 2006 and 2014, on the other extreme for 2014 Alta Verapaz has the lowest Human Development Index.

Graph 18: Departmental Human Development Index.



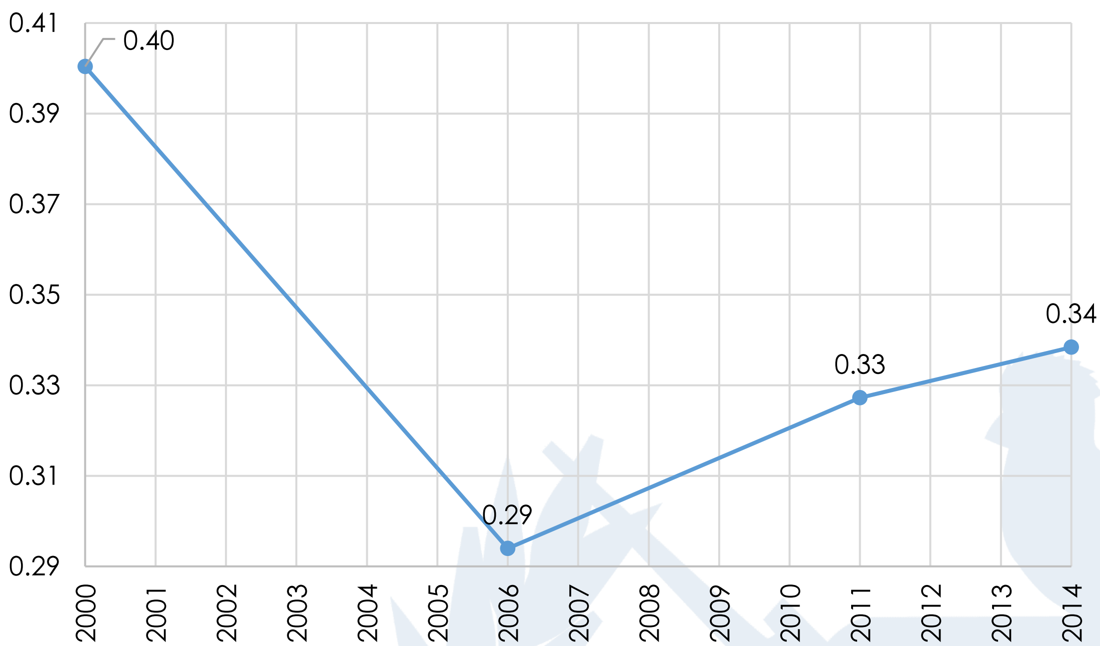
Source: National Human Development Report Guatemala, PNUD.

3.2. MULTIDIMENSIONAL POVERTY INDEX

The multidimensional poverty index is an indicator developed by the United Nations Development Program. This index reflects poverty conditions composed of different aspects, weighted according to their impact on people's quality of life. This index is a composite of 10 parameters: Years of Schooling, Children in School, Infant Mortality, Nutrition, Electricity, Sanitation, Drinking Water, Soil, Household Fuel and Assets. Lack of access to electricity supply contributes 0.055 to the multidimensional poverty index.

Graph 19 shows the development of Guatemala's multidimensional poverty index, the last estimate presented a country MPI of 0.338.

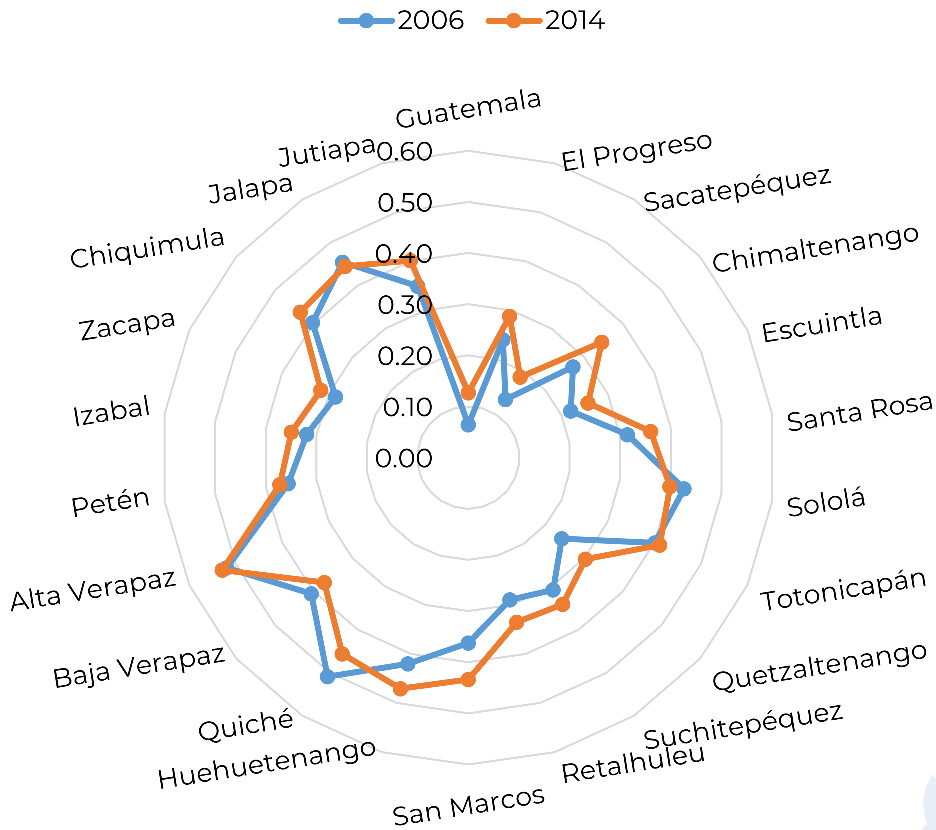
Graph 19: Multidimensional poverty index.



Source: National Human Development Report Guatemala, PNUD.

Graph 20 shows the Multidimensional Poverty Indexes for each department, from which it can be quickly inferred that the Department of Guatemala has the lowest index (0.127) while Alta Verapaz has the highest multidimensional poverty index (0.529).

Graph 20: Multidimensional poverty index by department.



Source: National Human Development Report Guatemala, PNUD.

In general, access to electricity has a cross-cutting influence on the basic dimensions of a country's human development. Access to electricity supply allows for nearby hospital facilities, access to sanitation and water services, technological access in education applications, and economic development, facilitating improved productivity and therefore improved income and job opportunities. The above shows the importance of access to electricity service in the quality of life of the country's inhabitants and the need to provide access to electricity to the nation's inhabitants.

3.3. ACCESS TO ELECTRICITY

The management of electrification projects developed in the country and the opening of the electricity market have contributed to achieve an increase in the electricity coverage index, however, there is still a significant gap to overcome. For the year 2021, an electrification index of 89.26% has been calculated, it is determined that 10.74% of households in the country still do not have access to the electricity network. The departments with the lowest electricity coverage index are Alta Verapaz (50.89%), Petén (74.70%), Baja Verapaz (78.34%), Quiché (80.46%), Chiquimula (81.73%), Huehuetenango (82.69%); departments for which new infrastructure investment has been analyzed.

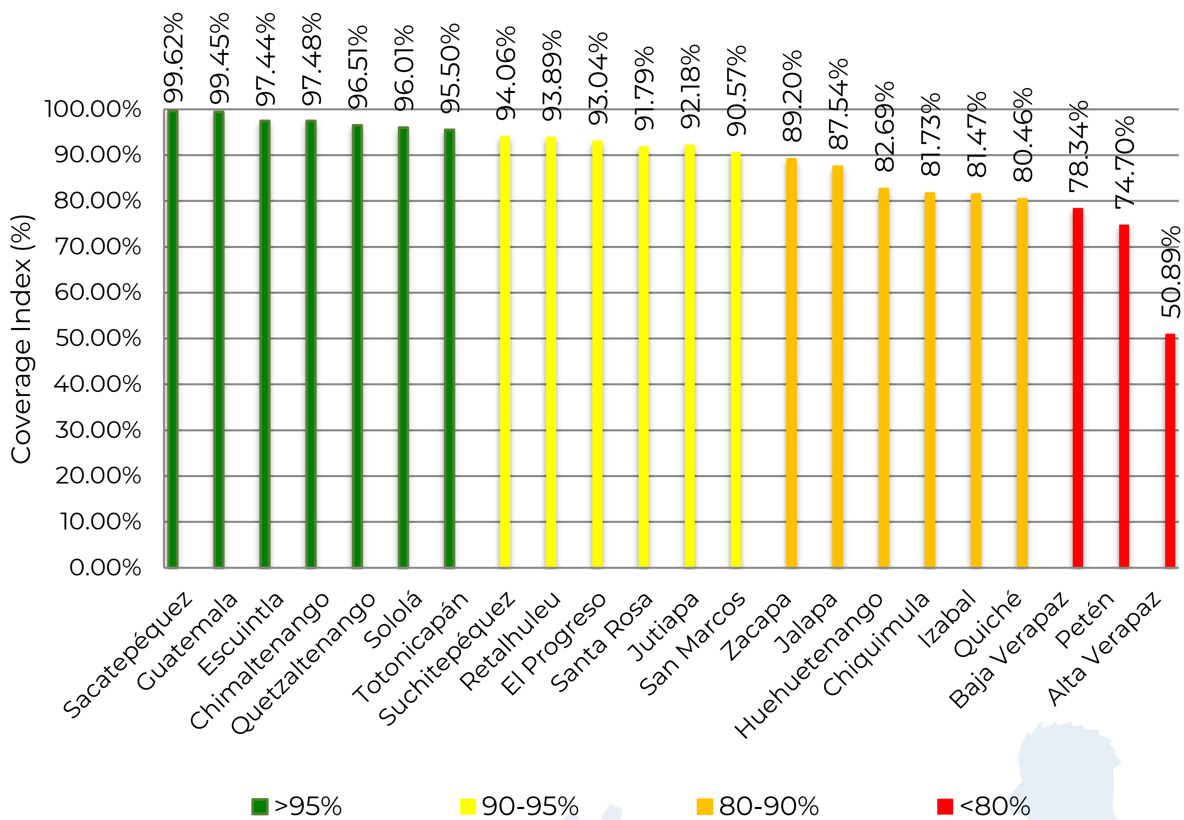
Table 6: Electricity coverage index by department as of 2021.

DEPARTMENT	HOUSEHOLDS 2021	HOUSEHOLDS WITHOUT COVERAGE ELECTRICITY 2021	ELECTRICITY COVERAGE INDEX 2021
Sacatepéquez	91,365	223	99.62%
Guatemala	882,350	4,598	99.45%
Chimaltenango	147,786	4,344	97.48%
Escuintla	195,215	5,085	97.44%
Quetzaltenango	190,808	7,158	96.51%
Sololá	91,204	4,004	96.01%
Totonicapán	86,659	4,208	95.50%
Suchitepéquez	128,628	8,237	94.06%
Retalhuleu	79,428	5,101	93.89%
El Progreso	44,915	3,409	93.04%
Jutiapa	119,645	10,509	92.18%
Santa Rosa	100,816	9,096	91.79%
San Marcos	211,477	21,991	90.57%
Zacapa	58,338	7,524	89.20%
Jalapa	74,652	10,608	87.54%
Huehuetenango	219,596	46,393	82.69%
Chiquimula	79,624	17,797	81.73%
Quiché	154,548	35,992	81.47%
Izabal	82,355	20,037	80.46%
Baja Verapaz	57,658	16,300	78.34%
Petén	104,120	33,985	74.70%
Alta Verapaz	125,759	123,096	50.89%

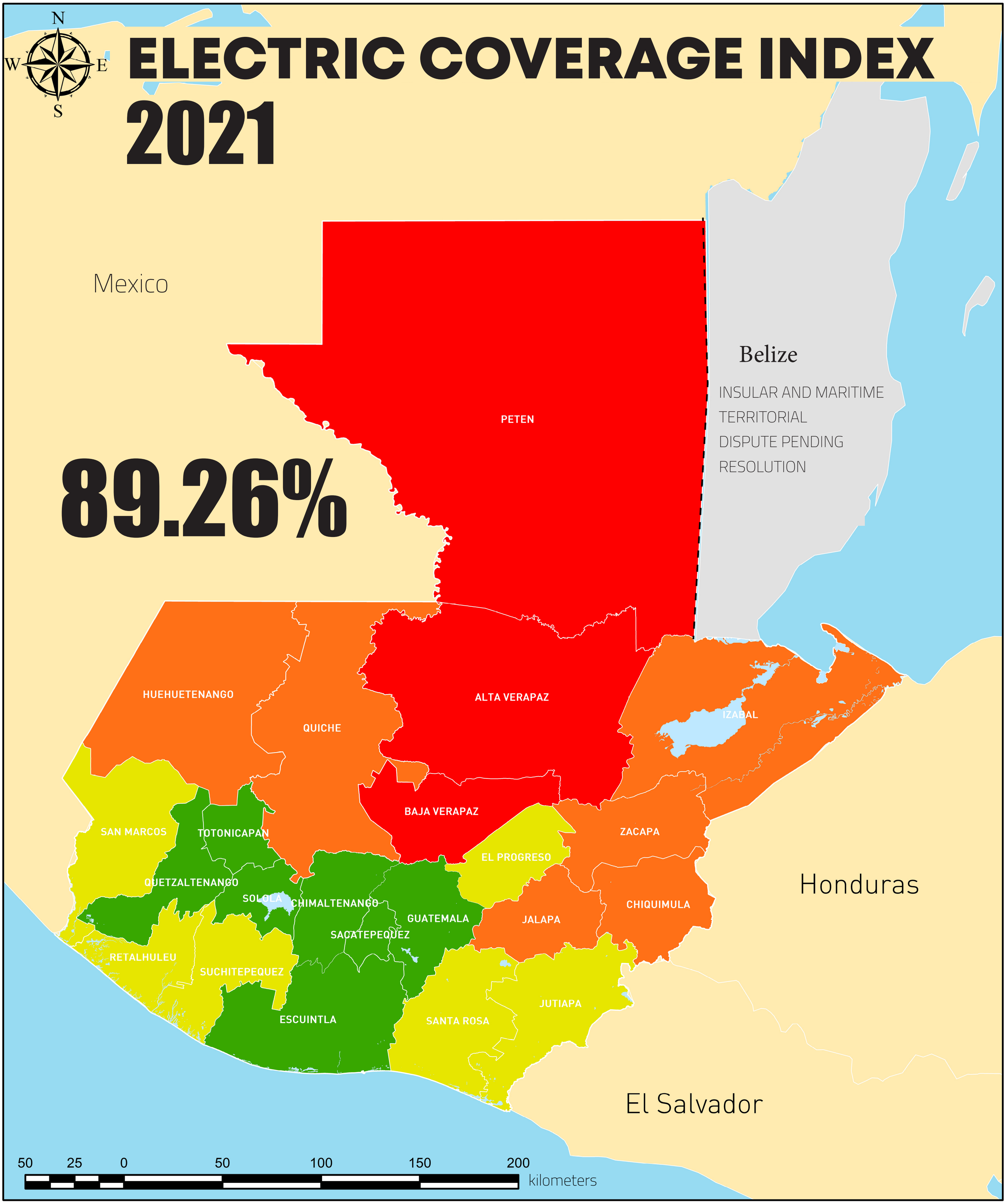
Source: Electricity Coverage Index 2021, Ministry of Energy and Mines.

Graph 21 presents the electricity coverage indexes by department. The departments mentioned are below the 85% electricity coverage line.

Graph 21: Departmental electricity coverage index.



Source: Electricity Coverage Index 2021, Ministry of Energy and Mines.



LESS THAN 80%
BETWEEN 80% AND 90%.
BETWEEN 90% and 95%
MORE THAN 95%

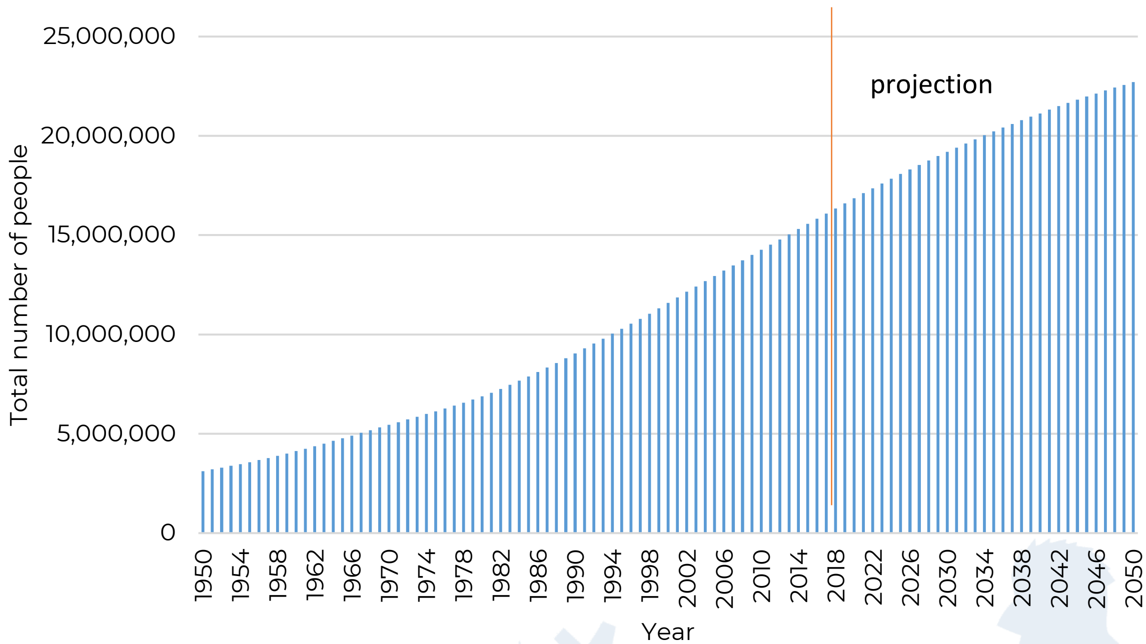
GOBIERNO de GUATEMALA
DR. ALEJANDRO GIAMMATTEI

MINISTERIO DE ENERGÍA Y MINAS

3.4. POPULATION GROWTH

According to the estimate and projection of the total population according to the population census published by INE, for the year 2020 a population of 16,858,333 inhabitants is projected, which represents a growth rate of 1.53% with respect to the previous year. A total population of 22 million 703 thousand 298 inhabitants is projected for 2050.

Graph 22: Total population estimate and projection. Revision 2019.



Source: Prepared by UPEM, with information from Estimates and projections of total population. Revision 2019, INE with the support of CELADE - CEPAL Population Division. 2019.

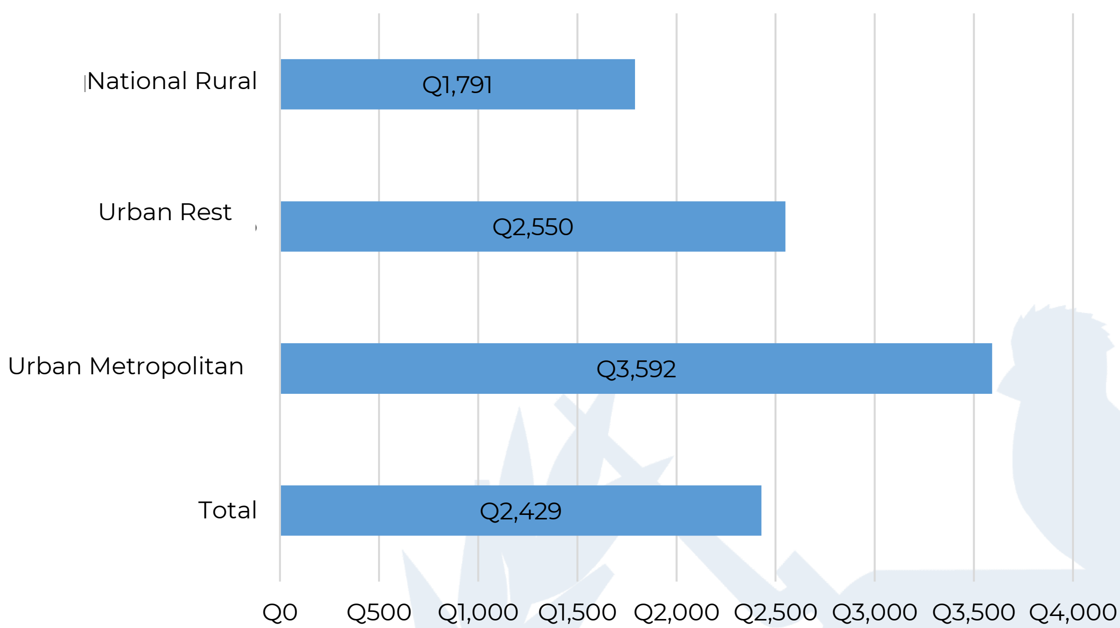
The previous graph represents the comparison of the years 2002 and 2018, on the distribution of the population in Guatemala; among the most relevant historical events, it is observed that Alta Verapaz has been the department with the greatest increase in population representation, gaining a total of 1.25% after the last 16 years, while Guatemala has reduced its population representation.

3.5. ECONOMIC INCOME

The National Institute of Statistics defines labor income as income from salaried employment plus income related to self-employment for profit or gain in the main agricultural and non-agricultural occupation.

Graph 23 shows income separated into three areas: Urban Metropolitan, Rest of Urban and Rural National. The national rural area represents 49.86% of the average monthly income of the urban metropolitan area. In electrification projects, this influences the economic feasibility of the project since it limits the possibility of the end user to cover the supply itself or any additional cost to have access to electricity.

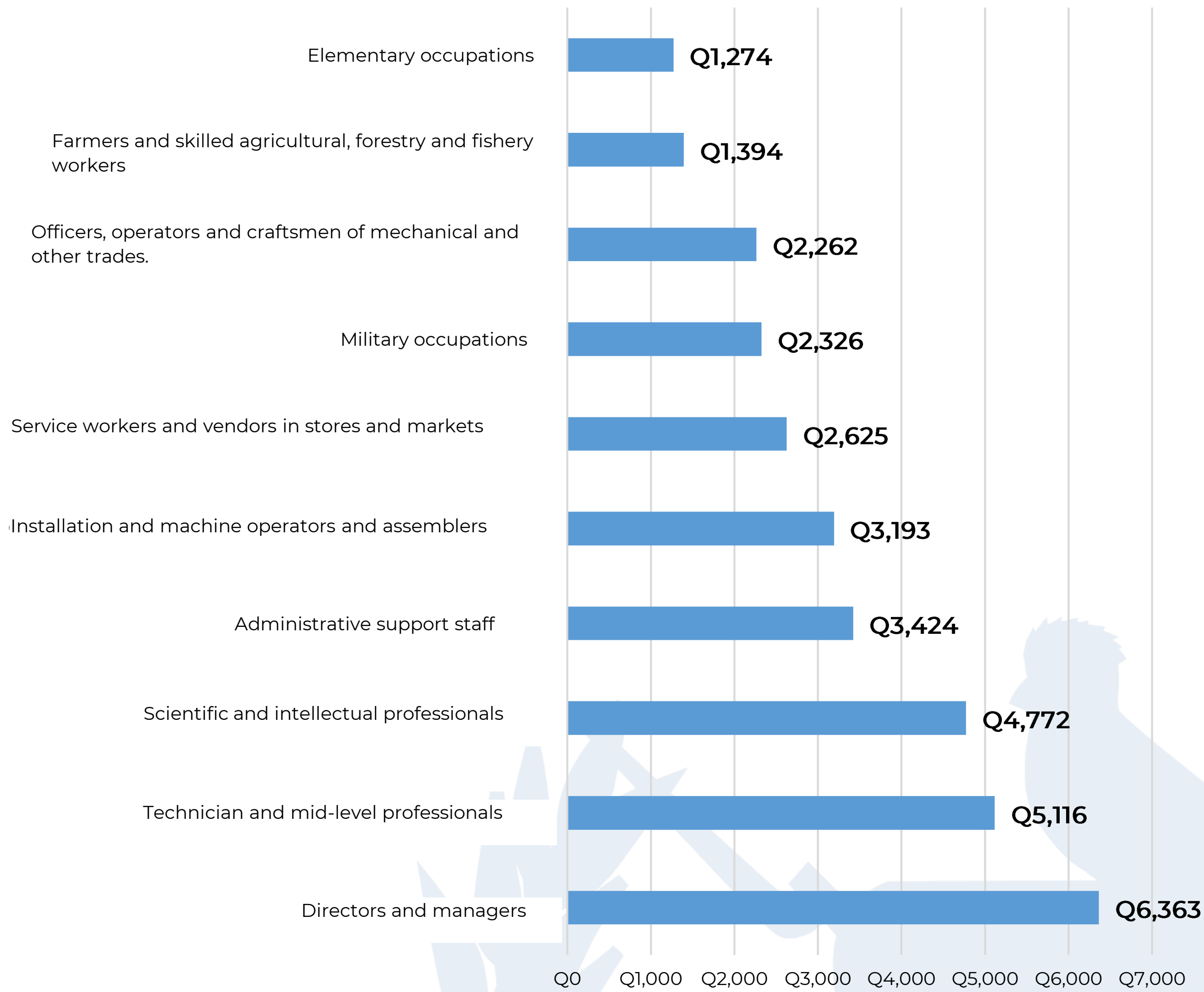
Graph 23: Average monthly income per study domain.



Source: ENEI 2-2019, National Employment and Income Survey, INE.

As shown in Graph 24, the main occupation with the highest income is that of directors and managers, which represents an average income of 500% in relation to the average income of the main occupation with the lowest income (elementary occupations).

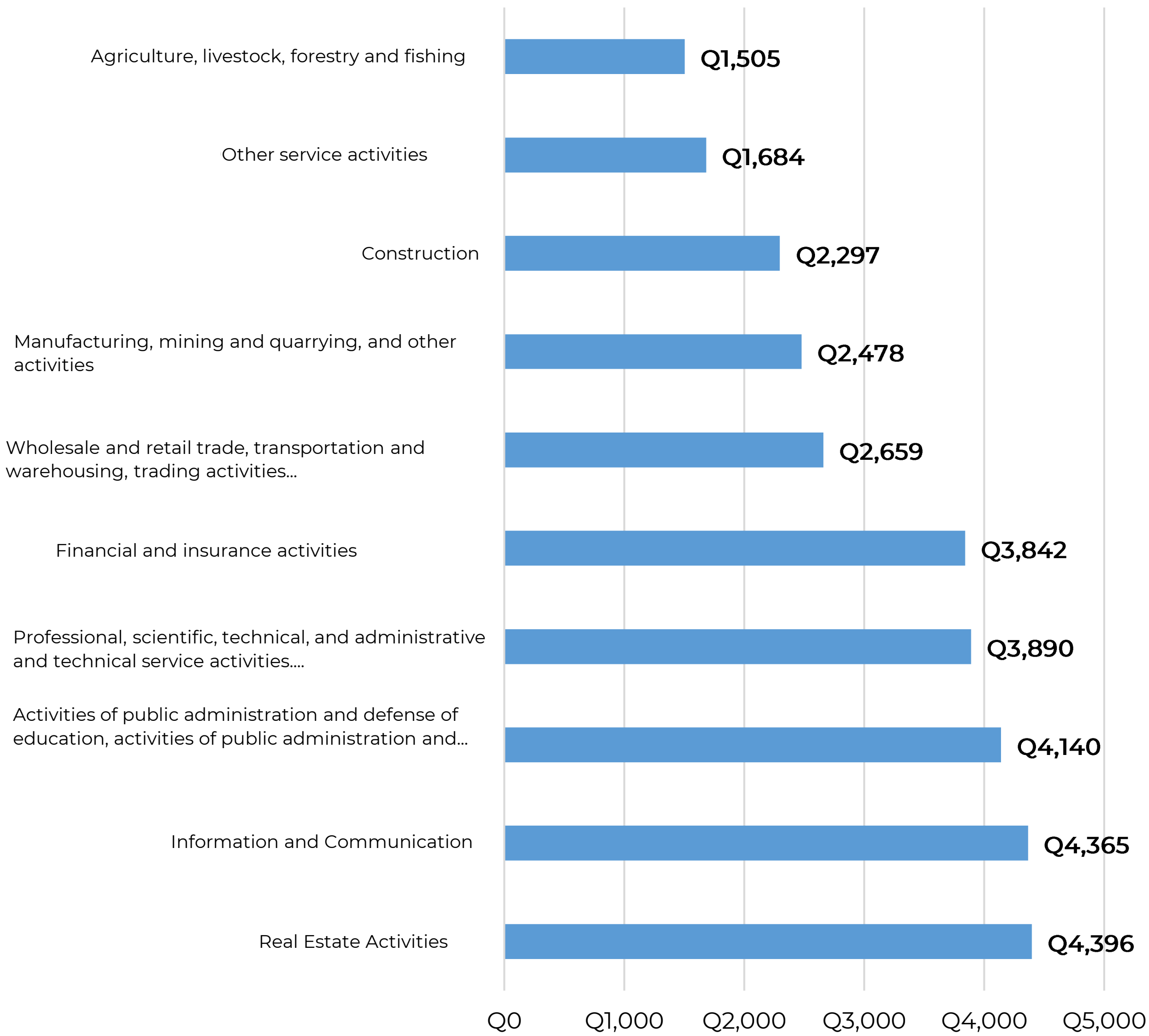
Graph 24: Average income by principal occupation.



Source: ENEI 2-2019, National Employment and Income Survey, INE.

In relation to monthly income by branch of activity, higher monthly income is observed in real estate and information and communication activities, while the lowest monthly income is found in agriculture, livestock, forestry and fishing activities.

Graph 25: Monthly income by industry.



Source: ENEI 2-2019, National Employment and Income Survey, INE.

Electric Generation Supply

CHAPTER 4

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

4. SUPPLY OF ELECTRICITY GENERATION

The information on the historical events of electricity production and demand related to the SNI, provide information to obtain a broad overview of the prospects to be expected in the coming years for the Guatemalan electricity subsector.

4.1. INSTALLED AND EFFECTIVE CAPACITY

The generation capacity can be classified in two ways; on the one hand, we find the Installed Capacity and on the other hand, the Effective Capacity, the former refers to the power for which the generator was designed, while the latter is the actual power that the generator can deliver under real operating conditions.

Table 7: Total installed and effective capacity connected to the SNI, as of 2021.

No.	Technology	INSTALLED CAPACITY	EFFECTIVE CAPACITY
		[MW]	[MW]
1	Reciprocating Motors	570.158	416.470
2	Hydroelectric	1578.713	1514.440
3	Geothermal	49.200	33.378
4	Photovoltaic	93.000	93.000
5	Wind	107.400	107.400
6	Steam Turbines	511.459	478.183
7	Gas Turbines	172.850	103.732
8	Cogeneration	1,020	630.78
9	Natural Gas Turbines	2.80	2.59
Total		4,111.54	3,380

Source: Proprietary production with information from the AMM.

As shown in Table 7, in Guatemala there is currently an Installed Capacity of around 4,111.54 MW, and an Effective Capacity of 3,381.03 MW, of course it is important to mention that the effective capacity is a very general representation of the true availability of the generation capacity of the system, since the electricity matrix in Guatemala is mainly constituted by generators that are highly susceptible to seasonality and climate change.

- ## INSTALLED AND EFFECTIVE CAPACITY BY TECHNOLOGY

In Guatemala, installed capacity in hydroelectric technology predominates, as well as cogeneration, both water and biomass are considered renewable resources; reciprocating engines and steam turbines are technologies that use non-renewable resources for generation and are also representative within the total installed capacity of the National Interconnected System.

The following is a list of the different plants by technology that are within the -SNI-:

Table 8: Total installed and effective capacity per plant connected to the SNI, as of 2021.

COGENERATORS						
NO	PLANT	BLOCK	INSTALLED MW	EFFECTIVE MW	FUEL	
1	MAGDALENA	1 TO 7	135	92.358	BUNKER	N/A
2	BIOMASS	1 TO 2	124	96.339	BIOMASS	BUNKER
3	PANTALEON	1 TO 2	60	24.83	BIOMASS	N/A
4		3	61.46	50.85	BIOMASS	BUNKER
5	LA UNIÓN	1	85	51.4	BIOMASS/CARBON	CARBON
6	SANTA ANA	1	40	21.375	BIOMASS/CARBON	CARBON
7		2	64	45.406	BIOMASS	BUNKER
8	MADRE TIERRA	1	36.8	29.93	BIOMASS/CARBON	CARBON
9	GENERADORA SANTA LUCIA	1	44.88	4.891	BIOMASS	BUNKER
10	CONCEPCIÓN	1	27.5	0	BIOMASS/CARBON	CARBON
11	TULULÁ	1 TO 2	12.5	5.667	BIOMASS	BUNKER
12		3	15	10.186	BIOMASS	BUNKER
13	TRINIDAD	1 TO 2	21	0	BIOMASS	CARBON
14		3	19.8	13.942	BIOMASS	CARBON
15		4	46	34.164	BIOMASS/CARBON	CARBON
16		5	46	44.767	BIOMASS	CARBON
17	EL PILAR	3	22.85	12.202	BIOMASS	N/A
18	PALO GORDO	1	30.9	0	BIOMASS	CARBON
19		2	46	33.89	BIOMASS/CARBON	CARBON
20	SAN DIEGO	1	5	0	BIOMASS	CARBON
21	SAN ISIDRO	1	64.2	57.56	BIOMASS	N/A
TOTAL COGENERATORS			1007.89	629.757		

RECIPROCATING MOTORS				
NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
1	GECSA 2	0	0	BUNKER
2	DARSA	0	0	BIOGAS/BUNKER
3	INDUSTRIA TEXTILES DEL LAGO	0	0	BUNKER
4	PUERTO QUETZAL POWER	59	56.8584	BUNKER
5	GENERADORA PROGRESO	21.968	0	BUNKER
6	SIDEGUA	44	0	BUNKER
7	GENERADORA DEL ESTE	70	64.385	
8	LAS PALMAS	66.8	20.808	BUNKER
9	GENOR	46.24	39.902	BUNKER
10	ELECTRO GENERACIÓN	15.75	14.447	BUNKER
11	COENESA	10	0	BUNKER
12	GENOSA	18.6	13.6851	BUNKER
13	ELECTRO GENERACIÓN CRISTAL BUNKER	5	3.158	
14	TERMICA	15.3	14.067	DIESEL
15	TERMICA B-2	37.5	30.532	BUNKER
16	ARIZONA	160	158.627	BUNKER
	TOTAL RECIPROCATING MOTORS	570.158	416.4695	

STEAM TURBINES				
NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
1	GENERADORA DEL ATLANTICO VAPOR	2.603	0.36	BIOMASS
2	GENERADORA DEL ATLANTICO BIOMASA	1.3	0.591	BIOMASS
3	BIOGAS VERTEDERO EL TREBOL	1.2	0.784	BIOMASS
4	GAS METANO GABIOSA	1.056	1.056	BIOMASS
5	BIOGAS VERTEDERO EL TREBOL FASE II	3.6	2.627	BIOMASS
6	SAN JOSÉ	139	139.87	Carbon
7	LA LIBERTAD	20	18.027	Carbon
8	ARIZONA VAPOR	12.5	1.945	
9	GENERADORA COSTA SUR	30.2	30.307	Carbon
10	JAGUAR ENERGY	300	282.616	Carbon/Petcoke
	TOTAL STEAM TURBINES	511.459	478.183	

GAS TURBINES				
NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
1	TAMPA	80	69.627	Diesel
2	STEWART & STEVENSON	51	0	Diesel
3	ESCUINTLA GAS 5	41.85	34.105	Diesel
	TOTAL GAS TURBINES	172.85	103.732	

HYDROELECTRIC POWER PLANTS				
NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
1	CHIXOY	300	286.577	NA
2	HIDRO XACBAL	94	100.004	
3	PALO VIEJO	85	88.192	
4	AGUACAPA	90	79.742	

5	JURÚN MARINALÁ	60	60.375	
6	RENACE	68.1	65.159	
7	HIDRO CANADA	48.1	45.928	
8	LAS VACAS	45	41.219	NA
9	EL RECREO	26	25.309	
10	SECACAO	16.5	16.204	
11	LOS ESCLAVOS	15	12.023	
12	MONTECRISTO	13.5	13.042	
13	PASABIEN	12.75	12.601	
14	MATANZAS	12	11.808	
15	POZA VERDE	12.51	9.881	NA
16	RIO BOBOS	10	10.31	
17	CHOLOMA	9.7	9.653	
18	SANTA TERESA	17	16.537	
19	PANAN	7.32	7.522	
20	SANTA MARÍA	6	6.029	
21	PALÍN II	5.8	4.222	
22	CANDELARIA	4.6	4.401	NA
23	SAN ISIDRO	3.932	3.421	
24	EL CAPULÍN	3.5	0	
25	EL PORVENIR	2.28	0	
26	EL SALTO	4	3.575	
27	CHICHAÍC	0.6	0.456	
28	SAN JERÓNIMO	0.25	0.2	
29	VISION DE AGUILA	2.07	2.059	NA
30	EL MANANTIAL I	3.78	3.451	
31	EL MANANTIAL II	27.42	22.954	
32	EL COBANO	11	8.851	
33	OXEC	26.1	24.287	
34	HIDROELECTRICA LA LIBERTAD	9.44	9.494	
35	RENACE II	114.784	107.197	
36	RAAXHA	5.1	5.022	NA
37	HIDROELECTRICA LAS FUENTES II	14.17	13.635	
38	HIDROELECTRICA EL CAFETAL	8.6	8.55	
39	HIDROELECTRICA FINCA LORENA	4.2	4.456	
40	RENACE III	66	67.016	
41	EL RECREO II	24.44	21.985	
42	XACBAL DELTA	58.44	58.404	
43	EL MANANTIAL III	0.52	0.437	NA
44	OXEC II	60	60.003	
45	RENACE IV	57	51.234	
46	EL MANANTIAL IV	14.64	16.103	
47	HIDROELECTRICA SANTA ELENA	0.56	0.56	
48	KAPLAN CHAPINA	2	1.702	
49	HIDROELECTRICA CUEVA MARIA 1 Y 2	4.95	4.95	
50	HIDROELECTRICA LOS CERROS	1.25	1.25	NA
51	HIDROELECTRICA COVADONGA	1.6	1.5	
52	HIDROELECTRICA JESBON MARAVILLAS	0.75	0.75	
53	CENTRAL GENERADORA EL PRADO (Sn Ant Morazán)	0.5	0.5	
54	HIDROELECTRICA FINCA LAS MARGARITAS	0.438	0.438	

55	HIDROPOWER SDMM	2.16	2.083	
56	HIDROELECTRICA LA PERLA	3.7	3.799	
57	HIDROELECTRICA SAC-JA	2	2	NA
58	HIDROELECTRICA SAN JOAQUIN	0.95	0.8	
59	HIDROELECTRICA LUARCA	1.02	1.02	
60	HIDROELECTRICA FINCA LAS MARGARITAS FASE 2	1.71	1.6	
61	HIDROELECTRICA EL LIBERTADOR	2	2.161	
62	HIDROELECTRICA LAS VICTORIAS	1.2	1	
63	EL CORALITO	2.1	1.927	
64	EL ZAMBO	0.98	0.98	NA
65	HIDROELECTRICA MONTE MARIA	0.691	0.691	
66	HIDROELECTRICA HIDROAGUNA	2	2.055	
67	HIDROELECTRICA LA PAZ	0.95	0.95	
68	HIDROELECTRICA IXTALITO	1.634	1.6	
69	HIDROELECTRICA GUAYACAN	2.9	2.875	
70	HIDROELECTRICA TUTO DOS	0.96	0.96	
71	HIDROELECTRICA SANTA TERESA	2.171	2.058	NA
72	HIDROELECTRICA EL PANAL	2.5	2.5	
73	HIDROELECTRICA PACAYAS	5	5	
74	HIDROELECTRICA SAMUC	1.2	1.2	
75	HIDROELECTRICA CONCEPCION	0.15	0.15	
76	HIDROELECTRICA SAN JOSE	0.43	0.43	
77	HIDROELECTRICA PEÑA FLOR	0.499	0.499	
78	HIDROELECTRICA SANTA ANITA	1.56	1.56	NA
79	HIDROELECTRICA CERRO VIVO	2.4	2.113	
80	HIDROELECTRICA MAXANAL	2.8	2.142	
81	HIDROELECTRICA LAS UVITAS	1.87	1.79	
82	HIDROELECTRICA EL CONACASTE	3	3	
83	HIDROELECTRICA EL BROTE	3.7	3.7	
84	HIDROELECTRICA MOPA	0.975	0.975	
85	HIDROELECTRICA LOS PATOS	5	4.766	NA
86	HIDROELECTRICA EL COROZO	0.9	0.9	
87	HIDROELECTRICA MIRAFLORES	0.837	0.837	
88	HIDROELECTRICA LA CEIBA I	0.7	0.7	
89	HIDROELECTRICA CARMEN AMALIA	0.686	0.686	
90	PEQUEÑA HIDROELECTRICA XOLHUITZ	2.3	2.286	
91	HIDROELECTRICA SAMUC II	1.8	1.68	
92	HIDROELECTRICA EL TRIANGULO	0.96	0.96	NA
93	HIDROELECTRICA NUEVA HIDROCON	1	1	
94	MINI HIDROELECTRICA LA VIÑA	0.29	0.29	
95	HIDROELECTRICA EL SALTO MARINALA	5	4.939	
96	HIDROELECTRICA CUTZAN	1.95	1.95	
97	HIDROELECTRICA CHOLIVA	0.736	0.7	
98	MINI HIDROELECTRICA HIDROXOCOBIL	1.4	1.2	
99	HIDROELECTRICA HIDROSAN I	2	2	NA
100	HIDROELECTRICA LA MEJANA	2	2	
101	HIDROELECTRICA HIDROSAN II	1.5	1.5	
102	HIDROELECTRICA LOS ENCUENTROS	1.25	1.25	
TOTAL HYDROELECTRIC POWER PLANTS		1,578.71	1,514.44	

NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
GEOTHERMICS				
1	ORZUNIL	24	17.027	NA
2	ORTITLAN	25.2	16.351	
	TOTAL GEOTHERMICS	49.2	33.378	

NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
SOLAR PLANTS				
1	HORUS 1	50	50	NA
2	HORUS 2	30	30	
3	GRANJA SOLAR TAXISCO	1.8	1.8	
4	GRANJA SOLAR EL JOBO	1.2	1.2	
5	GRANJA SOLAR LA AVELLANA	1.2	1.2	
6	GRAJA PEDRO DE ALVARADO	1.8	1.8	
7	GRANJA SOLAR BUENA VISTA	1.5	1.5	
8	CENTRAL SOLAR FOTOVOLTAICA SIBO	5	5	
9	GRANJA SOLAR XELA 1	0.5	0.5	
	TOTAL SOLAR PLANTS	93	93	

NO.	PLANTS	INSTALLED MW	EFFECTIVE MW	FUEL
WIND PLANTS				
1	SAN ANTONIO EL SITIO	52.8	52.8	NA
2	VIENTO BLANCO	23.1	23.1	
3	LAS CUMBRES	31.5	31.5	
	TOTAL WIND PLANTS	107.4	107.4	

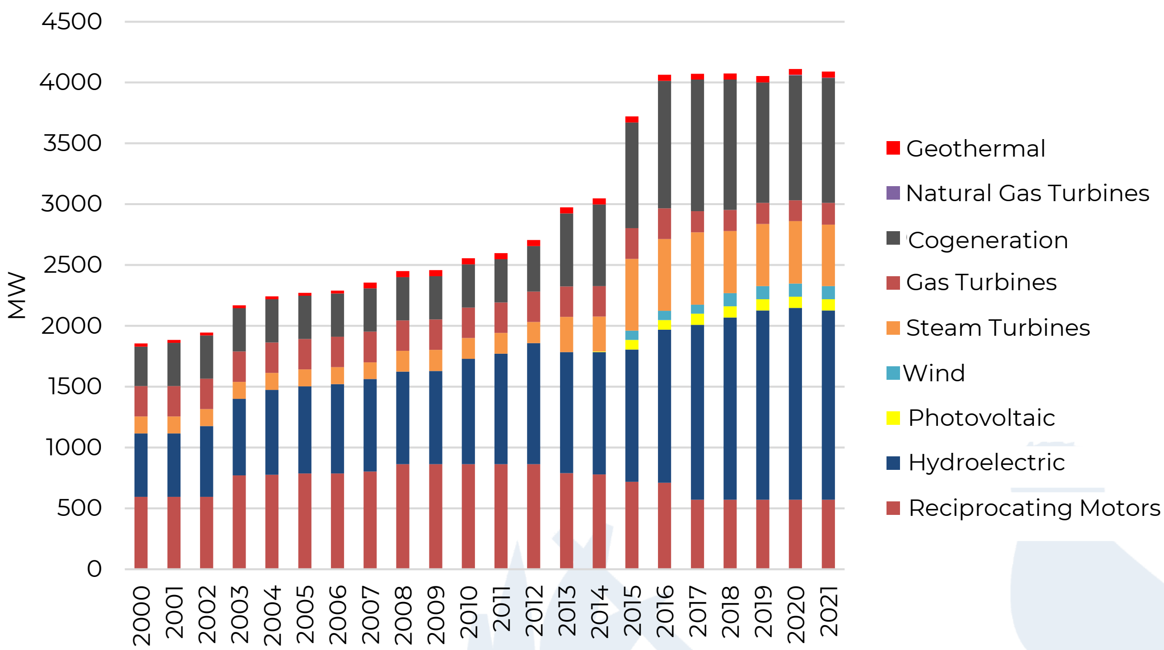
Source: Proprietary production with information from the AMM.

- ## EVOLUTION OF INSTALLED CAPACITY

In the last 20 years, cogeneration, steam turbine and hydroelectric technologies have experienced a growth, with average rates, in that period, of between 9.07% and 5.82% in relation to the MW installed.

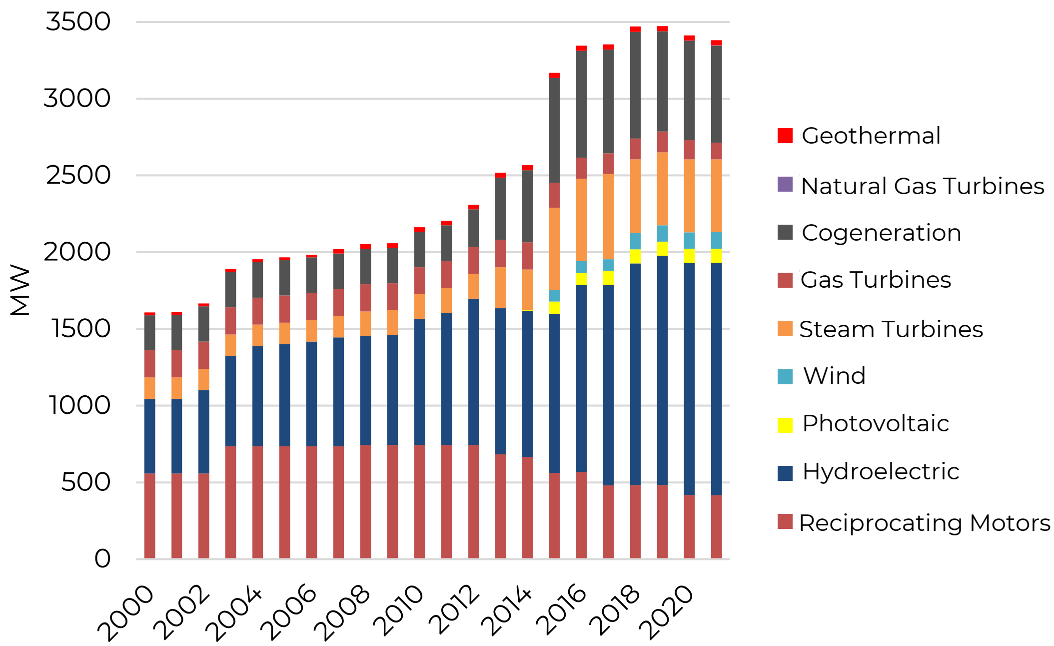
In the last 6 years, new technologies such as solar and wind have been added to the S.N.I., as well as biogas resources for generation; and it is worth mentioning that in 2020, 4 MW of installed capacity were added to produce electric energy with natural gas turbines in the department of Petén.

Graph 26: Capacity evolution (MW of plate).



Source: Proprietary production with information from the AMM.

Graph 27: Capacity evolution (effective MW).

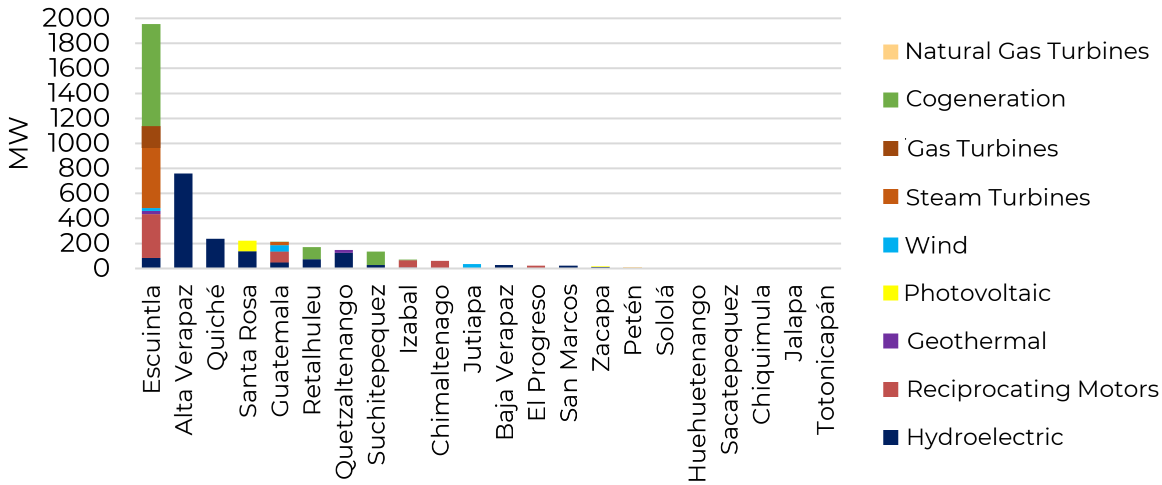


Source: Proprietary production with information from the AMM.

- ## INSTALLED CAPACITY BY DEPARTMENT

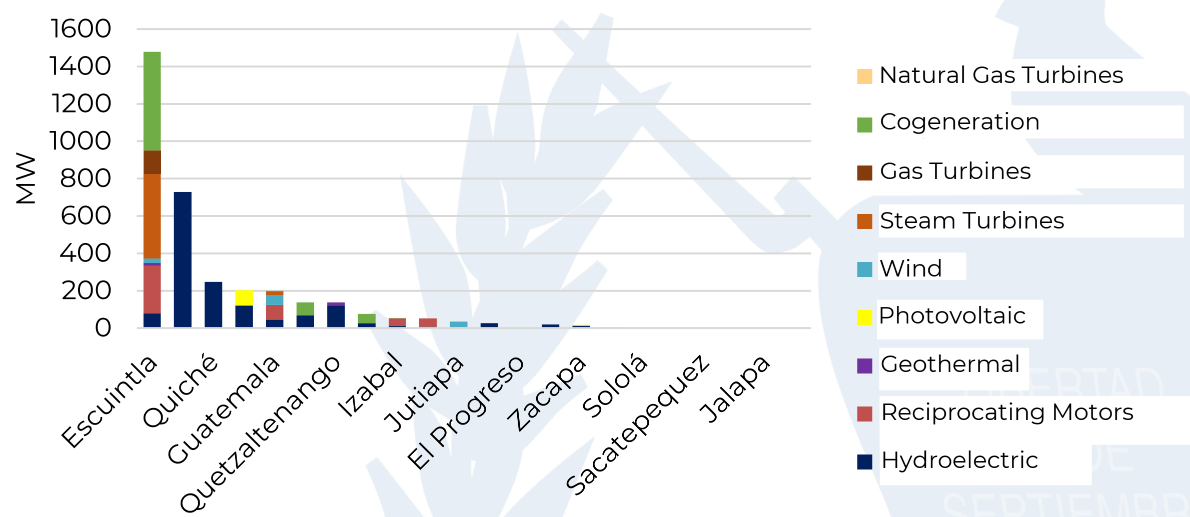
The departments with the largest installed capacity are Escuintla, with a predominance of cogeneration plants, steam turbines, reciprocating engines and gas turbines; and the department of Alta Verapaz, due to the high concentration of installed capacity that makes use of water resources.

Graph 28: Installed capacity by department (MW plate).



Source: Proprietary production with information from the AMM.

Graph 29: Installed capacity by department (MW effective).



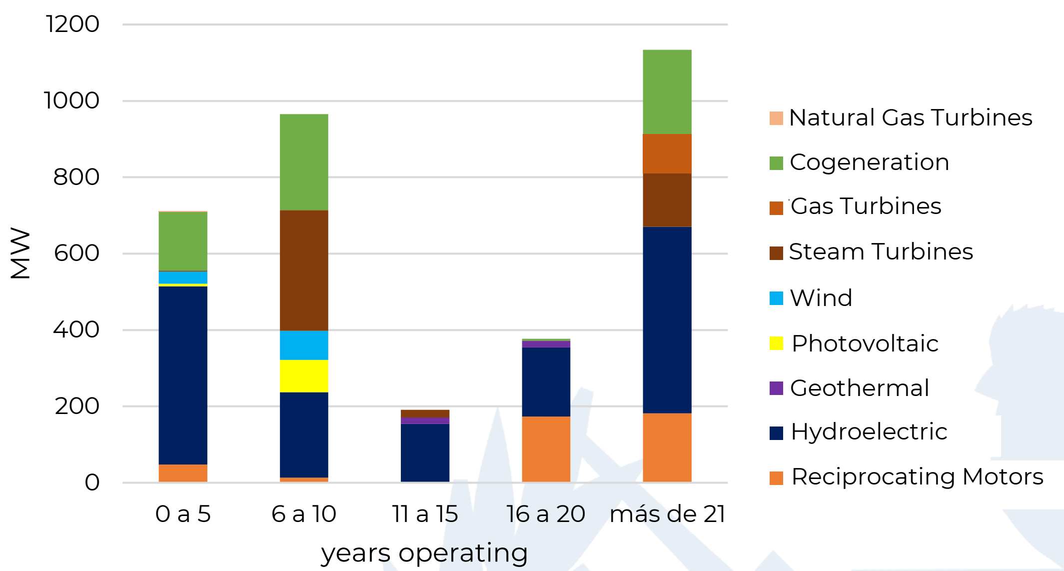
Source: Proprietary production with information from the AMM.

- **EFFECTIVE CAPACITY WITH RESPECT TO THE YEARS OPERATING IN THE SNI**

It is important to represent how old is the effective power operating in the SNI, for the hydropower potential; there are 466.9 effective MW operating in the system with 0 to 5 years old, however, there are also 488 effective MW that have been operating for more than 21 years.

In the SNI, there is a total of 1,133.56 MW of effective power, which has been operating for more than 21 years, and 712.115 MW effective power, which has been operating for between 0 and 5 years. The effective power that has been operating for more than 21 years represents 34% of the total effective power of the System.

Graph 30: Effective capacity with respect to years in operation.



Source: Proprietary production with information from the AMM.

Electric
Energy Production

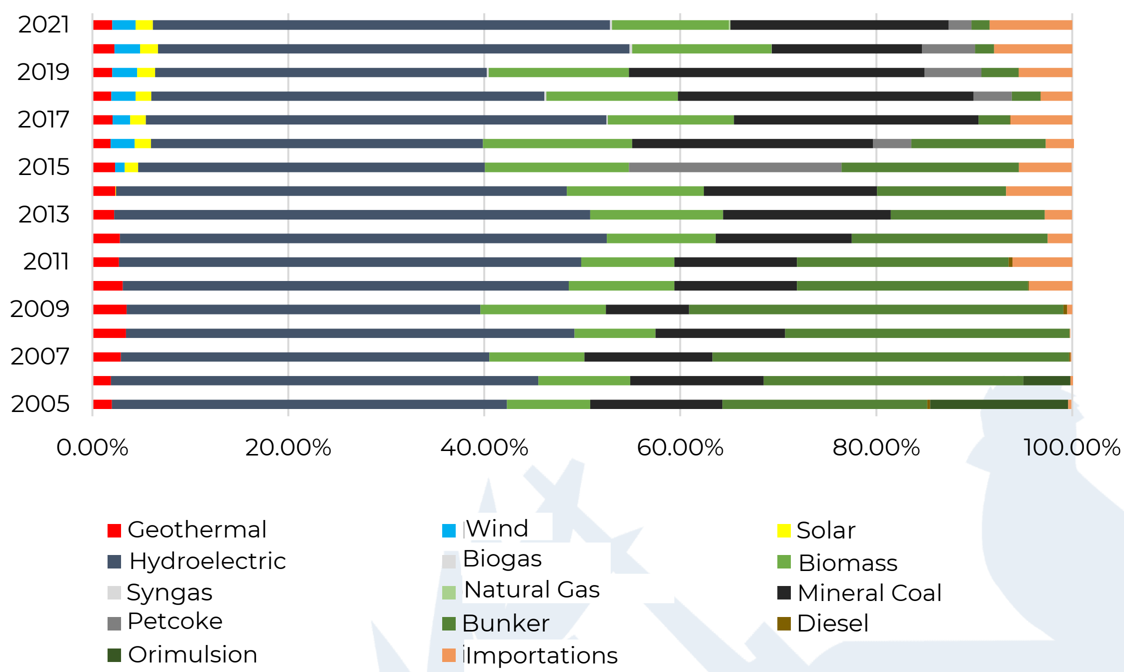
CHAPTER 5

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

5. ELECTRICITY PRODUCTION

The demand for electric energy in Guatemala has been historically supplied by means of the hydro-thermal generation system, which consisted of State-owned hydroelectric generators and private thermal power plants. Since the General Law on Electricity and its regulations came into force, and later with the reforms carried out between 2006 and 2008, the electric energy service has been supplied by national renewable resources, with a 65% renewable participation in the electric generation matrix for the year 2021, considering imports with 8% and the non-renewable participation with 27%.

Graph 31: Historical annual electricity generation matrix.

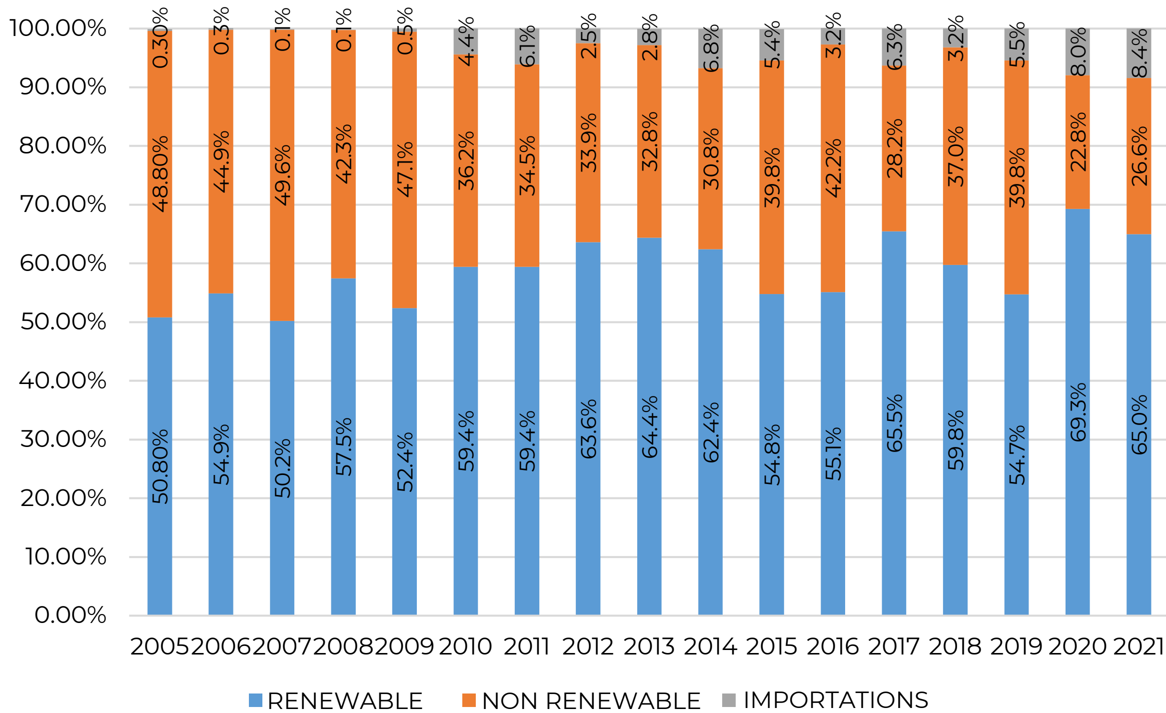


Source: Proprietary production with information from the AMM.

Graph 31 shows the annual electricity generation matrix for Guatemala from 2005 to 2021.

In 2021, generation from renewable resources accounted for approximately 65%, while non-renewable resources accounted for 27%.

Graph 32: Historical participation of renewable vs. non-renewable resources.

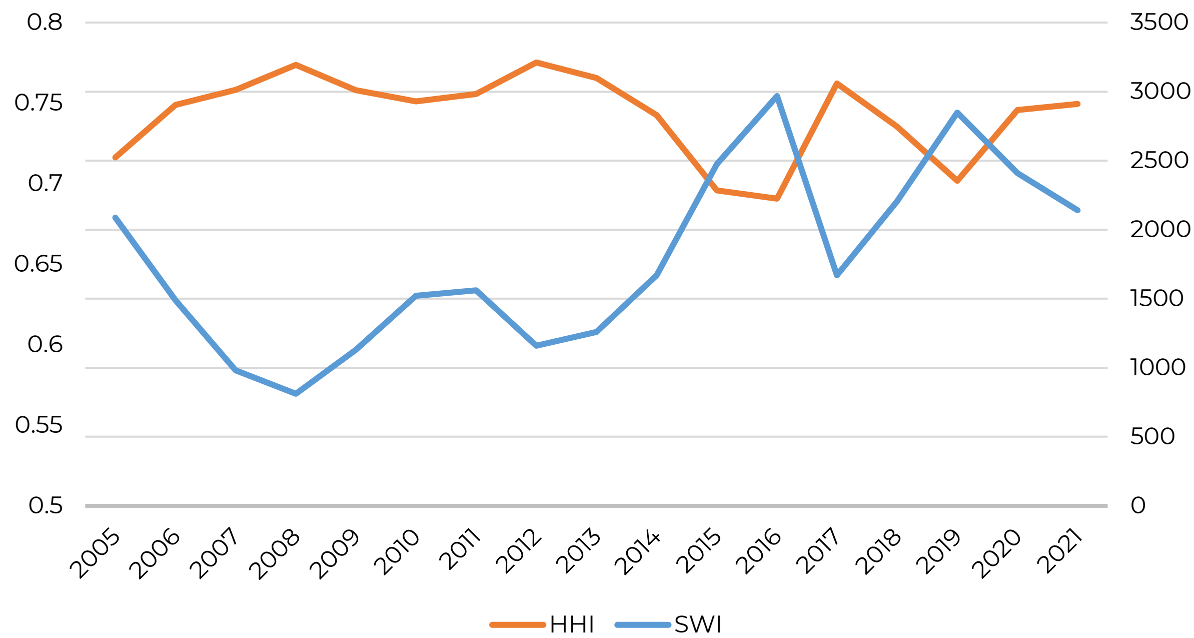


Source: Proprietary production with information from the AMM.

The diversification of the electricity generation matrix began to be measured and quantified by UPEM since 2016, by means of the Shannon-Wiener index (SWI), which is used to measure biodiversity in ecological systems, where the minimum value is zero and the higher the index, the more diverse the system is; and by means of the Herfindahl-Hirschman Index (HHI), which has values between 0 and 10,000 and is used to measure the concentration of a market in economics, where the higher the concentration, the higher the index, and generally determines the competitiveness of a market for regulatory matters.

In 2021, resource diversity resulted in a SWI of 0.70, since 2005, a growth from 0.67 to the current values, which hover around 0.75 since 2016, has been observed. The market concentration for 2021 was 2,909.78, showing an increase with respect to 2020, which was 2,866.58, this due to the increase in coal-fired generation for 2021. The historical diversification and concentration indexes for the period 2005 to 2021 are shown in 0.

Graph 33: Diversification indicators of the annual electricity generation matrix.

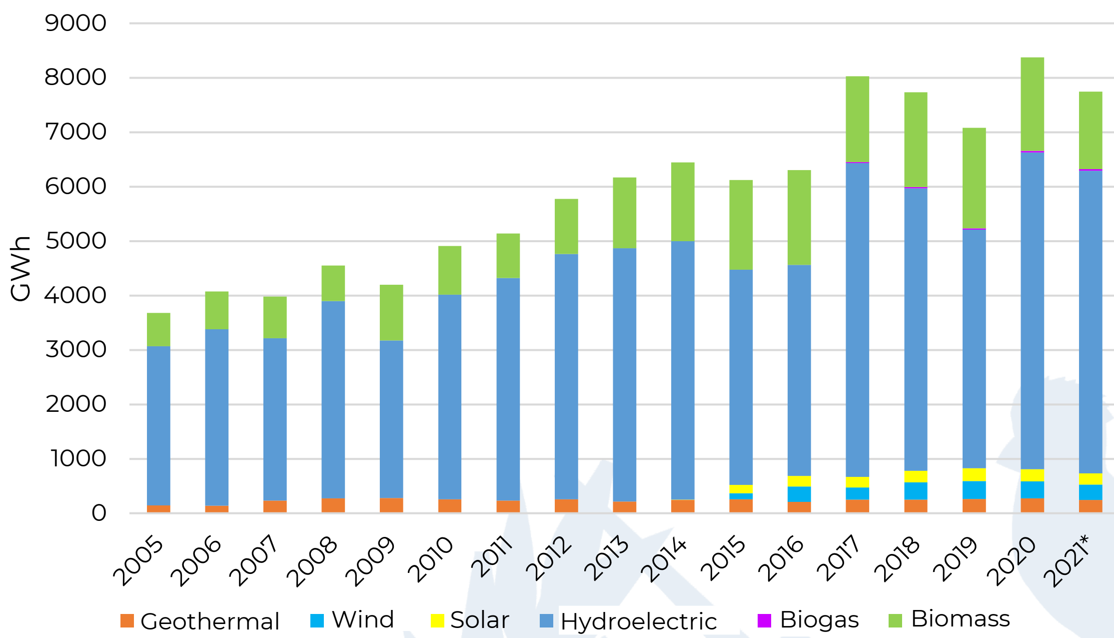


Source: Proprietary production, UPEM.

5.1. RENEWABLE RESOURCES

Electricity generation in the National Interconnected System by means of renewable resources has increased consistently since 2005, when it totaled 3,680 GWh, until 2020, when it totaled 8,373 GWh. The diversification of renewable generation sources is illustrated in Graph 34 , which shows the historical evolution since 2005, as well as the entry in 2015 of generation produced by photovoltaic and wind power plants. Generation by means of water resources has been one of the fastest growing in the national generation park, reaching 2,920 GWh in 2005 and increasing to 5,816.54 GWh in 2020.

Graph 34: Annual generation by type of renewable resource.



* Data as of November 2021.
Source: Proprietary production with information from the AMM.

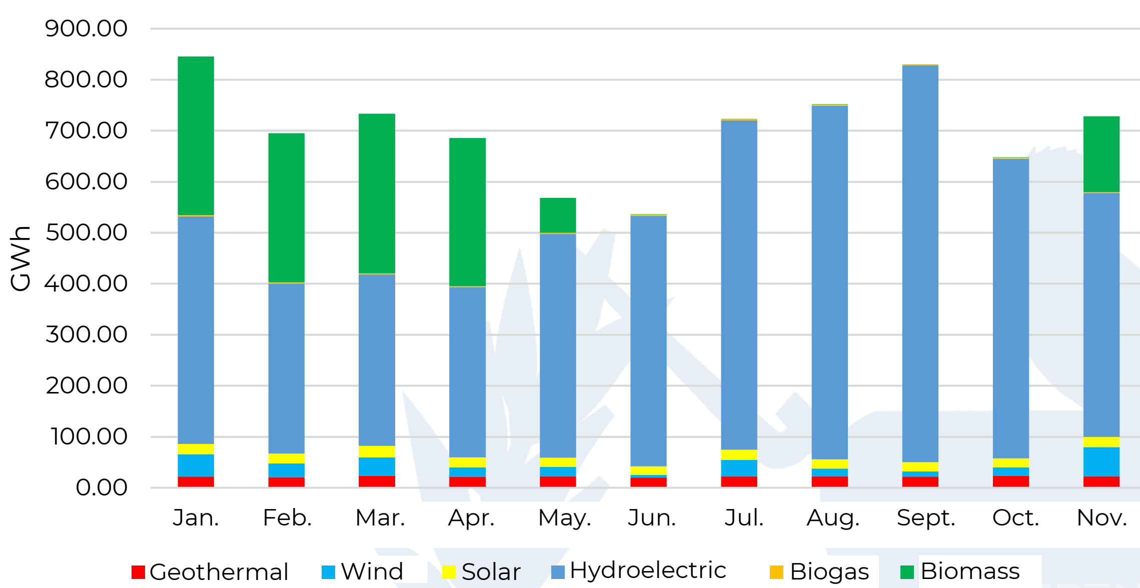
Renewable resources can be considered as conventional and non-conventional, being this technological differentiation a concept that is expected to be eliminated to consider a renewable technology only according to the intermittency of the primary energy source. For example, photovoltaic and wind technology, after a decade of operation in generation plants around the world can be considered a mature technology, being the lack of firmness the technological aspect that is still under development by means of electricity storage in batteries.

Seasonality is an aspect to consider regarding water resources; however, this is due to the perspective of the generating plant, since water storage in dams occurs only in some plants and is not a design constant, since hydroelectric plants can have annual, monthly, and daily storage by means of a dam; in the case of not using a dam, they are known as run-of-river plants.

The production of electricity from cogenerators occurs mainly during the sugar mills' harvest season, therefore, it is also considered as seasonal generation; therefore, the generation through the biomass resource occurs mainly in the period from December to April of the following year, complementing the water resources that are available from June to October.

Monthly generation by means of renewable resources in 2021 is shown in Graph 34, from which the above mentioned can be observed. It is worth mentioning that generation by means of geothermal steam and biogas are not seasonal and have plant factors higher than 80%; photovoltaic plants have slight variations in the generation produced monthly and their capacity curve is predictable; however, the plant factor of this technology and wind power plants ranges from 20% to 40%, subject to an hourly variability that is a challenge for grid operators.

Graph 35: Monthly generation by type of renewable resource for the year 2021.



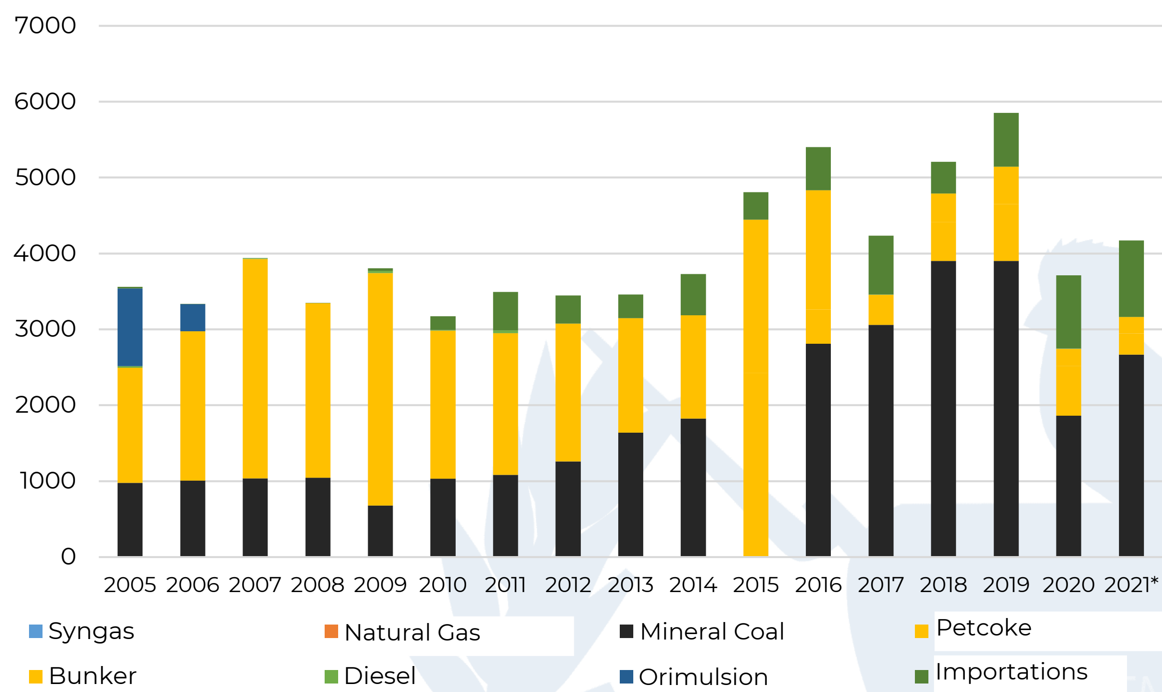
Source: Elaboration of the AMM.

5.2. NON-RENEWABLE RESOURCES

Electricity production from non-renewable resources in Guatemala has generally occurred to supply the base demand of the SNI, due to the seasonality of most of the plants using renewable resources. The electricity generation system, as part of a larger energy system, uses imported resources and therefore resources that are also subject to the world energy market.

Generation from non-renewable resources was 3,540 GWh in 2005 and has increased to supply the national demand to 2,750 GWh. However, in Guatemala there has been an economic transition in the production of electricity through non-renewable resources, since in 2005 at least 1,516 GWh of electricity was produced by bunker (fuel oil no. 6 with low sulfur content) and 979 GWh were produced by coal, which is a cheaper energy source. Graph 36 illustrates the evolution of annual production using non-renewable resources from 2005 to 2021.

Graph 36: Annual generation by type of non-renewable resource.



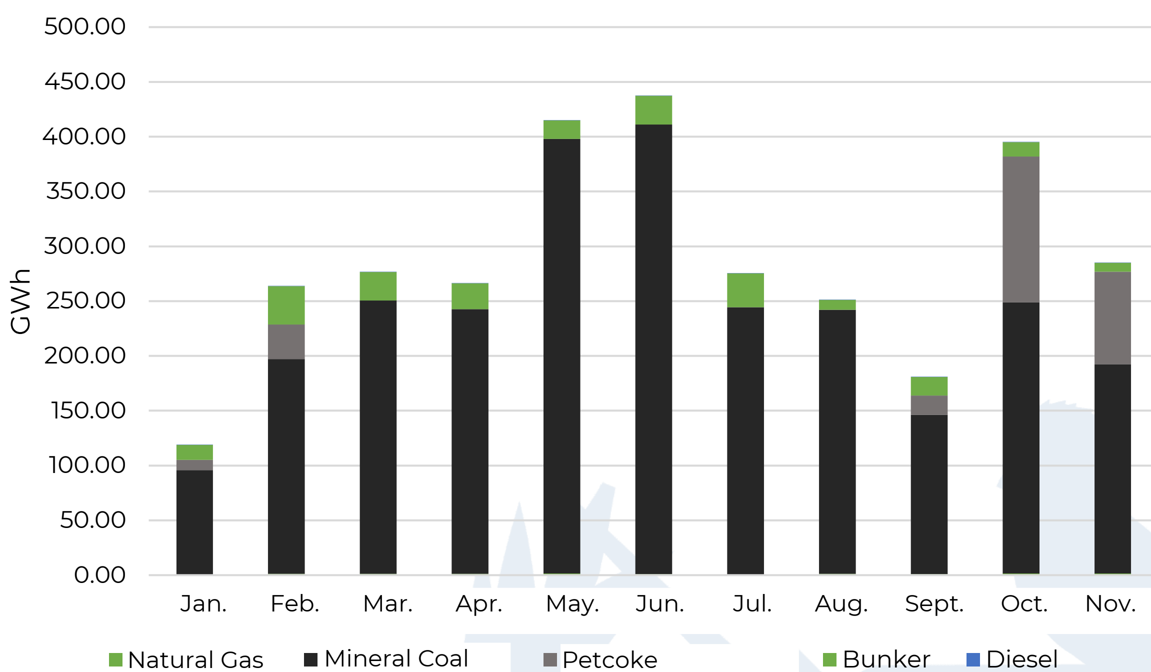
* Data as of November 2021.

Source: Proprietary production with information from the AMM.

Energy imports through Mexico's interconnection, or transactions in the Regional Electricity Market, have increased since 2010 from Mexico; however, for 2020, imports of approximately 962 GWh were accounted for, which represented an increase of 36% over 2019.

The correspondence between non-renewable generation with renewable generation can be observed again in Graph 37 where it is observed that the month with the highest production by means of non-renewable resources in 2020 is May and July, the former due to the end of the harvest period of the cogenerating mills and the lack of the water season which annually starts precisely this month, and in July due to the heat wave that happened in 2020, which mainly affected the amount of water resources. Since 2018, the energy known as petroleum coke has started to be used in steam power plants, which has been competitive in prices as well as thermal coal.

Graph 37: Monthly generation by type of non-renewable resources for the year 2021.

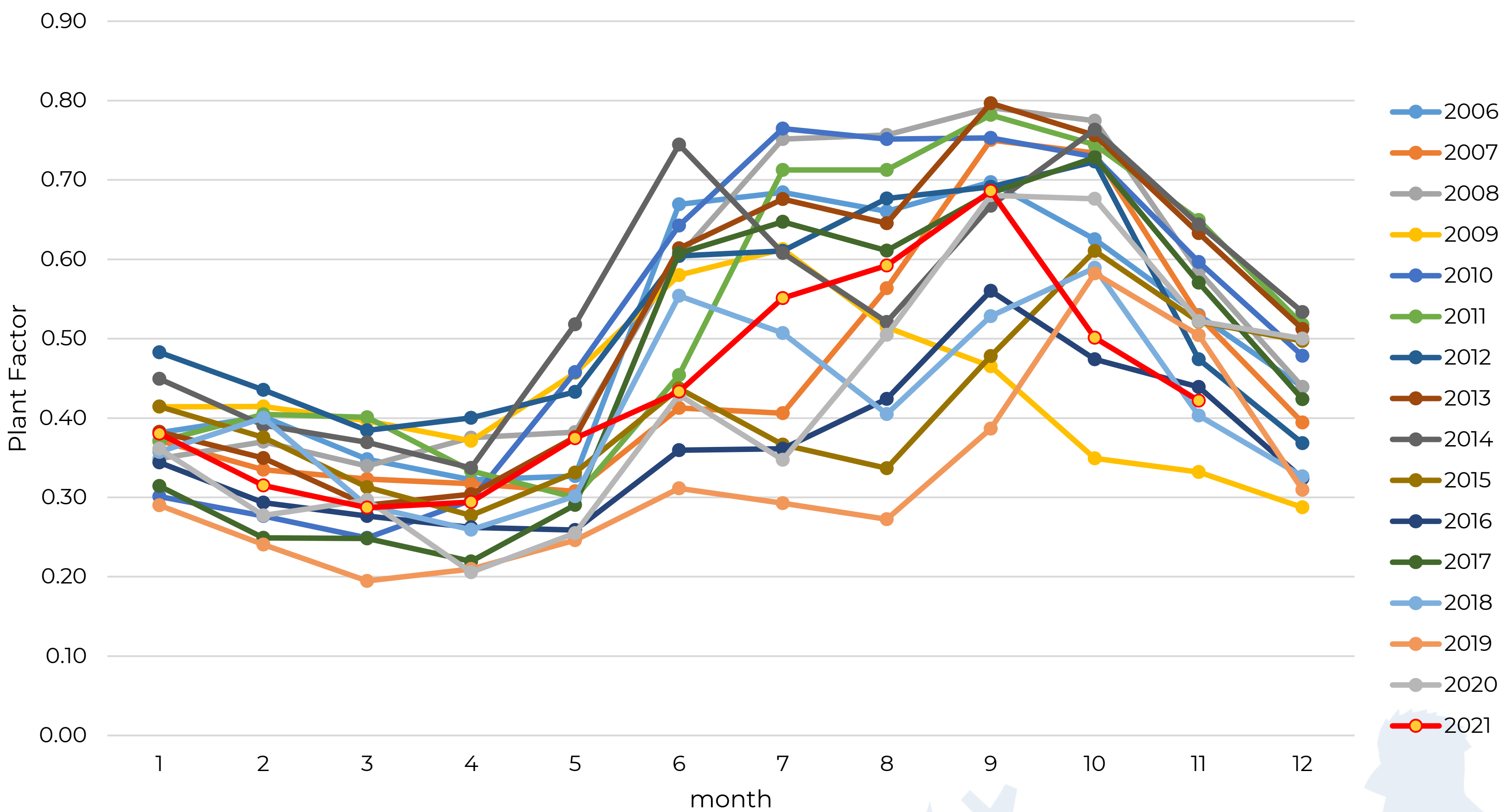


Source: Preparation of the AMM.

5.3.HISTORICAL PLANT FACTOR OF HYDROELECTRIC PLANTS

The historical plant factor for the country's hydroelectric plants, shown below, is a monthly quotient between the actual energy generated by the hydroelectric generation park (in a month), and the theoretical value of the energy generated, if the same generation park had worked at full capacity (for the same month).

Graph 38: Historical production factors for hydroelectric plants.

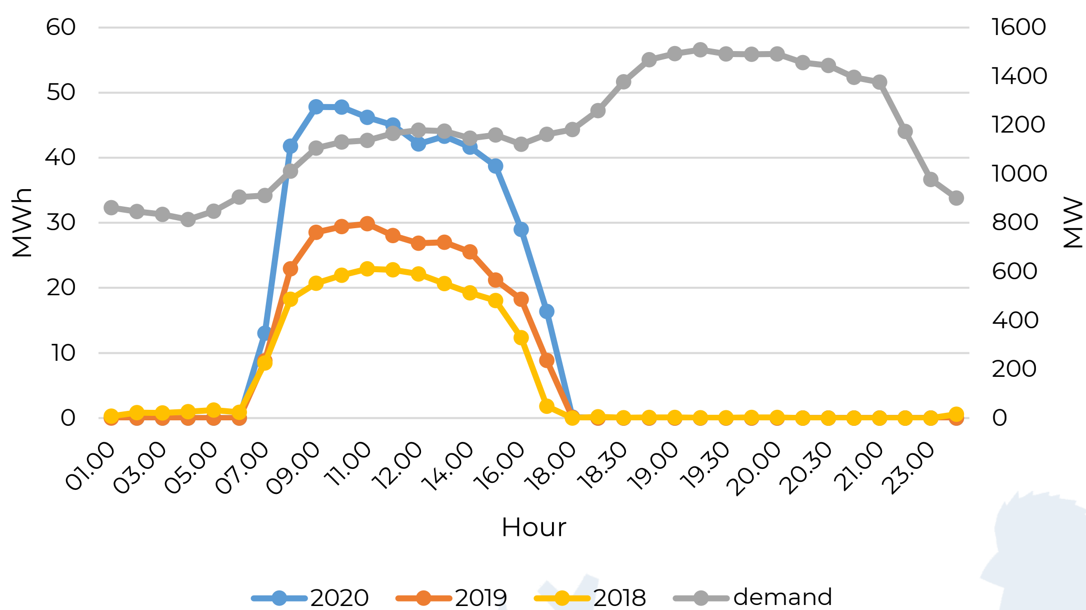


Source: Proprietary production with information from the AMM.

5.4. SOLAR HOURLY WIND AND SOLAR GENERATION PROFILE

The generation with photovoltaic technology is a phenomenon that is still increasing in Guatemala, the time slot of maximum use for this resource begins at 06:00 hours of the day, and ends at approximately 18:00 hours of the day, in the following graph you can see the behavior of the average hourly generation during the last three years.

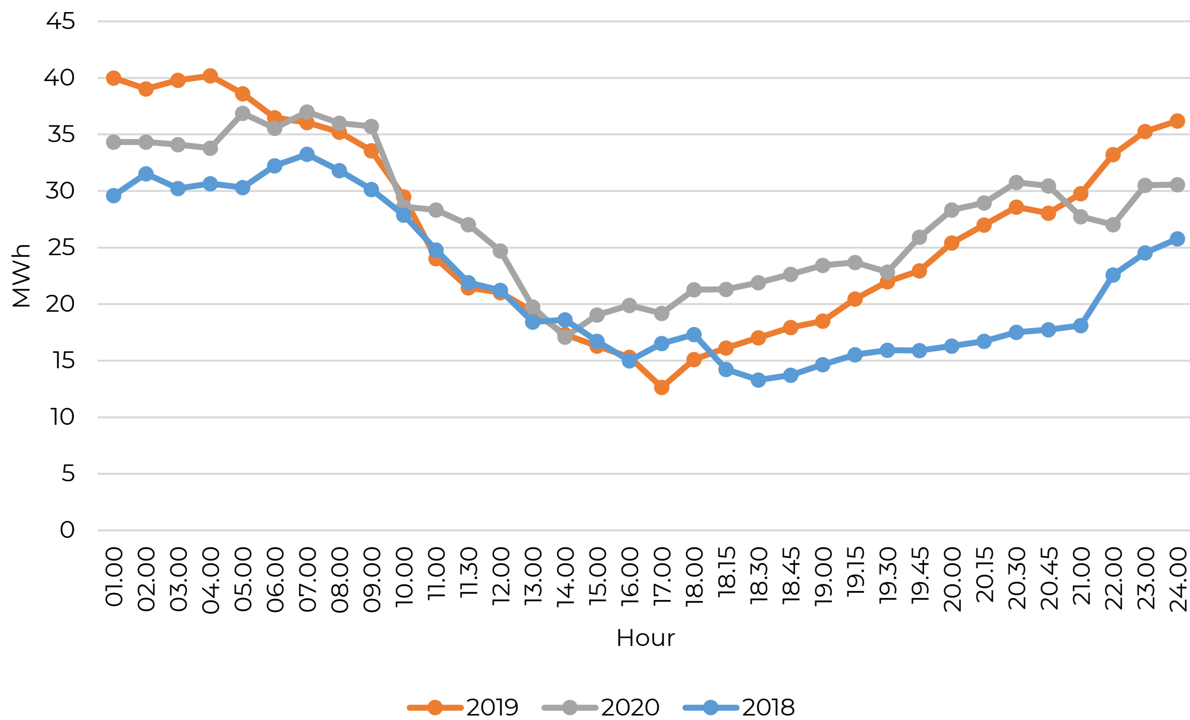
Graph 39: Historical profile of hourly solar generation.



Source: Proprietary production with information from the AMM.

The generation of electric energy by means of wind power plants is an alternative for clean energies that is on the rise in the SNI's generation matrix, being a technology capable of providing electric energy throughout the day, with maximum use during nighttime hours when there are temperature changes in the environment, as shown in the following graph.

Graph 40: Historical profile of hourly wind generation.



Source: Proprietary production with information from the AMM.

Historical Electric Power Demand

CHAPTER 6

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

6. HISTORICAL ELECTRICITY DEMAND

To understand which sectors are currently driving electricity consumption, it is important to determine which sectors currently dominate the electricity sub-sector, so the following is a breakdown of consumption by sector.

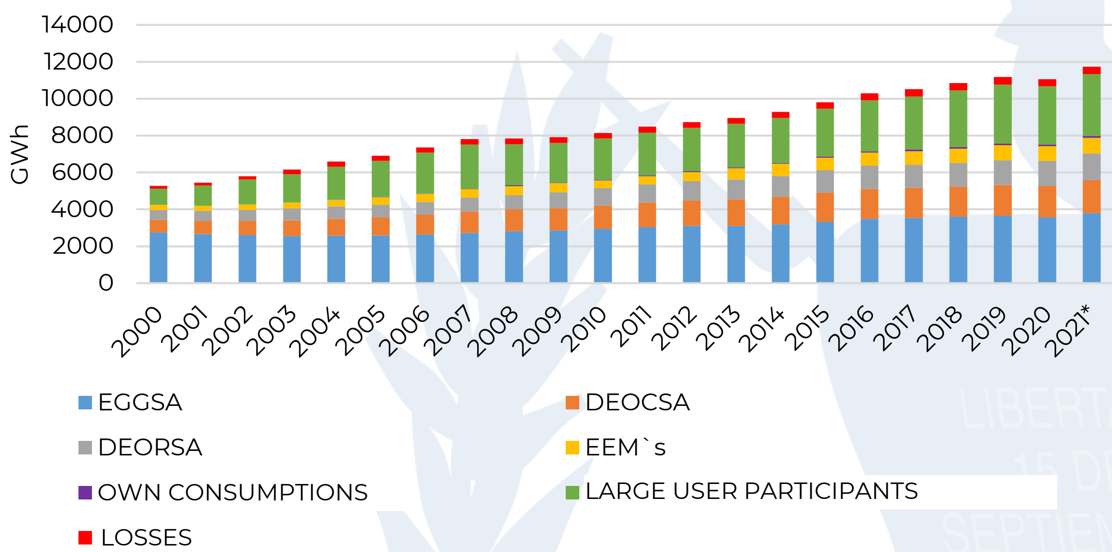
6.1. ENERGY DEMAND

The growth of electricity demand has shown correlation with the socioeconomic reality of a country, from 2000 to 2020 the national demand has increased at different rates, it should be noted that in 2008 there was only a 0.5% growth in demand compared to the previous year, also the year with the highest growth was 2015 with a rate of 7.42%.

The year 2020 is considered as an atypical year, since the growth in demand was not as expected, due to the restrictions adopted at the national level to contain the Covid-19 pandemic, there was a growth of -1.17% compared to 2019.

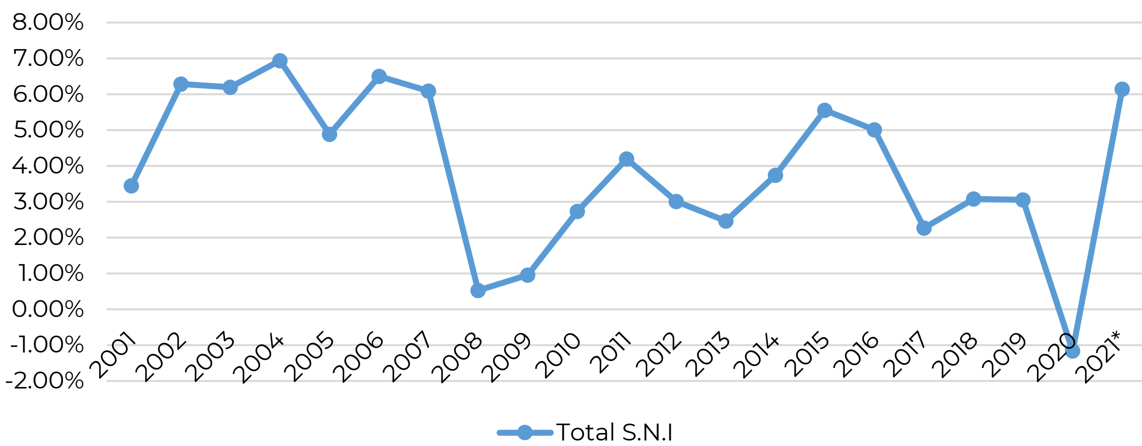
Graph 41 shows the annual growth trend in consumption, mainly driven by demand from large users and distribution agents.

Graph 41: Historical annual energy demand, period 2000-2021*.



Source: Proprietary production with information from the AMM.

Graph 42: Variation in the growth rate of energy consumed annually, period 2000-2021*.



Source: Proprietary production with information from the AMM.

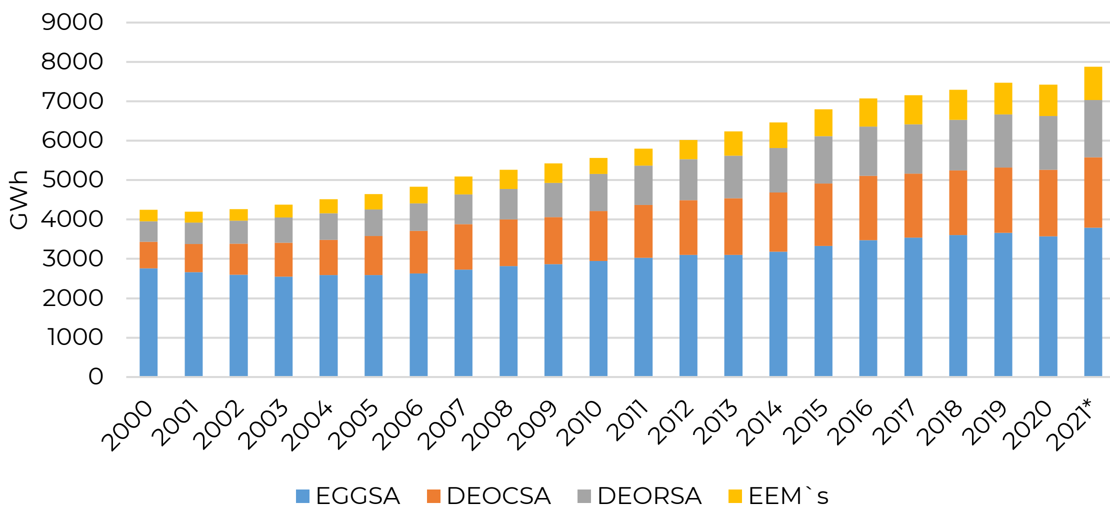
6.2. DISTRIBUTORS

The 2020 electricity demand of distribution companies in Guatemala was 7,421.42 GWh, which was 0.46% lower compared to 2019, which was 7,475.63 GWh. This demand represents approximately 67% of the national energy demand.

Graph 43 shows the growth of the historical energy demand of the three distribution companies registered as distribution agents, subject to the procedures indicated in the General Electricity Law. The growth on the part of DEOCSA and DEORSA is directly related to the rural electrification works carried out through the Rural Electrification Plan and INDE, which allowed the demand in 2000, around 1,186.75 GWh, to increase to 2,210.98 GWh in 2010, and 2,920.79 GWh in 2018. Likewise, even for the year 2020, which is considered an atypical year due to the crisis generated by the covid-19 pandemic, there was an increase in this demand to 3,051 GWh, which was higher than in 2019 of 3,005 GWh.

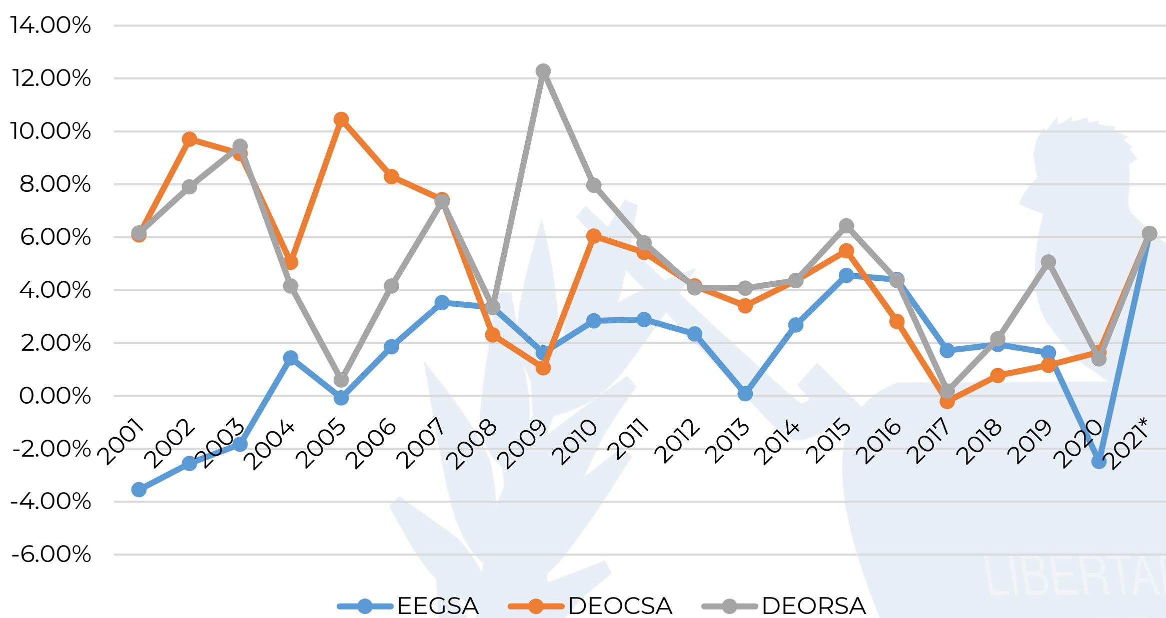
Graph 44 also shows the historical growth rates of demand by distribution agent, in the case of DEOCSA and DEORSA it can be observed that in 2008 the growth rate decreased abruptly. In 2020, the growth rate for the distributor DEOCSA was 1.65 %, which was a higher rate than that of 2019; for DEORSA the growth rate was 1.40 %, which was lower than that of the previous year and for EEGSA, the growth rate was -2.49%.

Graph 43: Annual historical energy demand of distribution companies, period 2000-2021*.



Source: Proprietary production with information from the AMM.

Graph 44: Variation in the growth rate of energy consumed by distribution agents.

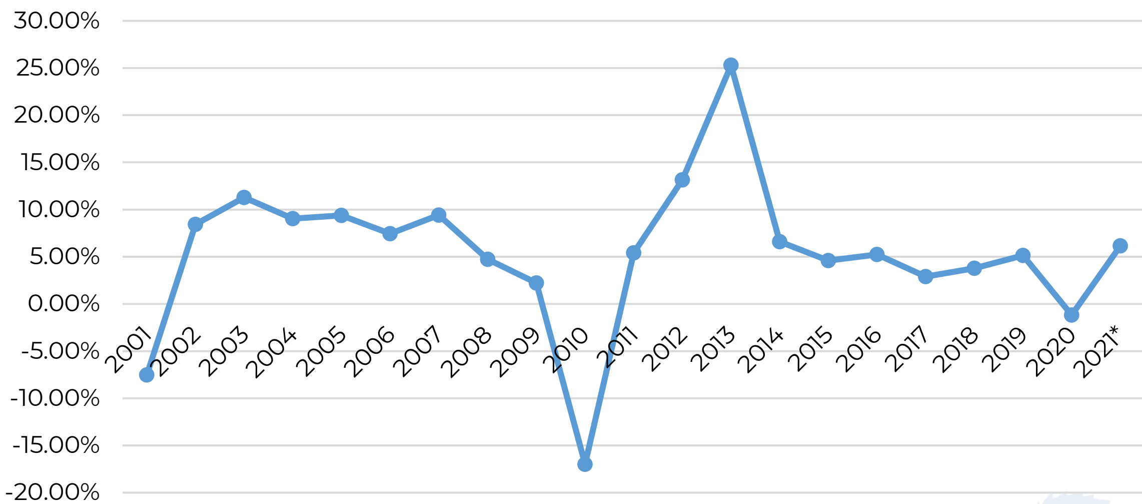


Source: Proprietary production with information from the AMM.

6.3. MUNICIPAL ELECTRIC UTILITIES

In 2020, annual demand was approximately 795.83 GWh, which represented a decrease of 1.16% with respect to the previous year; on average over the last five years, without considering the atypical year of 2020, annual demand has grown by 4.33%. Graph 45 shows the growth that has occurred from 2001 to 2020, with a 17% decrease in demand in 2010 compared to 2009.

Graph 45: Variation in the growth rate of energy consumed by municipal electric utilities.



Source: Proprietary production with information from the AMM.

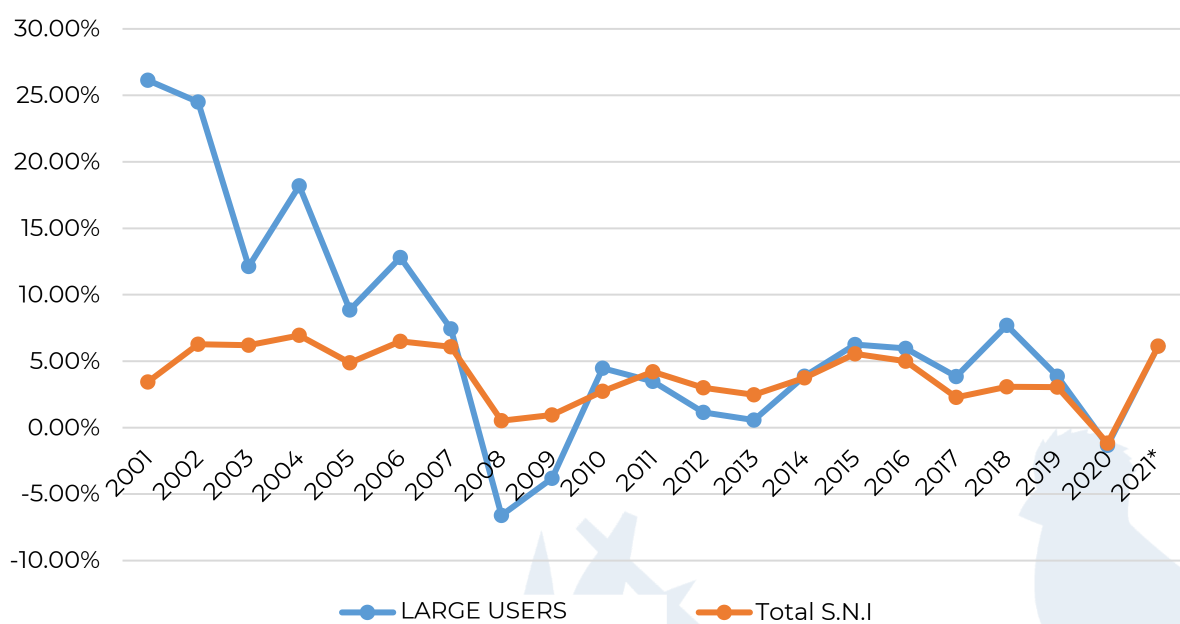
6.4. LARGE USERS

Economic growth drives energy consumption for the production of goods and services, for the year 2020 the demand of large electricity users was 3,158.27 GWh, representing 29 % of total demand and a reduction of 1.16 % compared to the previous year.

In recent years, a greater correlation has been observed between national economic growth and total energy consumption, partly because the demand of public and private distribution companies has occurred vegetatively, therefore, it could be assumed that the variable with the greatest impact on the growth assumptions of national demand is not population growth but economic growth.

Graph 46 illustrates the growth rates of both the National Interconnected System and large users, for example it can be observed in 2007 and 2008 a reduction of growth rates even to negative values, with its subsequent recovery in 2010, and a new drop in 2013. During the subsequent years it can be observed that the behavior is completely influenced by the optimistic or not optimistic perceptions of the economy, as during 2017 again the growth was reduced to 3.9%. For 2020, a reduction in growth rates is again shown for both energies consumed by large users and total consumed in the S.N.I. On average, during the last 5 years, without taking into account the outlier year of 2020, there has been a 5.5% growth in annual demand by large users.

Graph 46: Variation in the growth rate of energy consumed by Large Users.



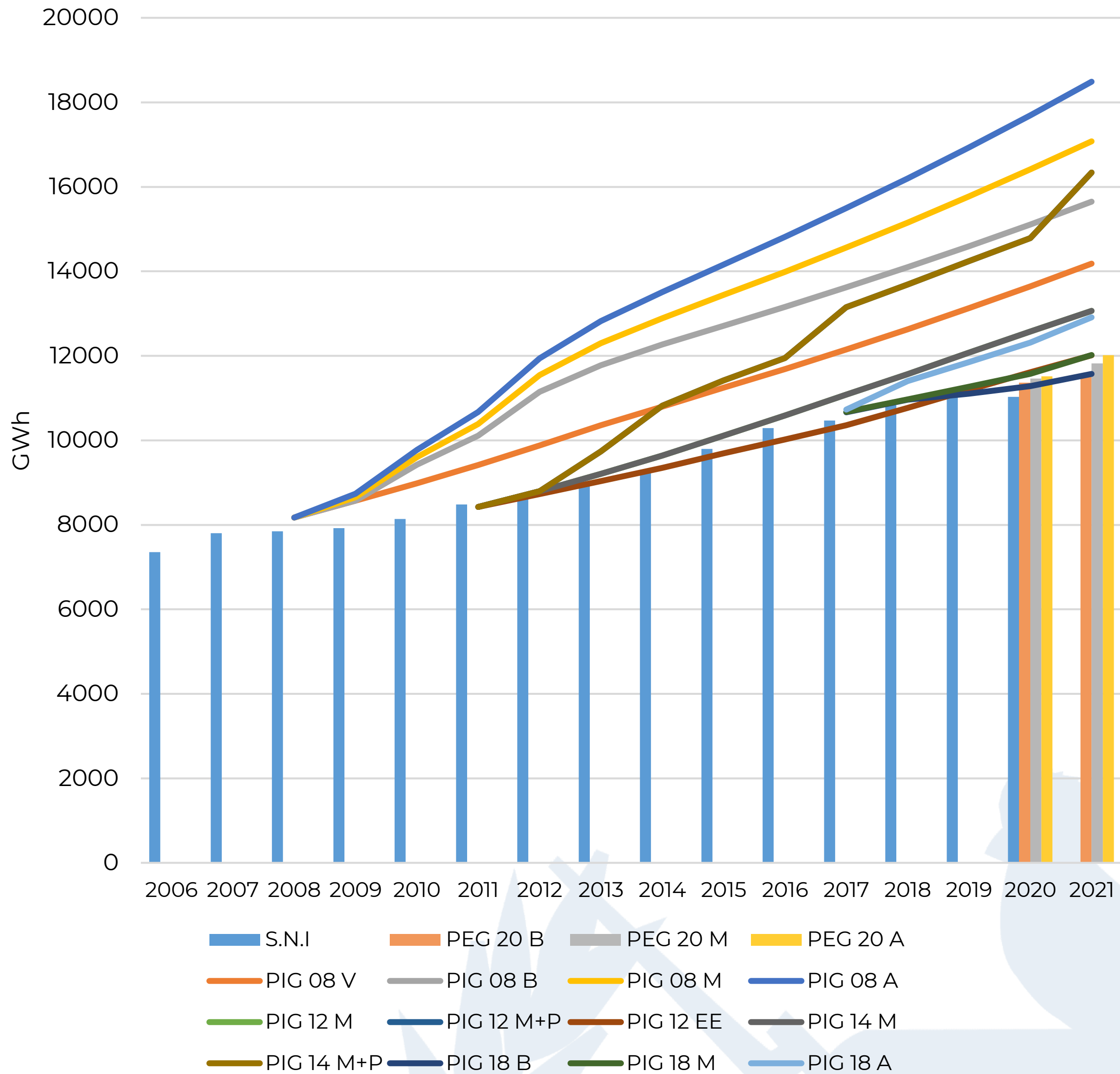
Source: Proprietary production with information from the AMM.

6.5. HISTORICAL DEMAND PROJECTIONS

In Guatemala, the projection of electricity demand is carried out with the purpose of evaluating the expansion plans for both generation and transmission of electricity, actions carried out since 2008 once the reforms to the Regulations of the General Law on Electricity and the Regulations of the Wholesale Market Administrator came into force. In the period 2008 to 2012, the Indicative Plans were developed by the CNEE, however, the governmental agreement no. 631-2007 published on January 17, 2007. 631-2007 published on January 17, 2008, which reformed the Internal Organic Regulations of the MEM, created the Energy and Mining Planning Unit, which among its functions has the preparation of the Expansion Plans of the electricity system and establish the energy demand of the population and the productive economic activity of the country. From 2013 onwards the expansion plans have been carried out by the Ministry of Energy and Mines, and since 2016 they have been carried out by the Unit of Mining Energy Planning as a specialized Technical Body of the Ministry.

The projection of electricity demand used in 2012, made optimistic projections regarding economic and population growth in the medium and high scenarios, however, there were scenarios that when compared with historical information up to 2020, were in the margin of acceptance with respect to reality. For example, the annual energy demand of the 2012 energy efficiency scenario is representative of the current reality, since the error percentage was 5.31%; likewise, the annual energy demand of the 2014 medium scenario and the 2018 low scenario present errors of 14% and 2.33%, respectively, in relation to the real demand recorded in 2020. It should be noted that in 2020 there was a decrease in demand compared to 2019, mainly due to the collateral effects of the Covid-19 pandemic.

Graph 47: Historical electric power demand compared to the demand projection of the previous Plans.

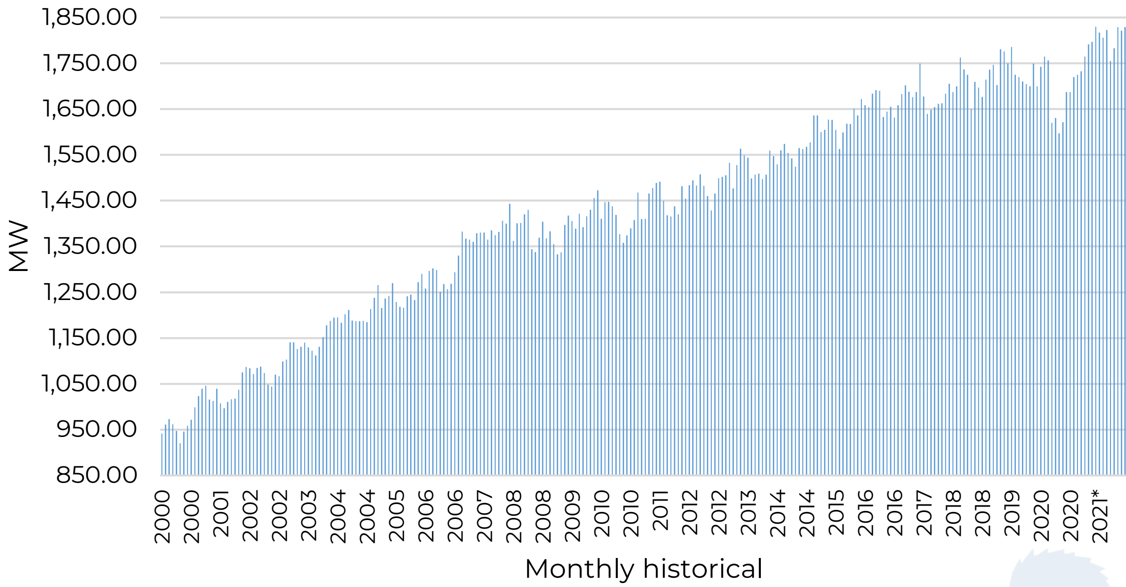


Source: Proprietary production with information from the AMM.

6.6. POWER DEMAND

The maximum electric power demand for each month since 2001 is shown in Graph 48, which has grown at an average monthly rate of 0.23%, and an average annual rate of 3.0%. However, as mentioned above, demand for 2020 decreased, thus presenting an annual growth rate of -1.2% with respect to 2019.

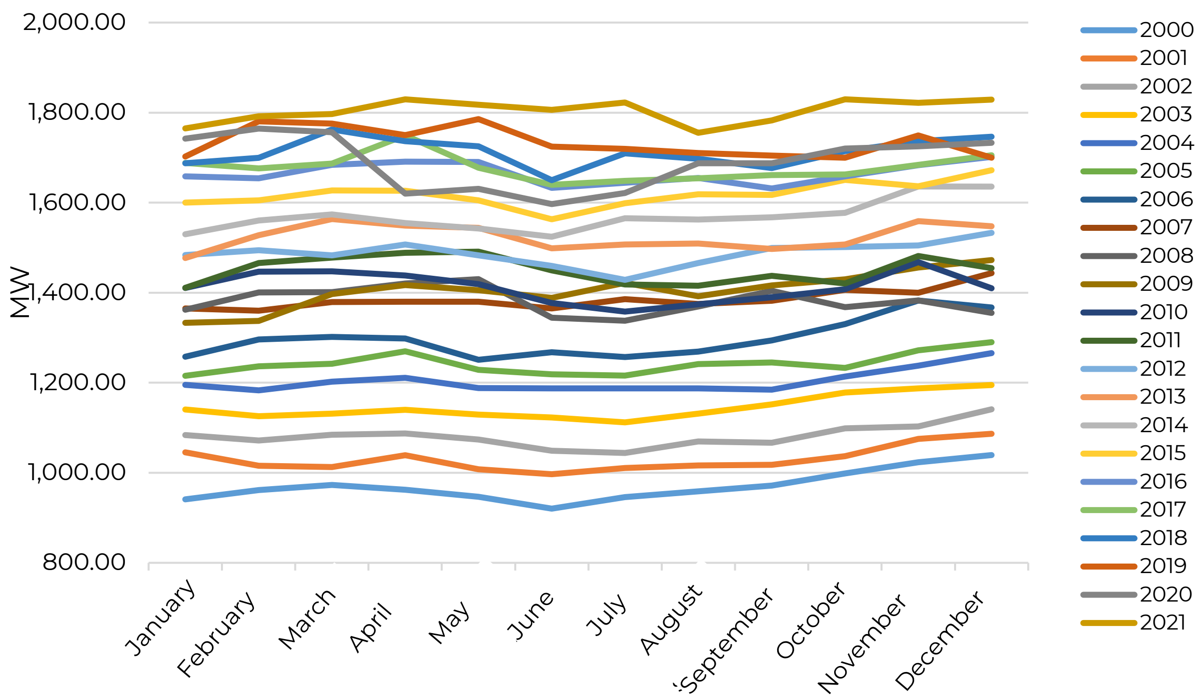
Graph 48: Maximum power demanded per month.



*Until November 2021.
Source: Proprietary production with information from the AMM.

The 2020 peak power demand was 1,765 MW, and this was submitted in the month of February; the 2019 peak power demand was 1,786 MW and was submitted in the month of May; and the 2018 peak power demand was 1,763 MW submitted in the month of April.

Graph 49: Maximum power demanded each month, ordered annually.



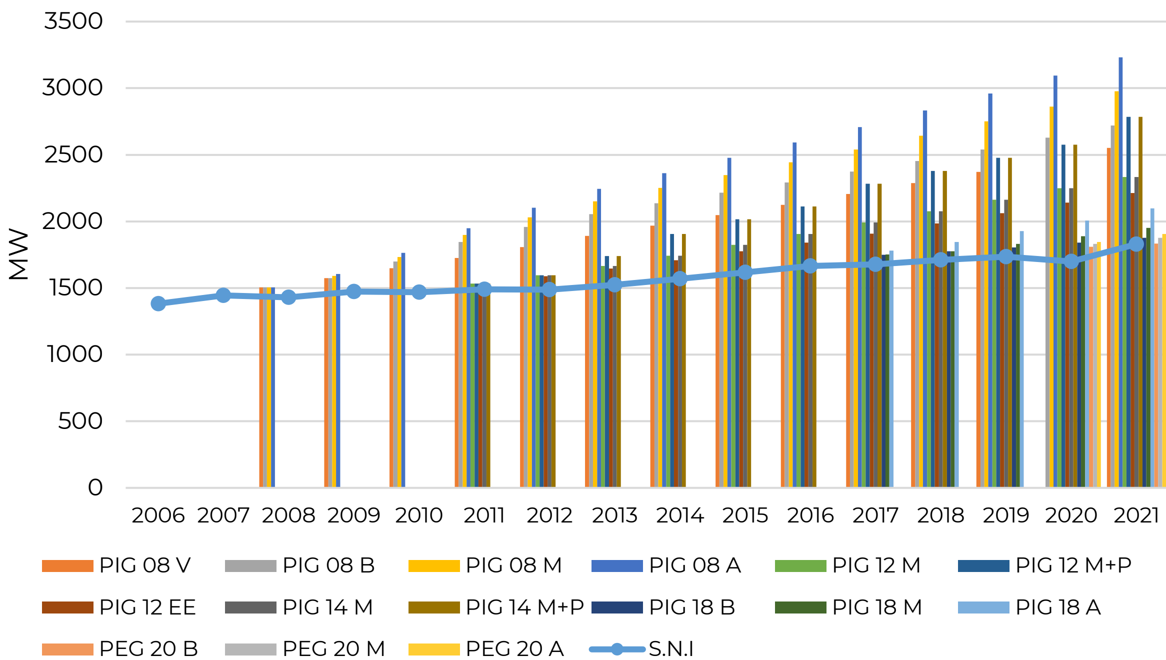
*Until November 2021.
Source: Proprietary production with information from the AMM.

Graph 49 presents the maximum power demanded each month, ordered to compare the annual growth from 2000 to 2021, it can also be clearly observed that in the first 10 years that the maximum demand tended to occur in the months of November or December, then from 2007 onwards a slight growth began to occur in the first half of each year and from 2017, the maximum annual demand has been given for this first period.

According to the legal and regulatory framework concerning the Guatemalan generation system, the Indicative Expansion Plans have presented the expected maximum demand projections since the first edition, made in 2008 by the National Commission of Electric Energy, until the last edition made by the Unit of Mining Energy Planning of the Ministry of Energy and Mines. Since then, the projections related to the growth of electric energy demand and the maximum power demand have allowed the expansion of both the generation system and the transportation system, which allows the electric sub-sector to have sufficient supply for the residential, industrial, and commercial sectors.

Graph 50 allows comparing the demand projections made at the time for the different Indicative Expansion Plans of Generation with the historical maximum power demand.

Graph 50: Projections of maximum annual power demand compared to historical.

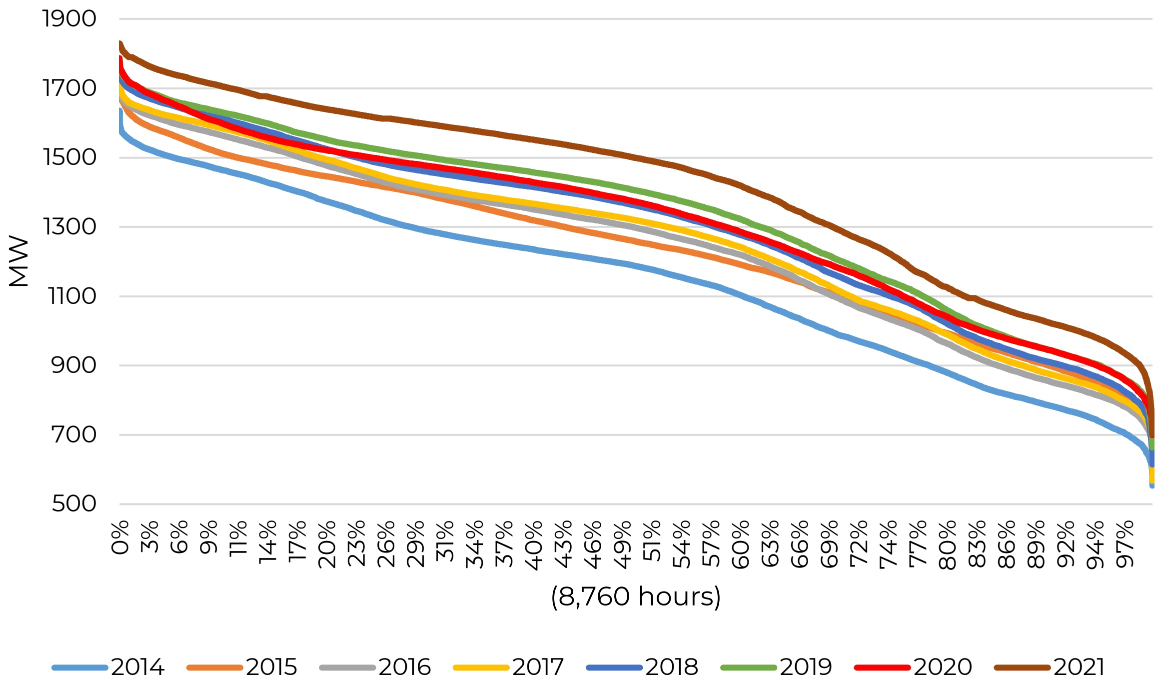


*Until November 2021.
Source: Proprietary production with information from the AMM, CNEE y MEM.

The growth of the maximum power demand has historically occurred vegetatively due to population growth and economic growth. It is the latter that has the greatest uncertainty and has the greatest influence on the growth of the maximum power demand, especially in the case of energy intensive industries. Historical information allows recommending to the national generation system and to the power plants that make up the generation park an approximate market in which they can participate; however, the attraction of energy-intensive industries is also an activity that can be done privately.

The hourly power demand of the Interconnected National System, ordered from the highest to the lowest, allows knowing the power demand from a market perspective. For 2020, 100% of the year it was necessary to supply 695 MW, which represents a growth of 4.5% with respect to 2019; 25% of the time, it was necessary to supply, for 2020, a demand of 1,376 MW, and only 10% of the year was demanded a power higher than 1,604 MW.

Graph 51: Annual Monotonic Hourly Power Demand Curves.



Source: Proprietary production with information from the AMM.

Greenhouse Gas Emissions

CHAPTER 7

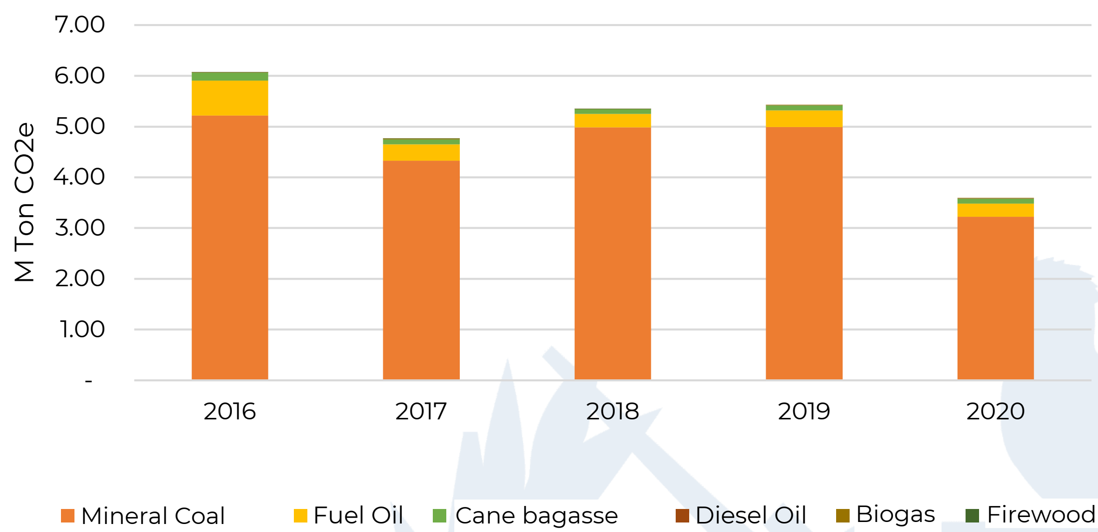
INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

7. GREENHOUSE GAS EMISSIONS

The calculation of GHG emissions for the country's energy sector is prepared annually on a voluntary basis by the Ministry of Energy and Mines, based on the IPCC 2006 methodology; of the electricity subsector, the generation system is the main emitter.

The following graph shows the calculation of GHG emissions for the last five years of electric power generation, showing that coal is the energy source with the highest share of emissions in the subsector. The year 2020 shows a considerable decrease with respect to previous years (51% with respect to 2019), this was due to the increase in the participation of hydroelectric plants in the generation matrix caused by storms Eta and Iota.

Graph 52: Annual calculation of GHG emissions from electricity generation.



Source: Proprietary production with information from the Ministry of Energy and Mines.

It is important to note that hydroelectric, photovoltaic and wind power plants do not appear in this count, since their direct emissions are zero, and their indirect emissions are included in the rest of the energy sources.

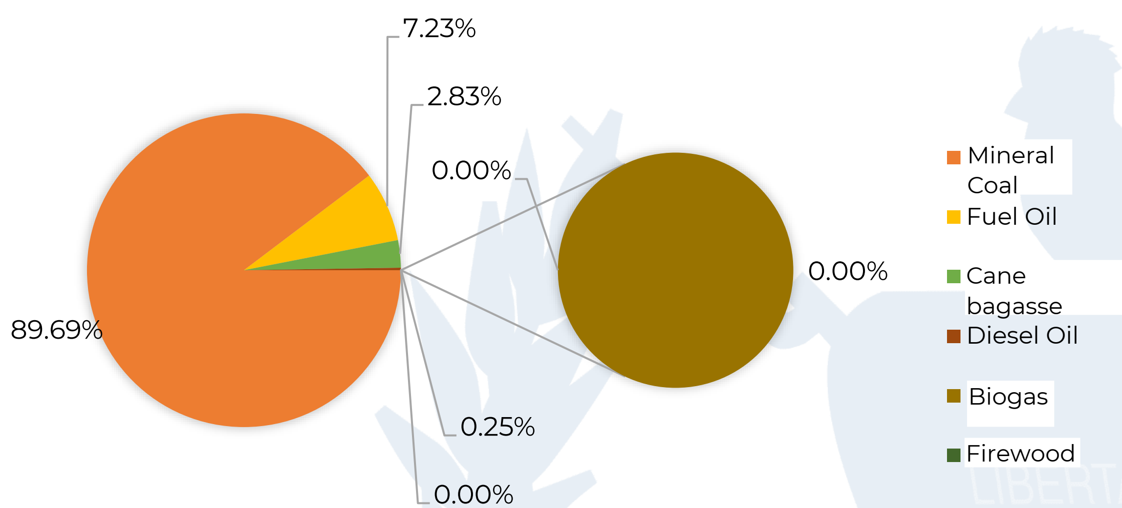
Table 9: Calculation of GHG emissions from electricity generation during 2020.

Energetic	Year 2020 (Ton CO2e)	Year 2020 (Ton CO2e)
Carbon	3,221,981.77	89.69%
Bunker	259,777.22	7.23%
Cane Bagasse	101,536.26	2.83%
Diesel	9,133.34	0.25%
Biogas	21.60	0.00%
Firewood	-	0.00%
Total	3,592,450.19	100 %

Source: Proprietary production with information from the Ministry of Energy and Mines.

During 2020, coal used as energy for electricity generation represented 89.69 % of the total emissions of this subsector, as shown in Table 9 and in the following graph, the energy sources that represent very low emissions in this subsector correspond to the energy sources of lesser use for electricity generation.

Graph 53: Calculation of GHG emissions from electricity generation during 2020.



Source: Proprietary production with information from the Ministry of Energy and Mines.

7.1. ENERGY POTENTIAL

Guatemala still has a large potential for renewable energy resources. Statistics and estimates made by the Ministry of Energy and Mines, published through the National Plan of Energy indicate that:

- The greatest exploitable potential is the water resource, since it is the country's largest resource, and it is estimated that 4,690 MW remain to be exploited.
- The geothermal resource has been little exploited; there is still 966 MW available for exploitation.
- Guatemala's wind potential is estimated at 204.12 MW.

- **SOLAR**

The solar potentials found within the Guatemalan territory are extremely favorable for the installation of photovoltaic plants, being in the department of Alta Verapaz, where the lowest solar potentials for electricity generation are reached between 5,039000 to 5,100000 kWh/m^2.

In the rest of the country, except for some parts of the southern region, solar energy potentials range from 5,200001 to 6,500000 kWh/m^2; these values can be seen in detail in the following figure.

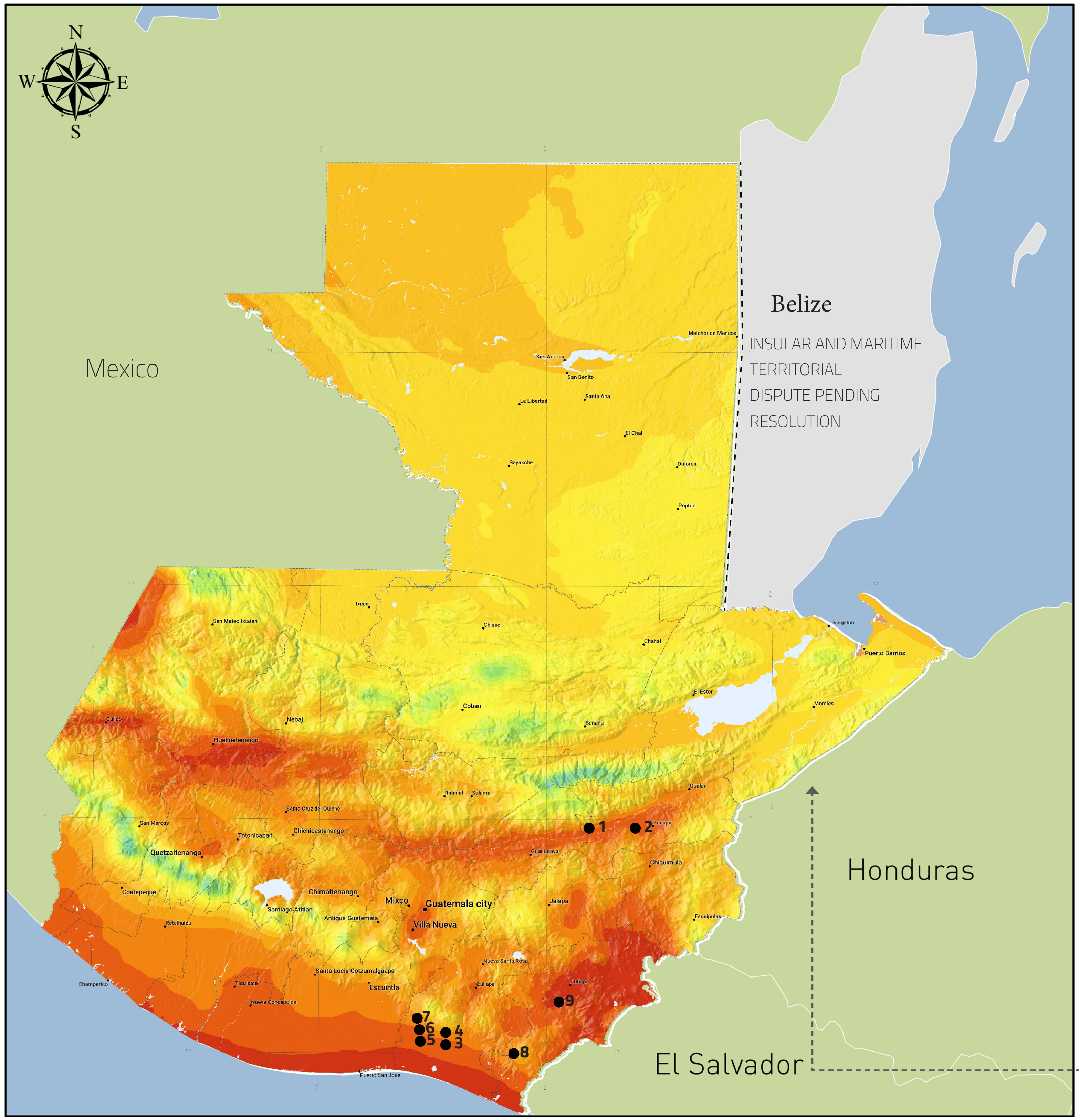
SOLAR RADIATION MAP

Location of Generating Plants in operation with incentives benefits

GOBIERNO *de* GUATEMALA
DR. ALEJANDRO GIAMMATTEI

MINISTERIO DE ENERGÍA Y MINAS
DIRECCIÓN GENERAL DE ENERGÍA

BICENTENARIO GUATEMALA 1821-2021



50 25 0 50 100 150 200 kilometers

Solar Radiation in Guatemala

Source: Global Solar Atlas

Long term average of daily/yearly sum, period 1999-2018

Daily sum: < 4.0 4.4 4.8 5.2 5.6 6.0 > kWh/m²

Yearly sum: < 1461 1607 1753 1899 2045 2191 >

● Solar Power Plants in operation

Solar Generating Plants in operation

No.	Entity	Project	Municipality	Department	Installed Capacity MW	Project Status
1	Fontana de Trevi, S.A.	Project for 119kWh solar photovoltaic installation of the roofs of the warehouses of Fontana de Trevi, S.A.	Usumatlán	Zacapa	0.135	Operation
2	Sibo, S.A.	Granja Solar Fotovoltaica Sibo	Estanzuel	Zacapa	5	Operation
3	Anacapri, S.A.	Horus I	Chiquimulilla	Santa Rosa	50	Operation
4	Anacapri, S.A.	Horus II	Chiquimulilla	Santa Rosa	30	Operation
5	Tuncaj, S.A.	Granja Solar Taxisco	Taxisco	Santa Rosa	1.8	Operation
6	Tuncaj, S.A.	Granja Solar El Jobo	Taxisco	Santa Rosa	1.2	Operation
7	Tuncaj, S.A.	Granja Solar La Avellana	Taxisco	Santa Rosa	1.2	Operation
8	Tuncaj, S.A.	Granja Solar Pedro de Alvarado	Moyuta	Jutiapa	1.8	Operation
9	Tuncaj, S.A.	Granja Solar Buena Vista	Jutiapa	Jutiapa	1.5	Operation

Database and proprietary production by the Renewable Energies Department of the General Direction of Energy

Information updated to December 2020

7.2. WIND

The wind potential, unlike the solar potential, is found in the eastern region of the country, where the largest capacities of this resource are located; the most relevant departments are Chiquimula, Jutiapa and Zacapa; and in the central region of the country, the department of Guatemala.

The following figure shows the points with the greatest wind potential in the country, with the red points being those with the greatest capacity to generate electricity with this resource.

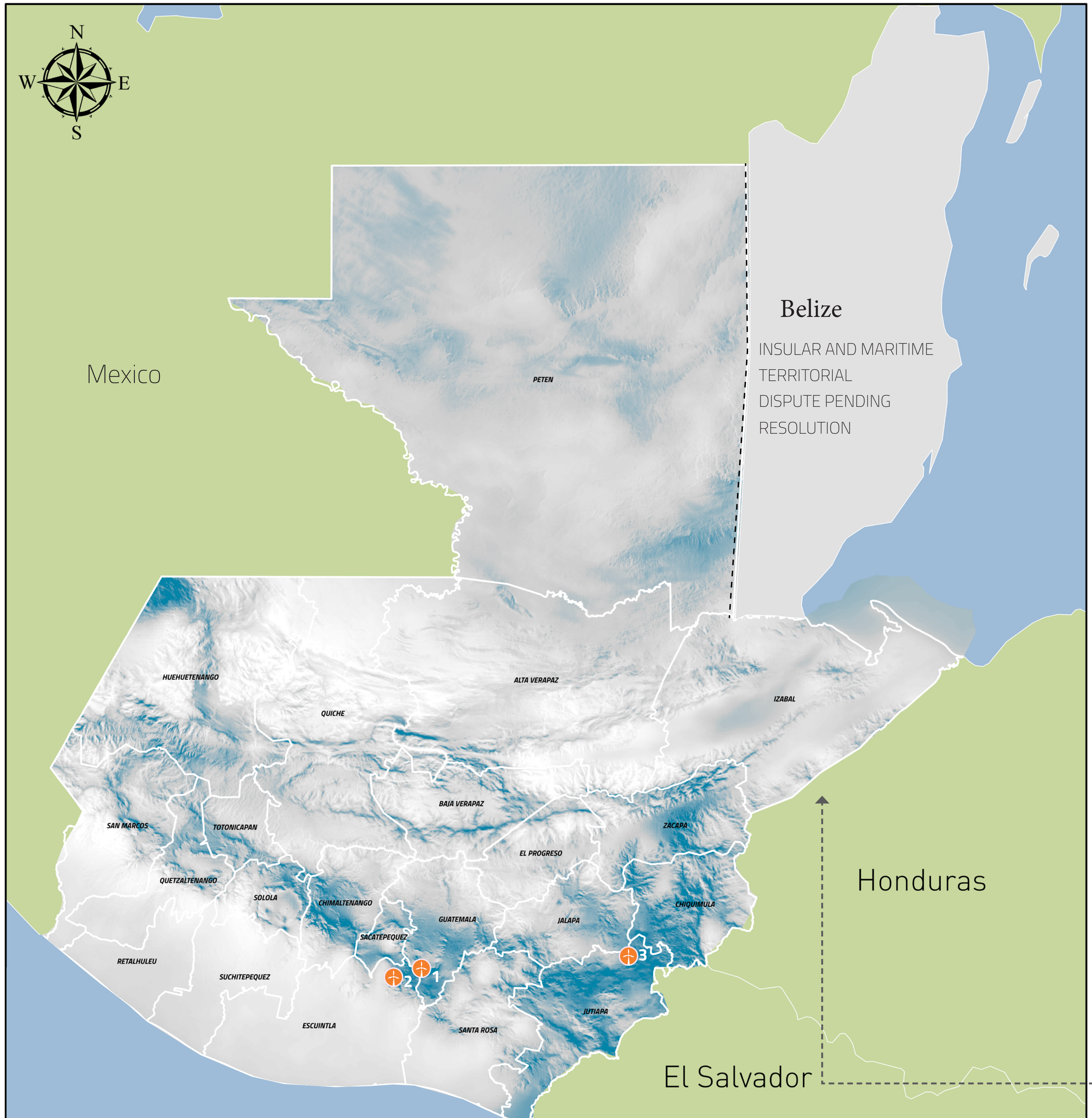
WIND DENSITY MAP

Location of Wind Power Generating Plants in operation with incentive benefits

GOBIERNO de GUATEMALA
DR. ALEJANDRO GIAMMATTEI

MINISTERIO DE ENERGÍA Y MINAS
DIRECCIÓN GENERAL DE ENERGÍA

BICENTENARIO GUATEMALA 1821-2021



50 25 0 50 100 150 200 kilometers

m/s 10+ — 0
Wind density at 100m altitude
Wind Power Plants in operation

Wind Potencial in Guatemala
Source: Global Wind Atlas

Wind Power Generating Plants in operation

No.	Entity	Project	Municipality	Department	Installed Capacity MW	Project Status
1	San Antonio el Sitio, S.A.	San Antonio El Sitio	Villa Canales	Guatemala	52.8	Operation
2	Viento Blanco, S.A.	Viento Blanco	San Vicente Pacaya	Escuintla	23.1	Operation
3	Transmisión de Electricidad, S.A.	Las Cumbres	Agua Blanca	Jutiapa	31.5	Operation

Database and proprietary production by the Renewable Energies Department of the General Direction of Energy.

Information updated to December 2020

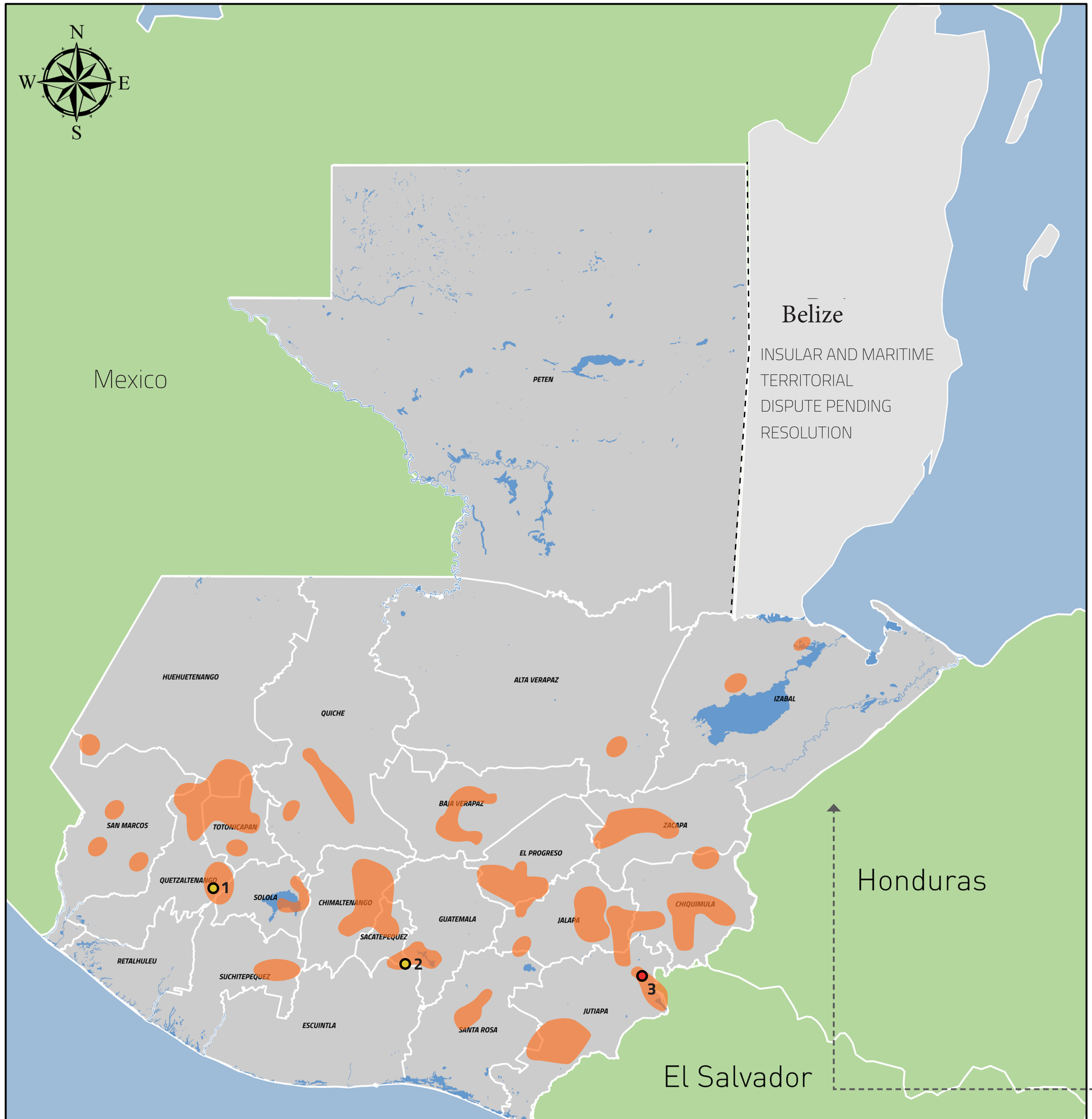
7.3. GEOTHERMICAL

Guatemala has geothermal potentials not yet exploited for electricity generation, in the following figure there is a map with descriptions of the geothermal points detected and classified within the national territory; in the northern region of the country are the most extensive areas of potential of this energy resource.

The same figure shows the approximate locations of the geothermal plants operating for the SNI.

MAP OF AREAS WITH GEOTHERMAL POTENCIAL

Location of Geothermal Power Plants



50 25 0 50 100 150 200 kilometers

Zone with geothermal potential
Geothermal power plants in operation
Geothermal power plants in process

Geothermal Potencial in Guatemala
Source: Geothermal Energy MEM-DGE.

GOBIERNO de GUATEMALA
DR. ALEJANDRO GIAMMATTEI
MINISTERIO DE ENERGÍA Y MINAS
DIRECCIÓN GENERAL DE ENERGÍA

BICENTENARIO GUATEMALA 1821-2021

Geothermal Generating Plants in process and operation

GEOTHERMAL PROJECTS IN GUATEMALA						
No.	Entity	Project	Municipality	Department	Installed Capacity MW	Project Status
1	Orzunil I de Electricidad, Limitada	Orzunil	Zunil	Quetzaltenango	24	Operation
2	Ortitlan Limitada	Ortitlan	San Vicente Pacaya	Escuintla	25.2	Operation
3	Geotermia Oriental de Guatemala, S.A.	Cerro Blanco	Asunción Mita	Jutiapa	50	In Process

Database and proprietary production by the Renewable Energies Department of the General Direction of Energy.

Information updated to December 2020

Areas with surface manifestations	
1	Momostenango
2	Sacapulas-Zacualpa
3	Chimaltenango
4	La Memoria
5	Atitlán
6	Sanarate
7	Monjas
8	Zacapa
9	Camotán
10	Granados
11	Esquipulas
12	Tajumulco
13	Quiché
14	Polochic- Agua Caliente
15	San Marcos-Tacaná
16	San Marcos-Malacatán
17	Polochic-Cantún
18	Polochic-Livingston

Fuente: Geothermal Resources Catalog Guatemala (DGE-MEM).

Geothermal Resources Catalog Guatemala (DGE-MEM 2015)

Compilation and updating of existing data of the fields that have been studied since 1972 by INDE with foreign assistance, which initiated the studies for the determination of this resource in order to produce electricity.

Generation System Planning Premises

CHAPTER 8

INDICATIVE EXPANSION PLAN OF THE GENERATION SYSTEM 2022 -2052

8. GENERATION SYSTEM PLANNING PREMISES

The Unit of Mining Energy Planning, in compliance with the legal and political framework of Guatemala, has carried out the Indicative Expansion Plan of the Generation System 2022-2052 considering a series of objectives and premises that allow the nation the sustainable and efficient supply of its energy needs, specifically those that require electricity.

This Plan uses a scenario evaluation methodology, each one evaluating the impact of several variables that act as premises, the first of these measurable variables being the one related to the role of the Government and the impact of public policies on the electricity generation system. This series of scenarios will focus on complying with the Energy Policy 2013-2027.

Guatemala's generation system has an effective capacity of 3,380.370 MW according to the Wholesale Market Administrator, 54% of this effective capacity uses renewable resources for electricity generation. It is for this reason that it is considered convenient to consider variables related to meteorology and climatic phenomena that have been scientifically demonstrated (climate change, El Niño, La Niña) to evaluate variables related to flow rates and rainy seasons, wind seasonality and the amount of available sunshine hours.

The current effective capacity that uses non-renewable resources is approximately 1,666 MW, therefore, the fuel cost variable is also considered in the evaluated scenarios; finally, the supply of energy and electric power demand must evaluate the demand growth rates, therefore, scenarios for low and medium growth are evaluated, since these have a higher probability of occurrence.

8.1. OBJECTIVES

The main objective of the Indicative Expansion Plan of the Generation System is to guarantee the national energy security of the electricity sub-sector.

The specific objectives are the following:

- Maintain a reliable electric energy service in its operation through the diversification of the electric generation matrix.
- To analyze, through different scenarios, the development of the national generation system, under the premises related to climate, fuel costs and the growth of energy demand.
- Promote the investment of new generation plants, especially by means of renewable and clean resources, for the efficient supply of the energy demand for the next thirty years.
- To offer security of electricity supply at competitive prices, seeking to optimize the costs of electricity supply through the entry of generating plants with higher efficiency and better technology than the current ones in the generation park.
- Evaluate the cost associated with the implementation of public policies related to national commitments with the mitigation of greenhouse gases, commitments acquired both nationally and internationally.
- Evaluate contingency scenarios related to climatic emergencies, as well as the shutdown of important generation plants in the system.

8.2. PLANNING METHODOLOGY

The methodology proposed by OLADE was used to design the scenarios included in the current plan, and computational tools were used to optimize the country's resources.

- Stochastic Dual Dynamic Program [SDDP].

In Guatemala, the generation system is planned on an annual basis, under the responsibility of the Wholesale Market Administrator, with the objective of operating at the lowest possible cost, respecting a series of quality premises in the operation of the system. UPEM uses the SDDP model, in the same way, for long-term planning, simulating the operation of the system, on this occasion, for thirty continuous years (2022 - 2052).

The model takes into consideration the historical information of variables such as the flow rates reported by the generating agents. Based on this information, the model produces synthetic series of future flows, with an auto regressive parameter model (ARP), where each synthetic series represents, for the entire planning horizon, a hydrological scenario.

Subsequently, with the information of operation and maintenance costs, fuel costs, transmission network parameters, energy and power demand and the characteristics of hydro, thermal and non-conventional renewable generation plants, the operating cost of the system is minimized considering the future cost function. The objective function of the whole model is the operation at minimum cost.

- Optimal Generation Environment and Network.

The main objective of the expansion planning process is to ensure an appropriate balance between electricity supply and demand, i.e., to determine the optimal set of generation plants and transmission paths that should be built to meet demand requirements over a study horizon, while minimizing a cost function under consideration:

  - Investment costs.
  - Penalty for energy not supplied.

In general terms, this decision process involves compliance with economic, reliability and environmental criteria, within the scope of national energy policies.

In summary, the objective of OptGen is to determine a least-cost investment schedule for the construction of new generation capacity, regional interconnections, among others.

8.3. PREMISES OF THE INDICATIVE PLAN FOR THE EXPANSION OF THE GENERATION SYSTEM

The assumptions of the plan are based on the projection of energy and electric power demand, fuel cost considerations, hydrological aspects, and the cost of the deficit. The methodology and assumptions considered in the demand projection scenarios for the 2022 - 2052 study period will be presented below.

8.4. ENERGY AND ELECTRIC POWER DEMAND PROJECTION

Upon reanalyzing the demand projections of the previous indicative plans, the common denominator found was that the projection has been overestimated. Currently, demand growth has increased conservatively with respect to the optimistic forecasts previously made.

The projection of energy and electric power demand scenarios in the Interconnected National System is one of the most important indicators, since this is a market signal and will determine the need for the execution of generation and transportation projects, and given the social conflict, it is necessary to establish more precise deadlines that give the opportunity to plan the construction of these projects.

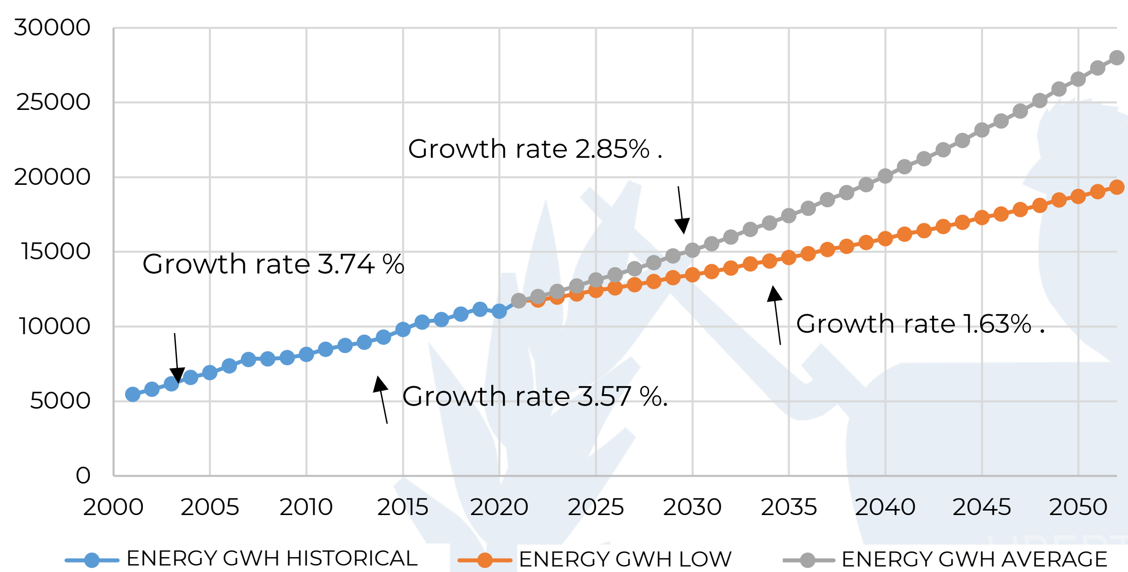
- **RESULTS**

To estimate energy demand there are several methodologies that can be used to determine consumption over time, traditionally econometric methods have been used that only use as explanatory variables the Gross Domestic Product and Population Growth, among others.

For the present indicative plans, a methodology designed by the Unit of Mining Energy Planning will be used, which has the objective of increasing the model's precision, in which a monthly breakdown was made where economic variables were related for the projection of the two most probable growth scenarios of energy and electric power demand.

As mentioned in the section on generation system planning assumptions, only the low and medium demand growth scenarios were considered, thus discarding the high scenario, since historically it has been shown that this scenario has a very low probability of occurrence. However, in the modeling of scenarios, the medium demand is considered since this is the one with the highest probability of occurrence.

Graph 54: Energy Demand Projection.



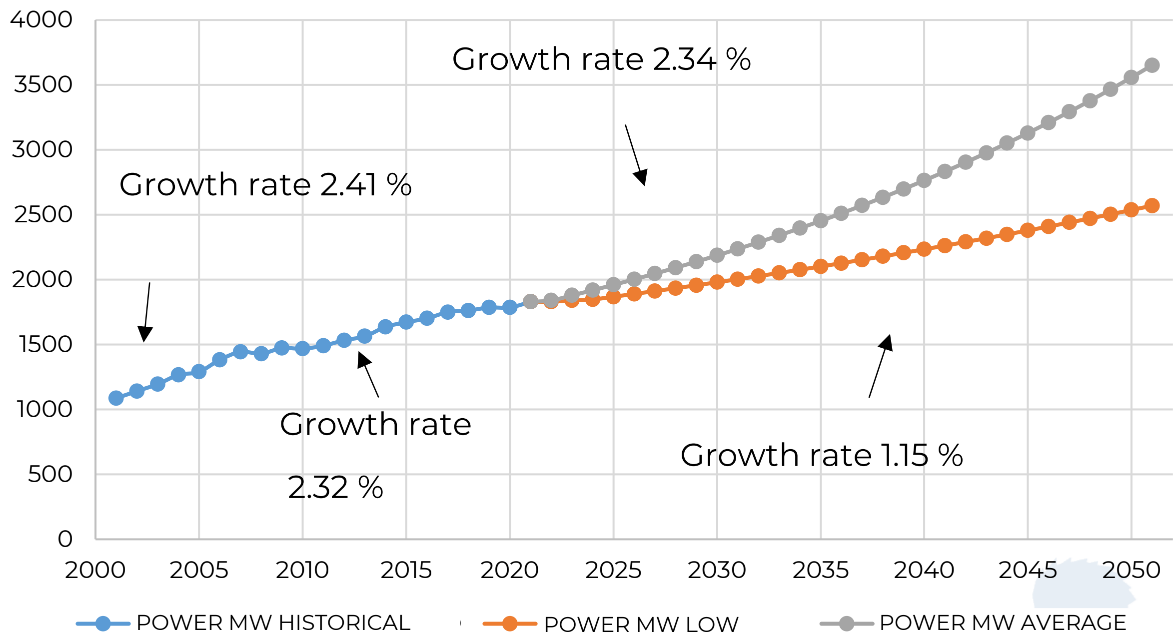
Source: Proprietary Production

After analyzing the different methodologies used to arrive at a demand as close to reality as possible, Graph 54 shows two demand scenarios, which will serve to fulfill the scenarios proposed.

○ ELECTRIC POWER PROJECTION

After analyzing the variables that directly affect demand growth, it was determined that this power projection will give a more effective plan, since it is not overestimating energy demand. This demand was analyzed in two scenarios directly related to electric power demand.

Graph 55: Annual Peak Power Projection.



Source: Elaborated by UPEM.

8.5. FUEL CONSIDERATIONS

In Guatemala, three types of fuels are imported for generation: coal, diesel, and bunker; in addition to these, two types of fuels are produced for the same purpose: firewood (energy forests) and biogas; it is important to note that all the fuels indicated in this section make up the group of non-renewable energy sources within the electricity generation matrix. Likewise, in 2020, natural gas began to be used as a resource for electricity generation in the department of Petén.

- ### FUEL PRICES

The long-term information on the prices of energy used for electricity generation in Guatemala was obtained from reliable sources that consider the perspectives of the international energy markets; it must be considered that future prices are uncertain and have unexpected fluctuations, however, there are explanatory variables and events that allow forecasting their evolution or having a reference of the expected price through a probable trajectory elaborated with coherent premises.

For Guatemala, these prices depend to a great extent on external events, for example, the exploitation of non-conventional crude oil; extreme weather situations, geopolitics and speculation in international markets also affect the price of fuels necessary for the generation of national thermal plants.

○ COAL

Guatemala does not have thermal coal mines; therefore, the power plants import coal from various Latin American countries, especially Colombia. Coal prices are subject to variability, especially due to the demand for coal in emerging countries such as China and India; however, it is an energy source with low extraction costs. Coal prices continue to fall, partly due to the increase in supply from several coal exporting countries.

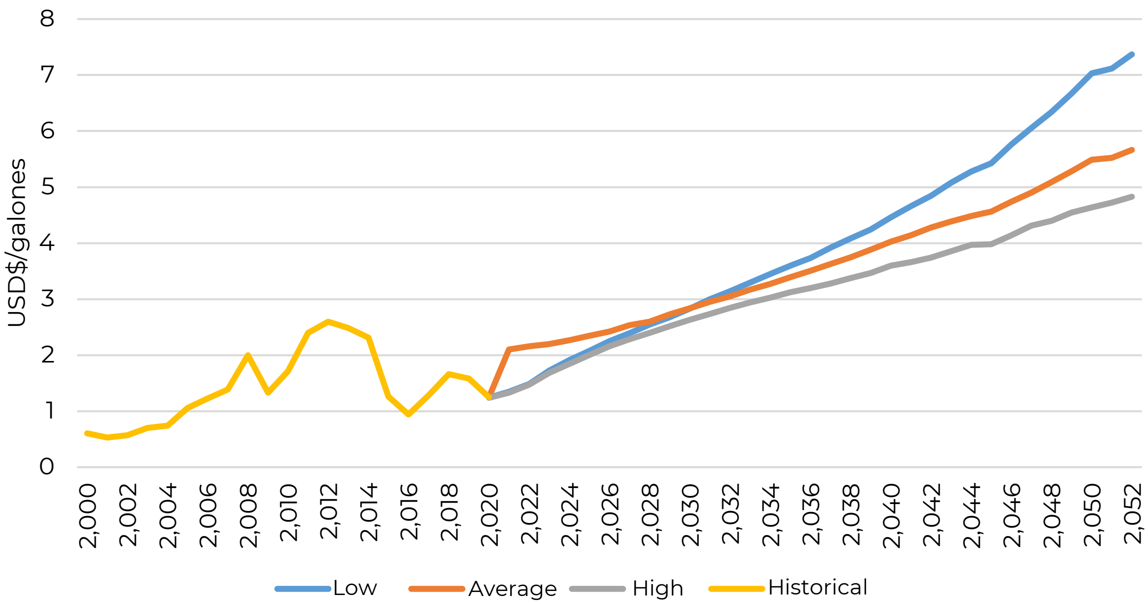
Graph 56: Projected Thermal Coal prices.

Source: EIA Annual Energy Outlook 2021.

- ### PETROLEUM DERIVATIVES

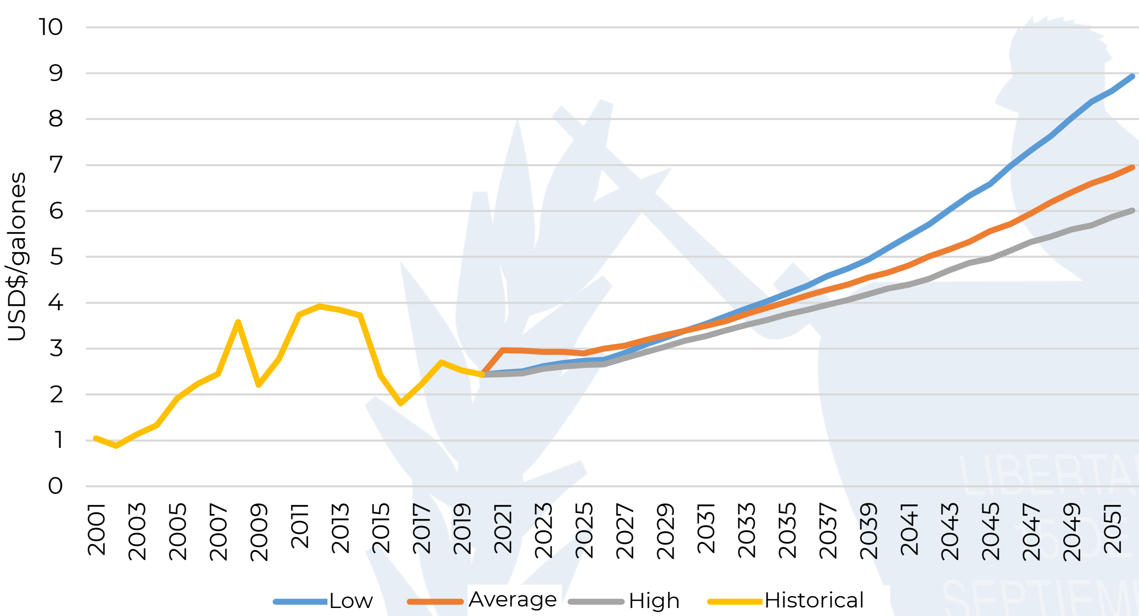
Fuel Oil No. 6, also known as Residual Fuel Oil or Bunker, is one of the most widely used petroleum derivatives in Guatemala for electricity generation; to a lesser extent Diesel is also used in reciprocating engines, and due to the refining process needed to obtain these derivatives, it is not possible to produce them in the country. These fuels are imported from those countries with refineries, the closest being Mexico and the USA; for the price projection, information from the EIA (Energy Information Agency, USA) was used, which reflects the sale price to power plants.

Graph 57: Projected Fuel Oil #6 prices at nominal values.



Source: EIA Annual Energy Outlook 2021.

Graph 58: Projected diesel prices at nominal values.



Source: EIA Annual Energy Outlook 2021.

○ NATURAL GAS

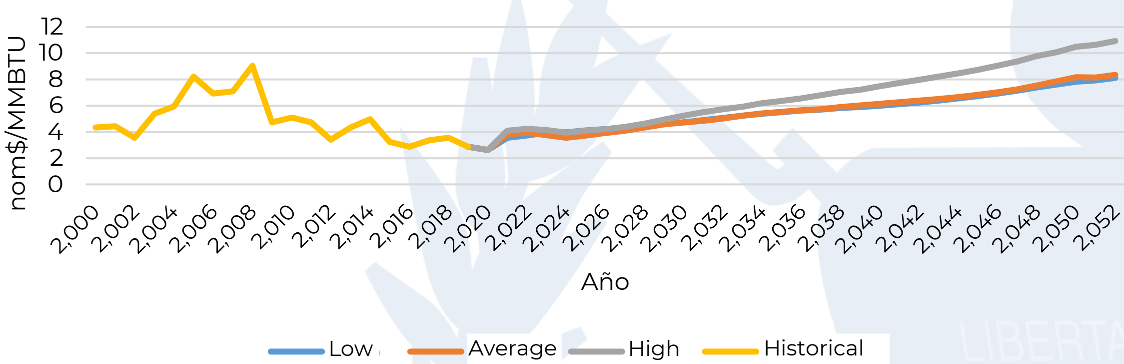
Natural gas has been one of the main energy sources for export and consumption throughout the Americas, where countries such as Colombia, Mexico, Argentina, Chile or Brazil satisfy their energy needs through its direct use and also through power generation plants that use this fuel.

In Central America, there were no known historical antecedents until 2018, when Panama inaugurated generation plants using liquefied natural gas -LNG-. The main LNG exporting countries in the Americas are Trinidad and Tobago, Peru and the USA, countries that have invested in liquefaction plants.

In August 2020, "Actun Can Gas Generación" began operating, which is an electricity generation project that uses natural gas, located in the municipality of Santa Elena in the department of Petén, with an installed capacity of 4 MW and an effective capacity of 2,586 MW, according to the AMM report as of June 2021. Therefore, this resource is an interesting option in the national electricity generation matrix.

The present Plan also makes the respective consideration of a power generation plant using liquefied natural gas located in the Guatemalan Caribbean, due to the possibility of supply from Sabine Pass (USA), Point Fortin (Trinidad and Tobago) or from the Panama Canal considering the investment in LNG storage tanks that they have made. Likewise, a liquefied natural gas generation plant located in Puerto San José and an additional plant located in Champerico are also being considered.

Graph 59: Projected Natural Gas prices.



Source: EIA Annual Energy Outlook 2021.

8.6. HYDROLOGICAL AND CLIMATIC ASPECTS

For the design of the synthetic flows, the flow database provided by the wholesale market administrator was used to simulate the new plants, considering the plants closest to the proposed plant, as well as the basin to which it belongs.

Three hydrological scenarios were generated, where the first one considered 25% of the driest flows, the second is the median and the third is 25% of the rainiest flows. However, for the preparation of the scenarios of this plan, only the driest and medium flows were considered, thus discarding the rainiest flows, because the probability of occurrence of rainy scenarios is very low compared to a dry or medium scenario.

Aspects related to the amount of available sunshine hours and wind patterns can also be considered as intrinsic to climatic phenomena, since a low amount of precipitation has coincided with windier periods in the main canyons of the country. The quantity and quality of photovoltaic generation has also correlated over the past four years with factors affecting hydroelectric production.

8.7. DEFICIT COST

The following shows how the Wholesale Market Manager proceeded to use the costs of energy not supplied, the priority being to guarantee the supply of the projected demand for the long term without probability of deficit. For each demand reduction step specified in the NCC-4, a price for energy not supplied was defined, as shown in Table 10.

The following shows how the costs of energy not supplied were estimated according to the criteria of the technical team of the Unit of Mining Energy Planning, used for each step of demand reduction. The cost of failure was considered that the lack of energy affects economic and social development.

Table 10: Demand Reduction Stages.

Demand Reduction Stages (DR)	Failure Cost Stages	Failure Cost Stages
	% del CENS	US$/MWh
0% < DR ≤ 2%	16%*CENS	279.7
2% < DR ≤ 5%	20%*CENS	349.6
5% < DR ≤ 10%	24%*CENS	419.5
DR > 10%	100%*CENS	1748.1

Source: Unit of Mining Energy Planning.

8.8.CANDIDATE PLANTS

In this Plan, fifty-seven projects were considered in evaluation condition for a total of ten most probable scenarios, in addition to which five contingency scenarios are evaluated, in which some important plants are taken out of operation and must be replaced in an optimal manner, these scenarios will be detailed in the following section.

The candidate plants were selected based on realistic criteria, since there is a likelihood that they will start operating on the agents' own initiative. Based on the collection of strategic information, the projects that each institution had were integrated and after the individual analysis of each one, the final list of feasible projects was established for their evaluation.

These aspects and criteria taken by the Unit of Mining Energy Planning, in review with the orientation of the previous Indicative Plans and their tangible results such as the Open Bidding PEG-1-2010, with the purpose of obtaining competitive prices in the purchase of power and energy for the Distributors, the Open Bidding PEG-2-2012, which was aimed to transform and diversify the electricity generation matrix with the purpose of reducing and stabilizing the prices in the electricity tariffs of the end users and the Open Bidding PEG-3-2013 which has the purpose of obtaining competitive prices in the purchase of power and energy for the Distributors, which was aimed at transforming and diversifying the electricity generation matrix in order to reduce and stabilize the prices of electricity tariffs for end users, and the Open Bidding PEG-3-2013, whose purpose is to purchase power and electric energy of up to 250 MW to cover the demand of end users of the distributors.

Derived from the fact that the General Law on Electricity states that "The installation of generating plants is free, which will not require authorization from any governmental entity and without any limitations other than those related to the conservation of the environment and the protection of people, their rights and property...", the Ministry of Energy and Mines gathered information and samples of interest from the different generating agents related to new generation plants.

Furthermore, in compliance with the Energy Policy, once the objective of supplying demand at competitive prices has been achieved, energy security must be sought. For this reason, at least fifty plants using renewable resources were modeled, in addition to natural gas thermal plants in the vicinity of potential Guatemalan deposits and in the Caribbean. Likewise, two additional plants with Natural Gas resources were considered, whose location is proposed in Puerto San José and Champerico, given the possibility of supplying them with Liquefied Natural Gas from the Pacific.

Due to the intermittent nature of the wind and solar plants, for this plan we considered the costs that would be incurred by providing them with an appropriate power backup, according to the capacity of each of these plants. Inder to have a better energy management on intermittent renewable plants.

The following is a list of all the plants that were selected to be candidates in the various scenarios of the proposed planning.

Table 11: Candidate Plants

	PLANTS	CODE	POWER (MW)	RESOURCE	INVESTMENT COST (M USD)	FIXED COST $/KW AÑO	OYM $/MWH
1	GDR Biogás 1	BGS-I	5	Biogas	13	7.11	5
2	GDR Biogás 2	BGS-II	5	Biogas	13	7.11	5
3	GDR Biogás 3	BGS-III	5	Biogas	13	7.11	5
4	Eólica ESC	ESC-EI	20	Wind Onshore	81.34	56	9.7
5	Eólica GUA	GUA-EI	25	Wind Onshore	100	56	9.7
6	Eólica HUE	HUE-E	40	Wind Onshore	192	56	9.7
7	Eólica JUT 1	JUT-EI	50	Wind Onshore	200	56	9.7
8	Eólica JUT 2	JUT-EII	25	Wind Onshore	101.67	56	9.7
9	Eólica JUT 3	JUT-EIII	50	Wind Onshore	195	56	9.7
10	Eólica JUT 4	JUT-EIV	60	Wind Onshore	240	56	9.7
11	Eólica JUT 5	JUT-EV	60	Wind Onshore	240	56	9.7
12	CPO-GNL	CPO-GNL	200	Natural Gas	200	9.7	3
13	PSJ-GNL	PSJ-GNL	200	Natural Gas	200	11	3
14	GN Petén	PTN-GNI	25 - 50	Natural Gas	55	11	9.42
15	GNL Pto. Barrios	PUB-GNL	100 - 200	Natural Gas	220	11.7	3
16	Geo AMA	AMA-G	50	Geothermic	200	120	1
17	Geo Atitlán	ATI-G	20	Geothermic	80	120	1
18	Geo Ayarza	AYA-G	20	Geothermic	80	120	1
19	Geo Cerro Blanco	CBL-G	7.5	Geothermic	30	120	1
20	Geo El Ceibillo	ECE-G	20	Geothermic	80	120	1
21	Geo EST	EST-G	15	Geothermic	60	120	1
22	Geo Los Achiotes	LAC-G	15	Geothermic	60	120	1
23	Geo MOY	MOY-G	20	Geothermic	80	120	1
24	Geo Palencia	PAL-G	20	Geothermic	80	120	1
25	Geo Retana	RET-G	15	Geothermic	60	120	1
26	Geo SMR	SMR-G	24	Geothermic	96	120	1
27	Geo TEC	TEC-G	40	Geothermic	160	120	1
28	Geo TOT	TOT-G	25	Geothermic	100	120	1
29	Geo ZUN 2	ZII-G	30	Geothermic	120	120	1

30	Geo ZUN	ZUI-G	35	Geothermic	140	120	1
31	GDR H1	GDR I	5	Hydric	19.5	54	10
32	GDR H2	GDR II	5	Hydric	19.5	54	10
33	GDR H3	GDR III	5	Hydric	19.5	54	10
34	GDR H4	GDR IV	5	Hydric	19.5	54	10
35	GDR H5	GDR V	5	Hydric	19.5	54	10
36	GDR H6	GDR VI	5	Hydric	19.5	54	10
37	GDR H7	GDR VII	5	Hydric	19.5	54	10
38	Alta Verapaz H1	HAV-HI	30	Hydric	78	40	10
39	Alta Verapaz H2	HAV-HII	45	Hydric	117	40	10
40	Alta Verapaz H3	HAV-HIII	80	Hydric	208	40	10
41	Huehuetenango H1	HUE-HI	30	Hydric	78	40	10
42	Huehuetenango H2	HUE-HII	50	Hydric	130	40	10
43	Huehuetenango H3	HUE-HIII	100	Hydric	260	40	10
44	La Paz	LPA-H	140	Hydric	490	40	10
45	Pojom	PJM-H	20	Hydric	78	40	10
46	San Andrés	SAN-H	10.8	Hydric	42.12	40	10
47	Usumacinta PTN H1	USU-HI	200	Hydric	600	40	10
48	Usumacinta PTN H2	USU-HII	200	Hydric	600	40	10
49	Jutiapa S1	SRO-SI	30	Solar Photovoltaic	116	8	13.75
50	Jutiapa S2	SRO-SII	20	Solar Photovoltaic	79.34	8	13.75
51	Jutiapa S3	SRO-SIII	30	Solar Photovoltaic	116	8	13.75
52	Sol Zacapa	SRO-SIV	20	Solar Photovoltaic	77.34	8	13.75
53	El Progreso Solar	SRO-SV	10	Solar Photovoltaic	40	8	13.75
54	Santa Rosa S1	SUR-SI	20	Solar Photovoltaic	73.34	8	13.75
55	Santa Rosa S2	SUR-SII	50	Solar Photovoltaic	167.5	8	13.75
56	Escuintla S1	SUR-SIII	100	Solar Photovoltaic	314	8	13.75
57	Escuintla S2	SUR-SIV	30	Solar Photovoltaic	116	8	13.75

Source: Elaborated by UPEM.

The plants evaluated in the different scenarios proposed comply with the premise of diversifying the electricity generation matrix, in addition to using different capacity options, which will allow the characteristics of the plants to be evaluated through all scenarios.

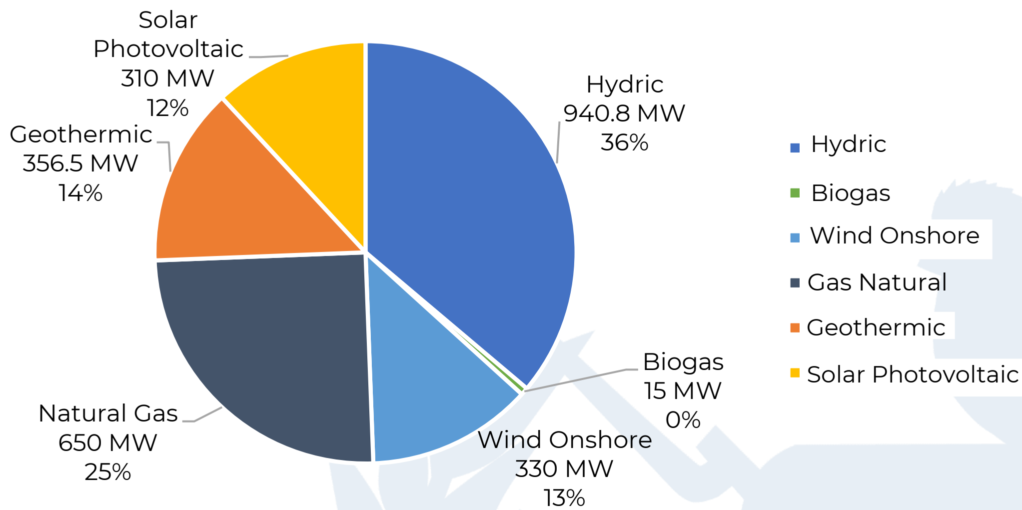
From Table 11 there are fifty-seven candidate plants to comply with the scenarios proposed, which are presented by type of resource in Table 12. A total of 2,602.30 MW is proposed, of which 100% are from clean resources and more than 75% are renewable.

Table 12: Candidate Plants by Resource.

Resource	Candidates	Power (MW)	Percentage
Biogas	3	15	0.58%
Wind	8	330	12.68%
Natural Gas	4	650	24.98%
Geothermic	15	356.5	13.70%
Hydroelectric	18	940.8	36.15%
Solar	9	310	11.91%
TOTAL	57	2,602.30	100.00%

Source: Proprietary Production.

Graph 60: Power of the Candidate Plants, in MW, evaluated for the most likely scenarios.



Source: Proprietary Production.

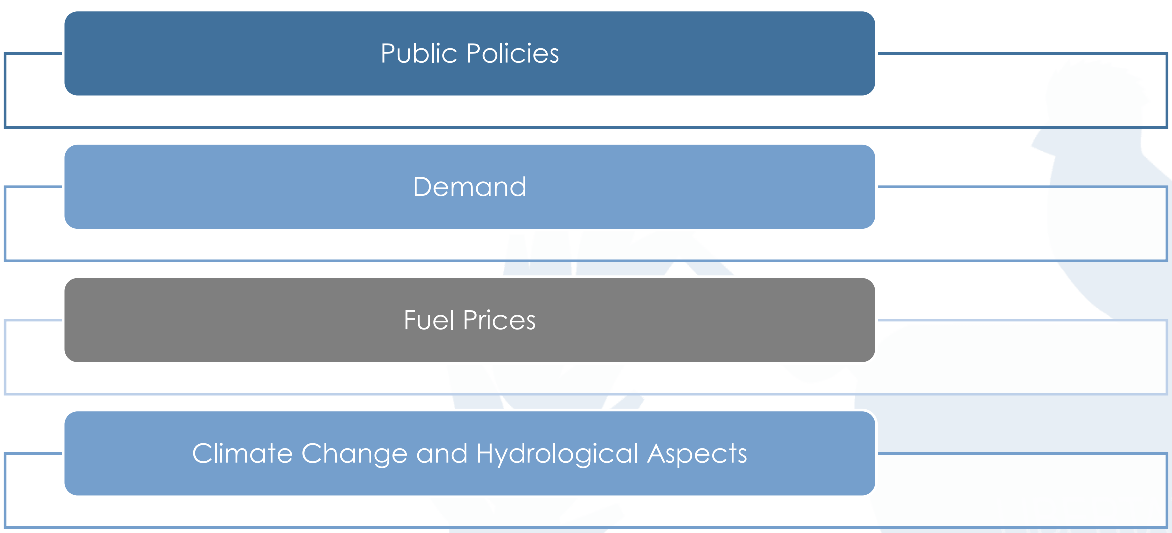
8.9. EXPANSION SCENARIOS

Long-term planning with the objective of guaranteeing the supply of energy and power demand in an efficient way must consider several variables that influence the production of electricity, especially with renewable generation systems in countries affected by weather phenomena, such as ours.

With the help of power generation planning software, system expansion schedules are obtained that will allow the supply of future demand in an optimized way. The assumptions related to this plan are four, in the case of the government actions variable, these act as constraints to be modeled. However, there are some that are outside the indicative planning that is currently being carried out. Figure 17 shows the variables considered, in summary, should be considered:

- Public policies
- Fuel price variability
- Climate change
- Droughts or floods.

Figure 17: Variables of the Different Scenarios.



Source: Proprietary Production.

From the above analysis of the variables considered, ten scenarios are presented, which are the most probable scenarios, given the combination of the previously described assumptions of energy and power demand, fuel costs and hydrological aspects; these are summarized in Table 13.

For the optimized electricity market variable, five scenarios were developed, and then another five scenarios were developed in which restrictions were included as a result of the country's goals related to the proportion of renewable energy in the electricity generation matrix, that is, taking into account Public Policies.

Five contingency scenarios are also evaluated, which, in addition to demand growth, fuel prices and hydrology and climate change, take the following as assumptions:

Cases are evaluated, in which for contingency reasons and/or contract expirations, some plant(s) are not available, which requires in the system, adding new capacity, seeking for this, the most optimal solution. These scenarios are described below:

1. - CMMS11- expiration of contract and exit from operation of coal-fired power plant: in this scenario, we consider the expiration of the contract and the definitive exit from operation of a thermal power plant that uses coal for generation, which leaves the system with a deficit of 279.5 MW of base capacity as of 2030.

2. - CMMS12 - contingency in a coal base plant: this scenario evaluates a contingency in a 105 MW coal thermal plant, which leaves the system without this capacity during the year 2024 only.

3. – CMMS 13 – hydroelectric plant contingency: For the following scenario, a contingency affecting 285 MW of capacity of a hydroelectric plant is considered, assuming that this plant will be out of operation only during the year 2024.

4. – CMMS 14- Climate Contingency: This scenario assumes that 600 MW of hydroelectricity are taken out of operation due to a climate emergency, as happened in November 2020 with the Eta and Iota storms, in this scenario it is considered that the 600 MW of hydroelectricity are taken out of operation during the year 2025.

5. - CMMS 15 – Definitive exit from operation of some coal-fired power plants: as a last scenario, a case is evaluated in which 384.5 MW of existing coal-fired thermal power plants are taken out of operation as of 2030, which leaves the system with a significant deficit of base capacity.

Under the five scenarios described above, the software will search for an optimal solution to supply the affected capacity, thus, the results obtained will help in making decisions to guarantee the energy supply in an efficient way in contingency situations.

Table 13: Summary of Most Likely Scenarios.

No.	SCENARIOS	SUB-SCENARIOS									ACRONYM
		GRAPHEMA	DEMAND	GRAPHEMA	FUEL	GRAPHEMA	HYDROLOGY	GRAPHEMA	SOLAR	WIND	
1	BAU	E	MEDIUM	M	LOW	B	DRY	S	HIGH	HIGH	EMBS6
2	BAU	E	MEDIUM	M	LOW	B	MEDIUM	M	MEDIUM	MEDIUM	EMBM10
3	BAU	E	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	EMMS2
4	BAU	E	MEDIUM	M	MEDIUM	M	MEDIUM	M	MEDIUM	MEDIUM	EMMM4
5	BAU	E	MEDIUM	M	HIGH	A	DRY	S	HIGH	HIGH	EMAS8
6	PUBLIC POLICIES	P	MEDIUM	M	LOW	B	DRY	S	HIGH	HIGH	PMBS5
7	PUBLIC POLICIES	P	MEDIUM	M	LOW	B	MEDIUM	M	MEDIUM	MEDIUM	PMBM9
8	PUBLIC POLICIES	P	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	PMMS1
9	PUBLIC POLICIES	P	MEDIUM	M	MEDIUM	M	MEDIUM	M	MEDIUM	MEDIUM	PMMM3
10	PUBLIC POLICIES	P	MEDIUM	M	HIGH	A	DRY	S	HIGH	HIGH	PMAS7

Source: Proprietary Production.

Table 14: Summary of Contingency Scenarios

No.	SCENARIOS	SUB-SCENARIOS									ACRONYM
		GRAPHEMA	DEMAND	GRAPHEMA	FUEL	GRAPHEMA	HYDROLOGY	GRAPHEMA	SOLAR	WIND	
1	Contingencia	C	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	CMMS11
2	Contingencia	C	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	CMMS12
3	Contingencia	C	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	CMMS13
4	Contingencia	C	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	CMMS14
5	Contingencia	C	MEDIUM	M	MEDIUM	M	DRY	S	HIGH	HIGH	CMMS15

Source: Proprietary Production.

The following descriptions of the scenario variables describe the characteristics of the items in the tables above.

Demand: The increase in annual energy and power demand is a very important variable for the planning of the generation system. The most probable demand growth scenario was considered, being the medium growth. The details of the values used can be found in Graph 54 and Graph 55 and were applied to the BAU and Public Policy scenarios. This variable is the second letter of the code associated with the scenario evaluated, and in this case it is the letter M.

Fuel: The increase in fuel prices also impacts on the marginal cost of energy, and due to the national context, that lacks the resource either in the form of deposits or mines, it has a price indexed to international reference values. The detail of the values used can be found from Graph 56 to Graph 59, and these price variables can be High, Medium and Low, this is the third letter of the code associated to the scenario evaluated and can be a letter A, M or B.

Climatic phenomena: Generation by renewable resources is mostly subject to climatic phenomena, except for geothermal and biogas, as they depend on hydrology, soil degradation, wind season and sunshine hours. The first scenario contains the following conditions: an intermediate flow scenario (average hydrology), as well as average sunshine hours and wind potential. The second scenario represents those years that have suffered droughts (low hydrological flows), with a higher number of sunshine hours and wind potential. Each variable of this premise can be according to its hydrology a Medium and Dry scenario, is the fourth letter associated to the evaluated scenario and can be a letter M or S respectively.

Table 15: Summary of Scenarios.

<table>
<tr><th colspan="2" rowspan="2"></th><th>BAU</th><th>Políticas Públicas</th><th colspan="3">Contingencias</th></tr>
<tr><th>D. Average</th><th>D. Average</th><th colspan="3">D. Average</th></tr>
<tr><td rowspan="2">C. LOW</td><td>DRY</td><td>EMBS6</td><td>PMBS5</td><td colspan="3"></td></tr>
<tr><td>MEDIUM</td><td>EMBM10</td><td>PMBM9</td><td colspan="3"></td></tr>
<tr><td rowspan="3">C. MEDIUM</td><td rowspan="2">DRY</td><td rowspan="2">EMMS2</td><td rowspan="2">PMMS1</td><td>CMMS11</td><td>CMMS13</td><td>CMMS15</td></tr>
<tr><td>CMMS12</td><td>CMMS14</td><td></td></tr>
<tr><td>MEDIUM</td><td>EMMM4</td><td>PMMM3</td><td colspan="3"></td></tr>
<tr><td>C. HIGH</td><td>DRY</td><td>EMAS8</td><td>PMAS7</td><td colspan="3"></td></tr>
</table>

Source: Proprietary Production.

This document presents the indicative planning for the national generation system, considering that the electric power generation business is a free market; the agents of this market make the most opportune decisions to invest in new projects concerning the generation park. This variable is the first letter of the code associated to the evaluated scenario.

It is recalled that the market variable without State influence and the commitments acquired in the electricity market is called BAU (Business As Usual) being identified by the letter E, it is applied to a series of 5 most probable scenarios, with other associated considerations.

With the identification of the letter P, a series of 5 additional scenarios are made contemplating the fulfillment of the variables of Public Policies, in this case the goal of the energy policy 2013 - 2027 was considered, which establishes a percentage of renewable generation of 80%.

The letter C identifies the 5 contingency scenarios evaluated for this plan, described above.

9. RESULTS OF THE INDICATIVE PLAN FOR THE EXPANSION OF THE GENERATION SYSTEM

As described in the previous chapter, 15 scenarios were analyzed in the preparation of this plan, these are divided into three base scenarios, which the BAU scenario is developed under no type of restriction, unlike the Public Policy scenario, which considers restrictions such as the percentage of renewable energy penetration and the contingency scenario, each of these base scenarios, consider other 3 fundamental variables, such as energy demand, international fuel prices and hydrology. As mentioned above, only the most probable scenarios were chosen, so the assumptions of Medium Demand, High, Medium or Low Fuel Prices and Medium and Dry Hydrology were considered.

Table 16: Probability of occurrence for each variable.

Variable	Scenario	Probability [%]
Demand[2]	HIGH	25%
	MEDIUM	55%
	LOW	20%
Fuels[3]	HIGH	20%
	MEDIUM	40%
	LOW	40%
Hydrology[4]	Lluvioso	15%
	MEDIUM	40%
	DRY	45%

Source: Proprietary Production.

As a result of evaluating each of the scenarios, a list of the most probable BAU-Public Policies scenario combinations was drawn up, which are as follows:

Table 17: Probability of occurrence of the most probable scenarios.

[2] The probability distribution was determined based on historical data on the increase in electricity demand, considering the actual growth figures.
[3] The distribution of probabilities was weighted according to the perspectives made by different international organizations, considering the strong investment in renewable energy made by developed countries, which is why it is not expected that there will be a considerable increase in these energies in the long term.
[4] The probability distribution used for hydrology is analyzed from a purely subjective analysis, it is practically impossible to determine the future hydrological conditions, but the perspective obtained from different international organizations is that Guatemala will face severe droughts, so in the selection of probable scenarios a greater weight is given.

No.	SCENARIOS	SUB-SCENARIOS						SCENARIOS		PROBABILITY OF OCCURRENCE [%]	HIERARCHICAL POSITION
		DEMAND	PROBABILITY	FUEL	PROBABILITY	HYDROLOGY	PROBABILITY				
1	BAU - PUBLIC POLICIES	MEDIUM	55%	MEDIUM	40%	DRY	45%	EMMS2	PMMS1	24.69%	1
2	BAU - PUBLIC POLICIES	MEDIUM	55%	MEDIUM	40%	MEDIUM	40%	EMMM4	PMMM3	21.95%	2
3	BAU - PUBLIC POLICIES	MEDIUM	55%	LOW	30%	DRY	45%	EMBS6	PMBS5	18.45%	3
4	BAU - PUBLIC POLICIES	MEDIUM	55%	HIGH	30%	DRY	45%	EMAS8	PMAS7	18.45%	4
5	BAU - PUBLIC POLICIES	MEDIUM	55%	LOW	30%	MEDIUM	40%	EMBM10	PMBM9	16.46%	5

Source: Proprietary Production.

9.1 TIMELINE FOR INPUT OF PROPOSED PLANTS

Through the calculations performed by the OPTGEN software, the optimal year of entry was determined for the candidate plants, and for each scenario.

Table 18: Plant entry schedule, BAU scenarios and Public Policy (PP).

INSTALLED CAPACITY PER SCENARIO [MW]		2,137	1,997	2,137.30	1,992	1,757	1,912	2,047	2,372	2,317	1,742
TOTAL INVESTMENT PER SCENARIO [MILLONES USD]		5,947.15	5,457.15	5,947.15	5,661.15	5,259.15	5,782.15	5,742.15	6,687.15	6,992.15	5,880.80
TECHNOLOGY	PLANT	EMMS2	EMMM4	EMBS6	EMAS8	EMBM10	PMMS1	PMMM3	PMBS5	PMAS7	PMBM9
HYDRAULICS	Pojóm	2026	2029	2025	2027	2027	2025	2025	2025	2025	2027
	San Andrés	2026	2028	2025	2027	2027	2025	2025	2025	2025	2027
	Huehuetenango H1	2022	2022	2022	2022	2022	2022	2022	2022	2022	2027
	Huehuetenango H2	2022	2022	2022	2022	2022	2022	2022	2022	2022	2027
	Alta Verapaz H1	2046	2047	2048		2039	2027	2052	2027	2027	2027
	Alta Verapaz H2	2047	2048	2048	2035	2039	2027	2027	2027	2027	2027
	Alta Verapaz H3	2046	2047	2048			2027	2027	2027	2027	2027
	Huehuetenango H3	2047	2047	2048					2027	2027	2027
	La Paz	2049		2052	2050	2050			2027	2027	2027
	Usumacinta PTN H1									2027	2027
	Usumacinta PTN H2						2027	2027	2027	2027	2027
GEOTHERMIC	Geo ZUN				2051		2026		2027		2027
	Geo ZUN 2				2051		2026			2027	2027
	Geo TEC	2022	2022	2027	2026	2022	2026	2022	2025	2027	2027
	Geo MOY	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo Cerro Blanco	2022	2022	2022	2024	2022	2024	2027	2025	2027	2027
	Geo EST	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo Atitlán	2022	2022	2027	2026	2022	2026	2022	2025	2027	2027

	Geo Palencia	2022	2022	2027	2024	2022	2026	2022	2025	2027	2027
	Geo Ayarza	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo Los Achiotes	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo Retana	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo SMR	2022	2022	2022	2024	2022	2025	2022	2025	2027	2027
	Geo TOT	2022	2022	2027	2024	2022	2024	2022	2025	2027	2027
	Geo AMA	2022	2022	2027	2024	2022	2026	2022	2025	2027	2027
	Geo El Ceibillo	2022	2022	2027	2026	2022	2026	2022	2025	2027	2027
PHOTOVOLTAIC	Jutiapa S1	2038	2039	2038	2038	2039	2038	2038	2038	2027	
	Jutiapa S2	2038	2039	2038	2038	2039	2038	2039	2038	2038	
	Jutiapa S3	2038	2039	2038	2038	2039	2038	2038	2038	2027	
	Sol Zacapa	2038	2039	2038	2038	2039	2038	2039	2038	2038	
	El Progreso Solar	2038	2039	2038	2038	2039	2038	2039	2039	2027	
	Santa Rosa S1	2037	2037	2037	2036	2039	2027	2039	2027	2027	2027
	Santa Rosa S2	2036	2037	2036	2036	2037	2027	2037	2027	2027	2027
	Escuintla S1	2036	2037	2036	2035	2037	2027	2037	2027	2027	2027
	Escuintla S2	2037	2039	2039	2037	2039	2037	2039	2027	2027	
WIND	Eólica JUT 1	2037	2039	2037	2036	2039	2027	2039	2027	2027	2027
	Eólica JUT 2	2037	2039	2037	2036	2039	2036	2039	2027	2027	
	Eólica JUT 3	2036	2037	2037	2036	2037	2027	2037	2027	2027	2027
	Eólica JUT 4	2037	2037	2037	2036	2039	2027	2039	2027	2027	2027
	Eólica JUT 5	2037	2037	2037	2036	2039	2027	2039	2027	2027	2027
	Eólica GUA	2037	2037	2037	2036	2039	2036	2027	2027	2027	2027
	Eólica ESC	2037	2037	2037	2036	2039	2036	2037	2027	2027	2027
	Eólica HUE	2039	2040	2039	2039	2040	2039	2040	2040	2027	
RENEWABLE DISTRIBUTED GENERATOR	GDR H1	2034	2035	2034	2033	2035	2027	2027	2027	2027	2027
	GDR H2	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
	GDR H3	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
	GDR H4	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
	GDR H5	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
	GDR H6	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
	GDR H7	2033	2034	2033	2033	2034	2027	2027	2027	2027	2027
BIOGAS	GDR Biogás 1	2022	2022	2022	2022	2022	2022	2022	2023	2024	
	GDR Biogás 2	2022	2022	2022	2022	2022	2022	2022	2023	2024	2027
	GDR Biogás 3	2022	2022	2022	2022	2022	2022	2022	2023	2024	2027
NATURAL GAS	GN Petén	2035	2044	2035	2033	2036			2048		
	GNL Pto. Barrios	2046	2046	2047	2038			2048	2049		
	CPO-GNL	2046	2045	2047	2038	2046	2050	2038	2048	2051	
	PSJ-GNL	2046	2045	2047	2038	2046	2050	2048	2048	2050	

Source: Proprietary Production, SDDP y OPTGEN.

Table 19: Plant entry timeline, Contingency scenarios.

INSTALLED CAPACITY PER SCENARIO [MW]		2,122	2,137	1,852.30	1,847	1,682
TOTAL INVESTMENT PER SCENARIO [MILLONES USD]		5,999.15	5,947.15	5,080.15	5,067.15	5,029.15
TECHNOLOGY	PLANT	CMMS11	CMMS12	CMMS13	CMMS14	CMMS15
HYDRAULICS	Pojom	2025	2026	2025	2025	2025
	San Andrés	2025	2025	2025	2025	2025
	Huehuetenango H1	2022	2022	2022	2025	2022
	Huehuetenango H2	2022	2022	2025		2022
	Alta Verapaz H1	2033	2046	2035	2025	2036
	Alta Verapaz H2	2052	2047		2044	2030
	Alta Verapaz H3		2047	2035	2025	
	Huehuetenango H3	2042	2047			
	La Paz	2048	2049			
	Usumacinta PTN H1					
	Usumacinta PTN H2					
GEOTHERMIC	Geo ZUN	2047				2030
	Geo ZUN 2	2046				2032
	Geo TEC	2025	2022	2026	2025	2025
	Geo MOY	2024	2022	2025	2025	2025
	Geo Cerro Blanco	2024	2022	2025	2025	2026
	Geo EST	2024	2022	2026	2025	2025
	Geo Atitlán	2025	2022	2026	2025	2025
	Geo Palencia	2025	2022	2026	2025	2025
	Geo Ayarza	2024	2022	2025	2025	2025
	Geo Los Achiotes	2024	2022	2026	2025	2025
	Geo Retana	2025	2022	2026	2025	2025

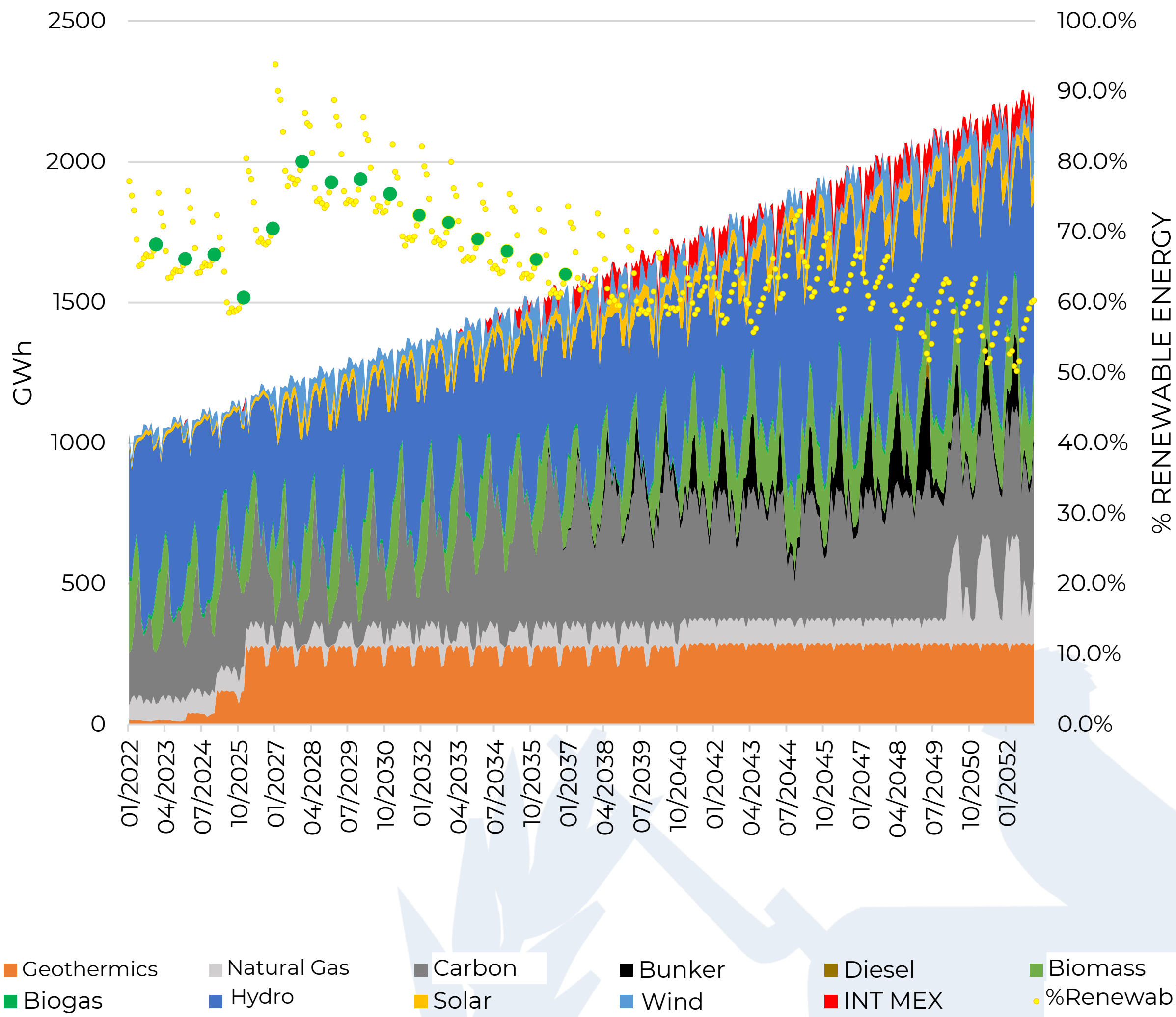
	Geo SMR	2024	2022	2024	2025	2025
	Geo TOT	2025	2022	2026	2025	2025
	Geo AMA	2025	2022	2026	2025	2025
	Geo El Ceibillo	2025	2022	2026	2025	2025
PHOTOVOLTAIC	Jutiapa S1	2037	2038	2038	2038	2037
	Jutiapa S2	2037	2038	2038	2038	2038
	Jutiapa S3	2037	2038	2038	2038	2037
	Sol Zacapa	2037	2038	2038	2038	2037
	El Progreso Solar	2038	2038	2038	2038	2038
	Santa Rosa S1	2036	2037	2037	2037	2035
	Santa Rosa S2	2034	2036	2036	2035	2035
	Escuintla S1	2033	2036	2036	2035	2032
	Escuintla S2	2036	2037	2037	2037	2035
WIND	Eólica JUT 1	2036	2037	2037	2037	2035
	Eólica JUT 2	2036	2037	2037	2037	2035
	Eólica JUT 3	2036	2036	2037	2035	2035
	Eólica JUT 4	2036	2037	2037	2037	2035
	Eólica JUT 5	2036	2037	2037	2037	2035
	Eólica GUA	2036	2037	2037	2037	2035
	Eólica ESC	2036	2037	2037	2037	2035
	Eólica HUE	2037	2039	2039	2039	2037
RENEWABLE DISTRIBUTED GENERATOR	GDR H1	2031	2034	2034	2034	2030
	GDR H2	2030	2033	2033	2033	2030
	GDR H3	2030	2033	2033	2033	2030
	GDR H4	2030	2033	2033	2033	2030
	GDR H5	2030	2033	2033	2033	2030
	GDR H6	2030	2033	2033	2033	2030
	GDR H7	2030	2033	2033	2033	2030
BIOGAS	GDR Biogás 1	2022	2022	2022	2026	2022
	GDR Biogás 2	2022	2022	2022	2025	2022
	GDR Biogás 3	2022	2022	2022	2025	2022

NATURAL GAS	GN Petén	2030	2035	2033	2029	2030
	GNL Pto. Barrios	2038	2046	2042	2043	
	CPO-GNL	2033	2046	2043	2044	2032
	PSJ-GNL	2033	2046	2050	2044	2033

Source: Proprietary Production, SDDP y OPTGEN.

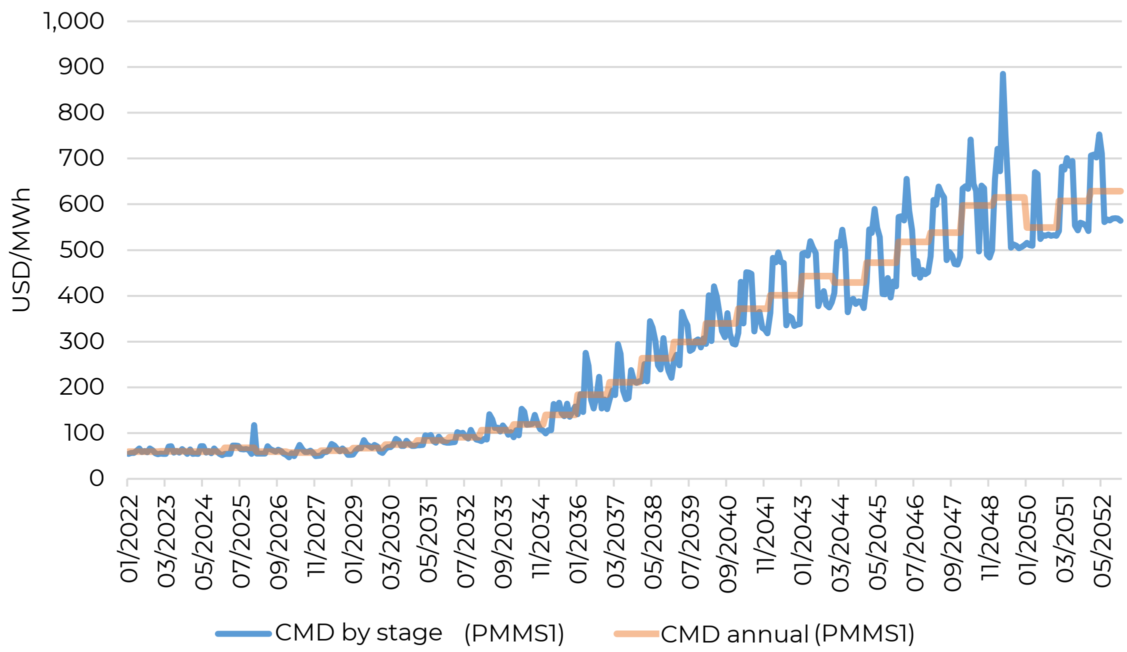
9.2 ANALYSIS BY SCENARIO: ENERGY DISPATCH AND MARGINAL COST OF DEMAND

Graph 61: Energy Dispatch of the PMMS1 scenario.



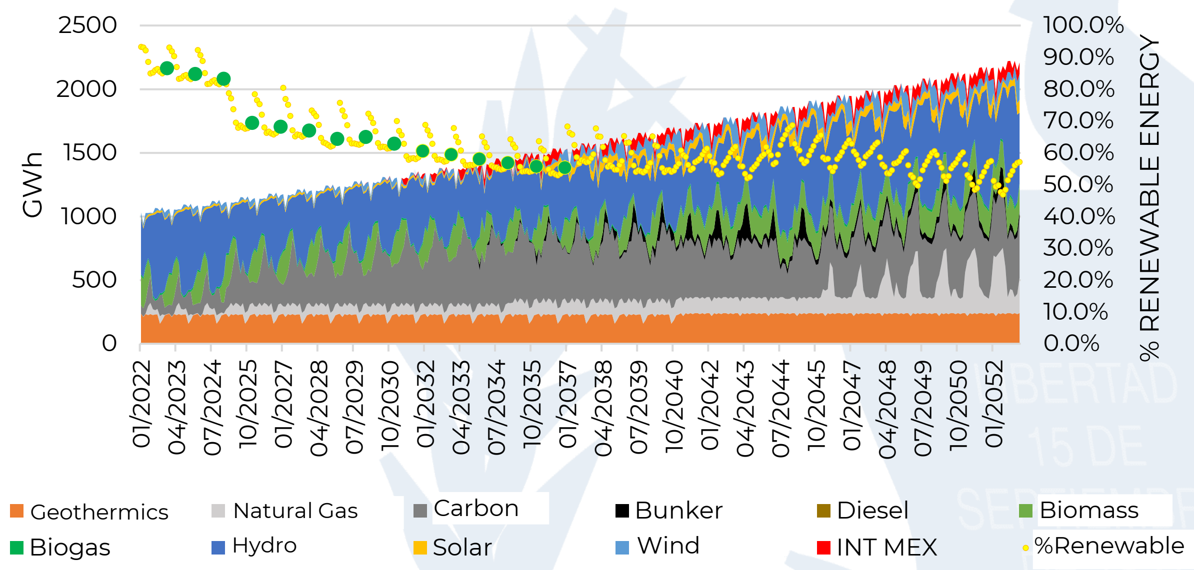
Source: Proprietary Production, SDDP-OPTGEN.

Graph 62: Marginal Cost of Demand by stage and annual average, PMMS1 scenario.



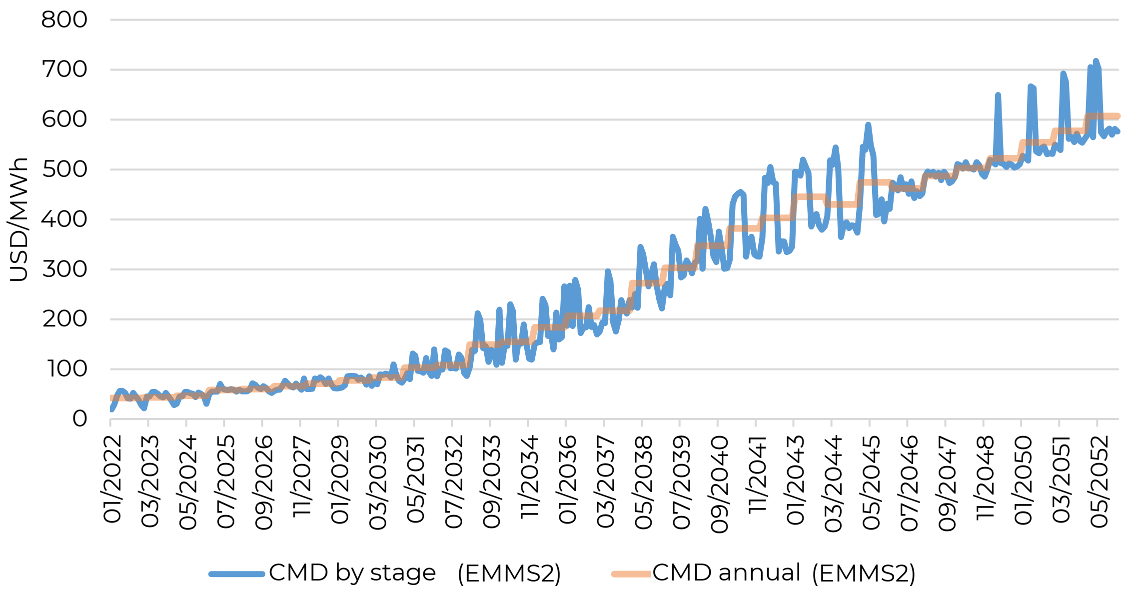
Source: Elaborated by UPEM.

Graph 63: Energy Dispatch of the EMMS2 scenario.



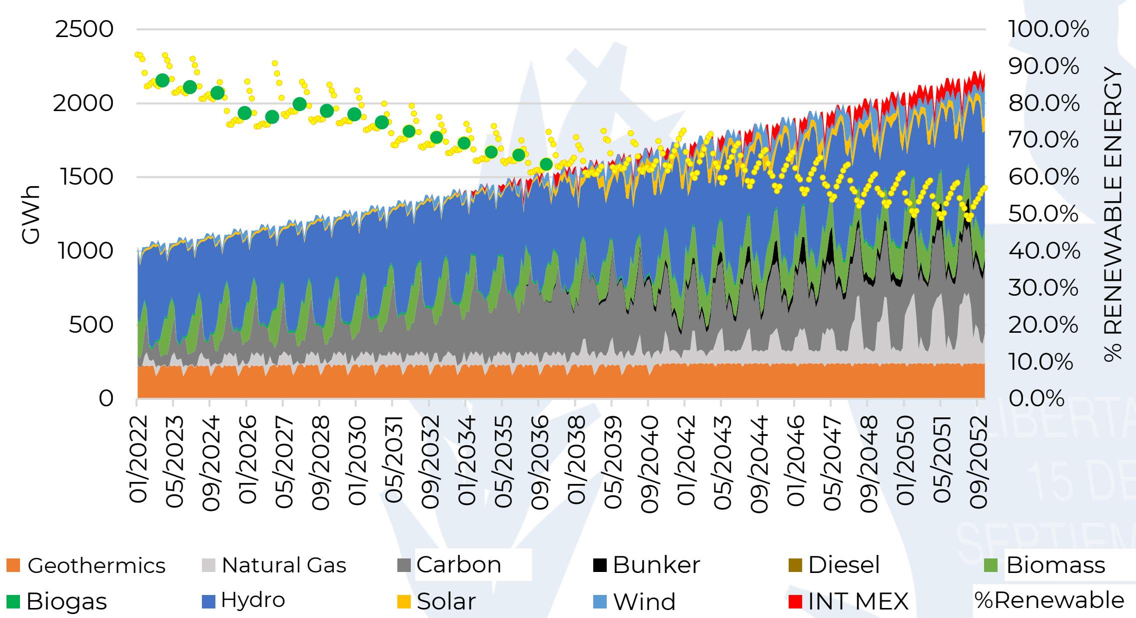
Source: Proprietary Production, SDDP-OPTGEN.

Graph 64: Marginal Cost of Demand by stage and annual average, EMMS2 scenario.



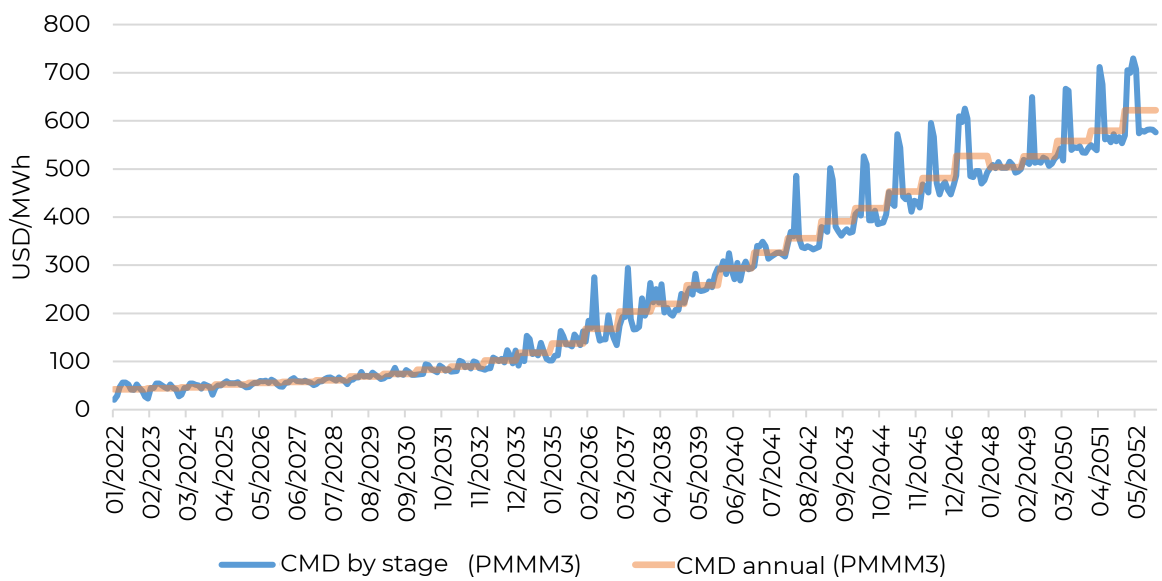
Source: Elaborated by UPEM.

Graph 65: Energy Dispatch of the PMMM3 scenario.



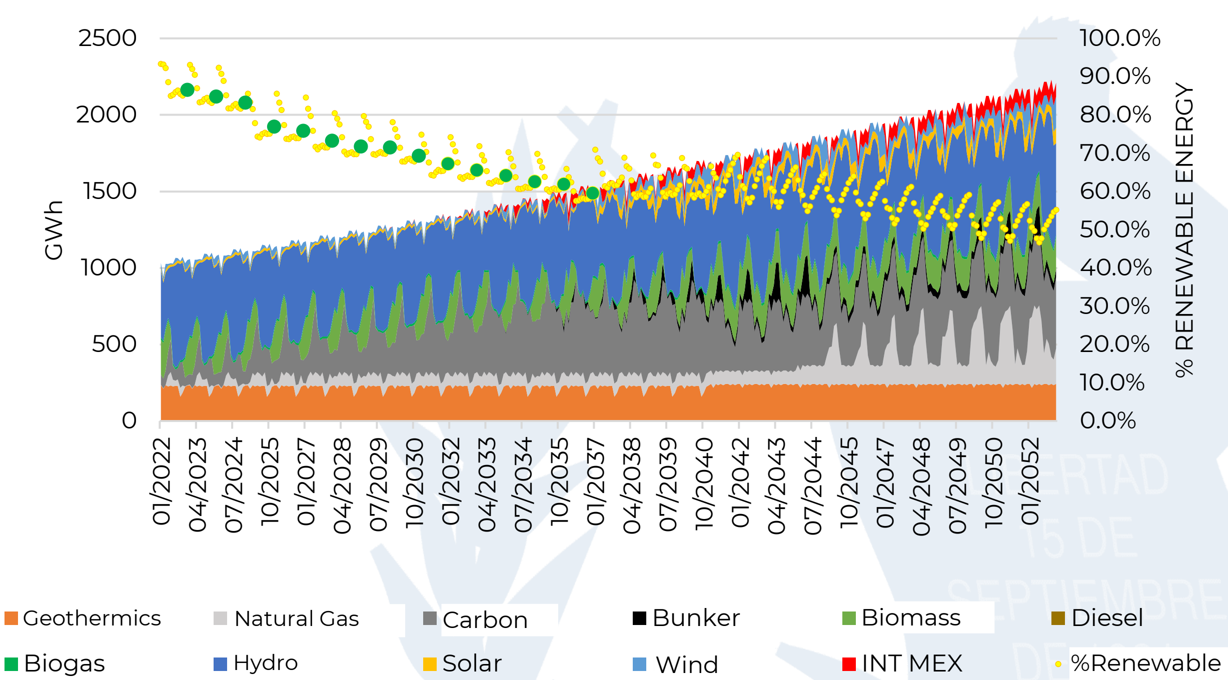
Source: Elaborated by UPEM.

Graph 66: Marginal Cost of Demand by stage and annual average, PMMM3 scenario.



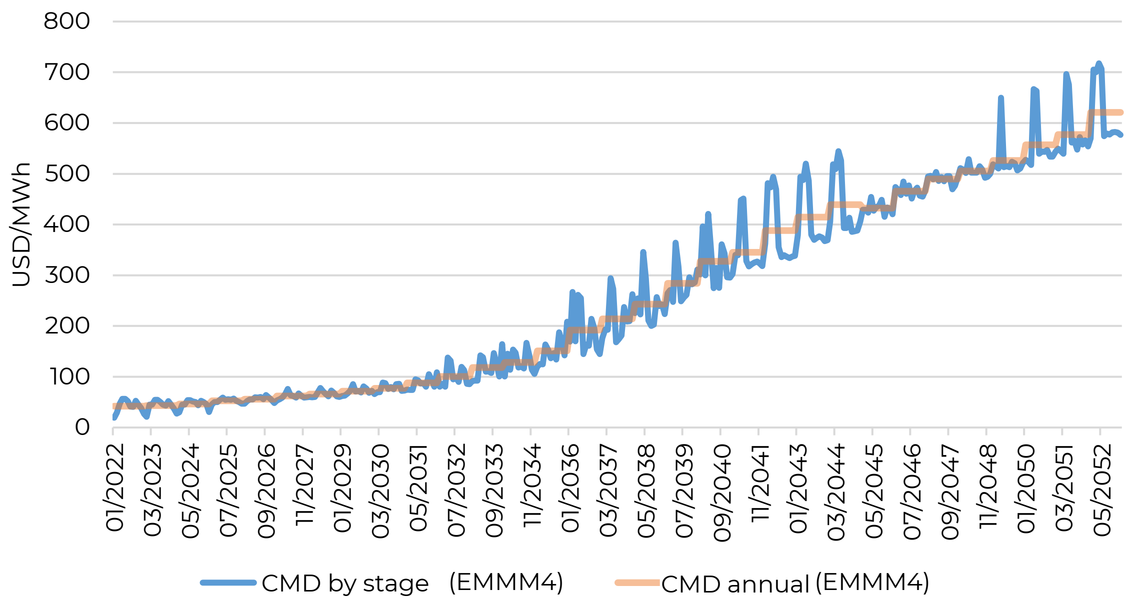
Source: Elaborated by UPEM.

Graph 67: Energy Dispatch of the EMMM4 scenario.



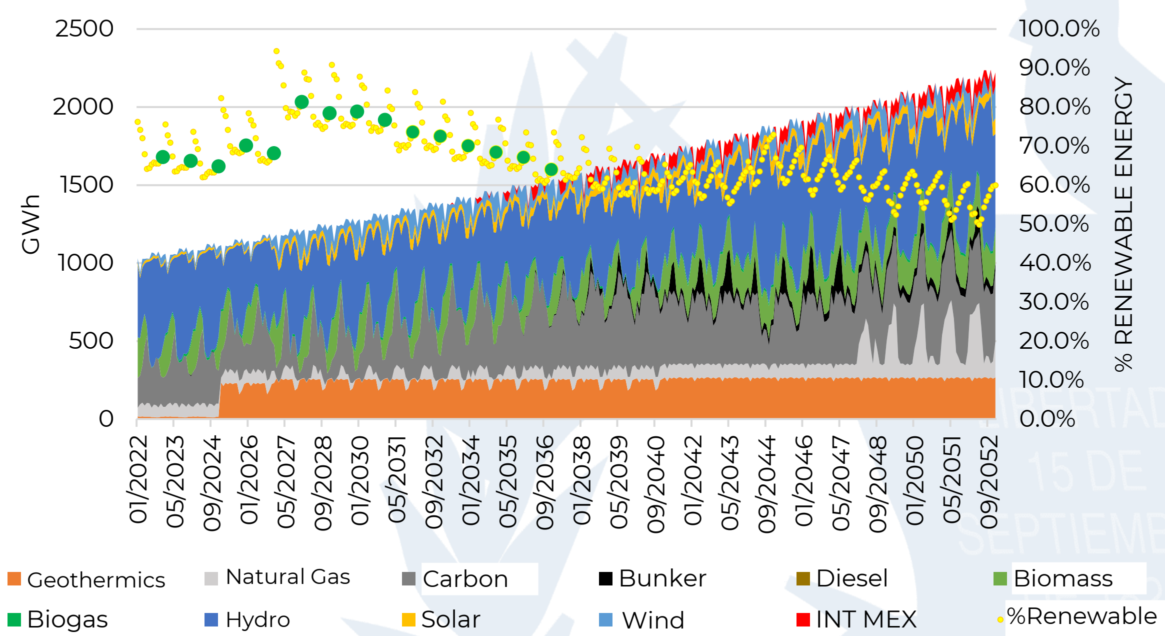
Source: Elaborated by UPEM.

Graph 68: Marginal Cost of Demand by stage and annual average, EMMM4 scenario.



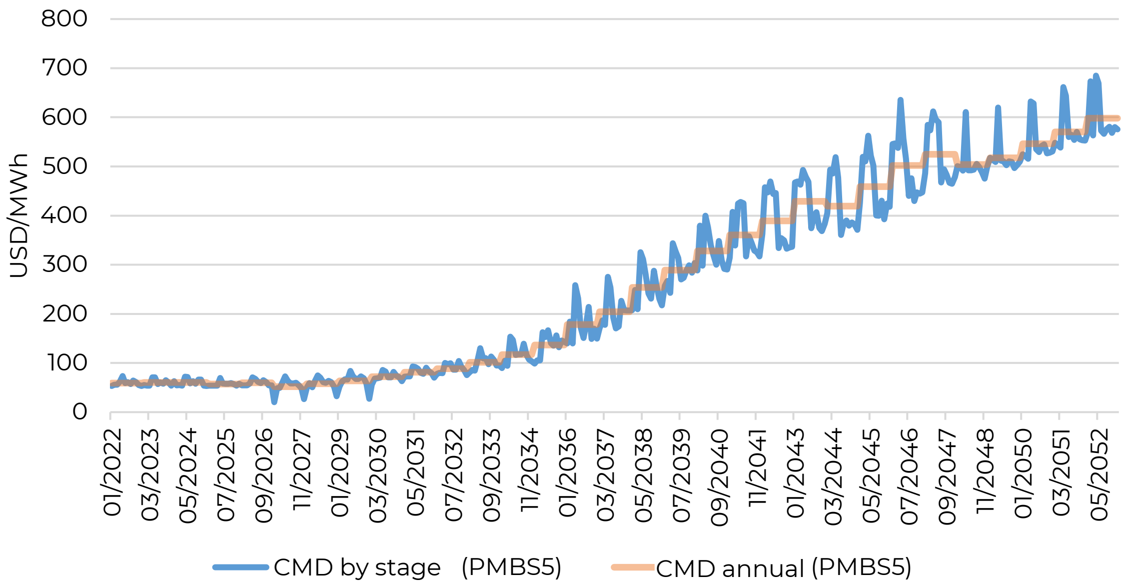
Source: Elaborated by UPEM.

Graph 69: Energy Dispatch of the PMBS5 scenario.



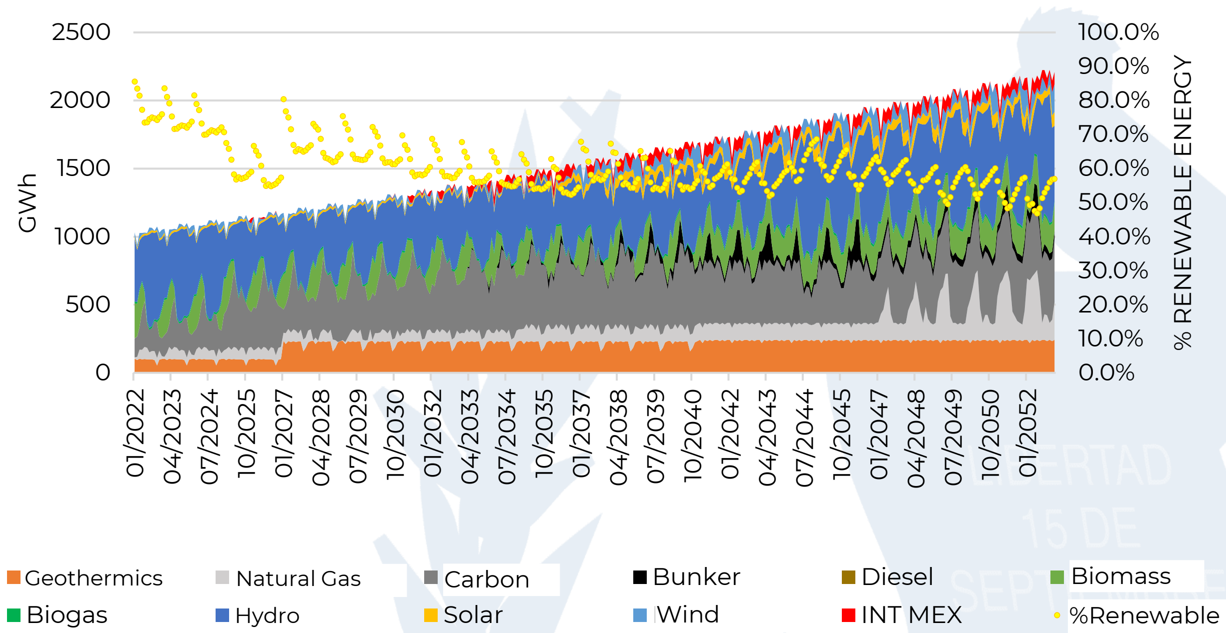
Source: Elaborated by UPEM.

Graph 70: Marginal Cost of Demand by stage and annual average, PMBS5 scenario.



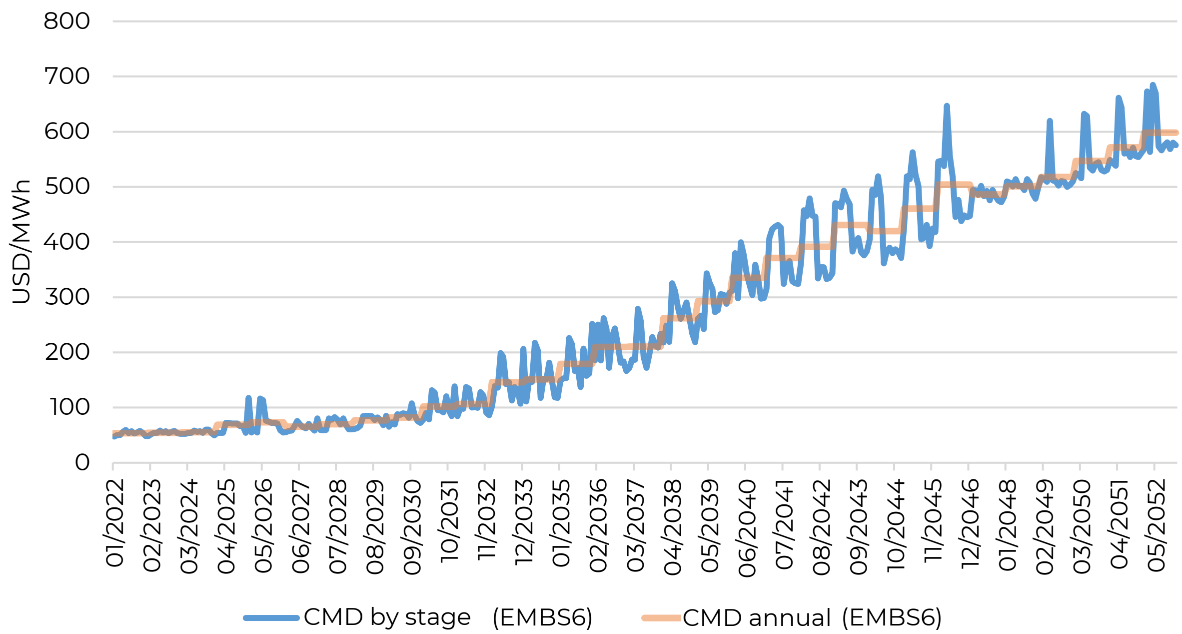
Source: Elaborated by UPEM.

Graph 71: Energy Dispatch of the EMBS6 scenario.



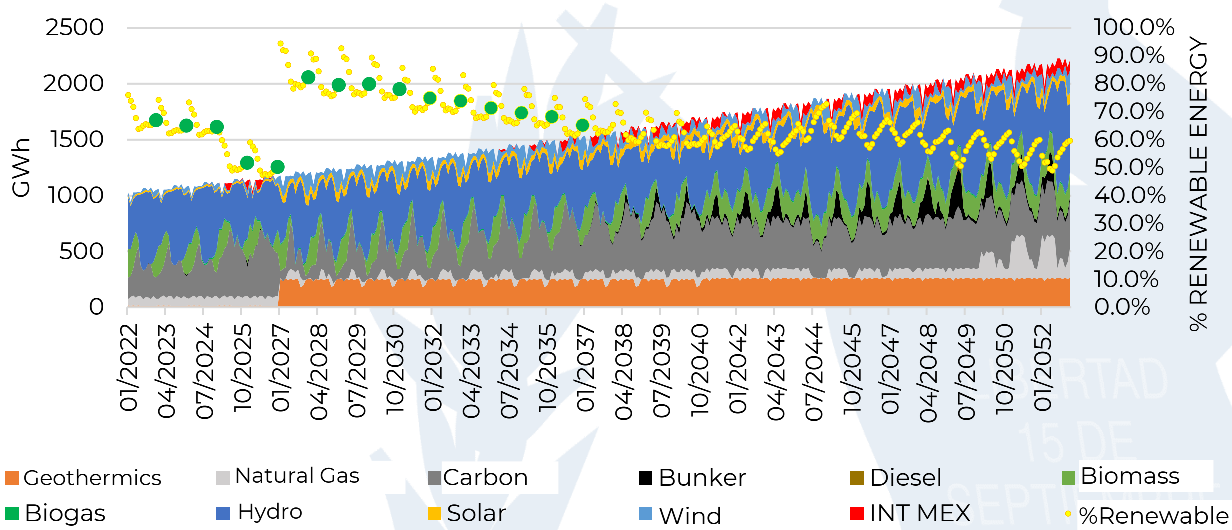
Source: Elaborated by UPEM.

Graph 72: Marginal Cost of Demand by stage and annual average, EMBS6 scenario.



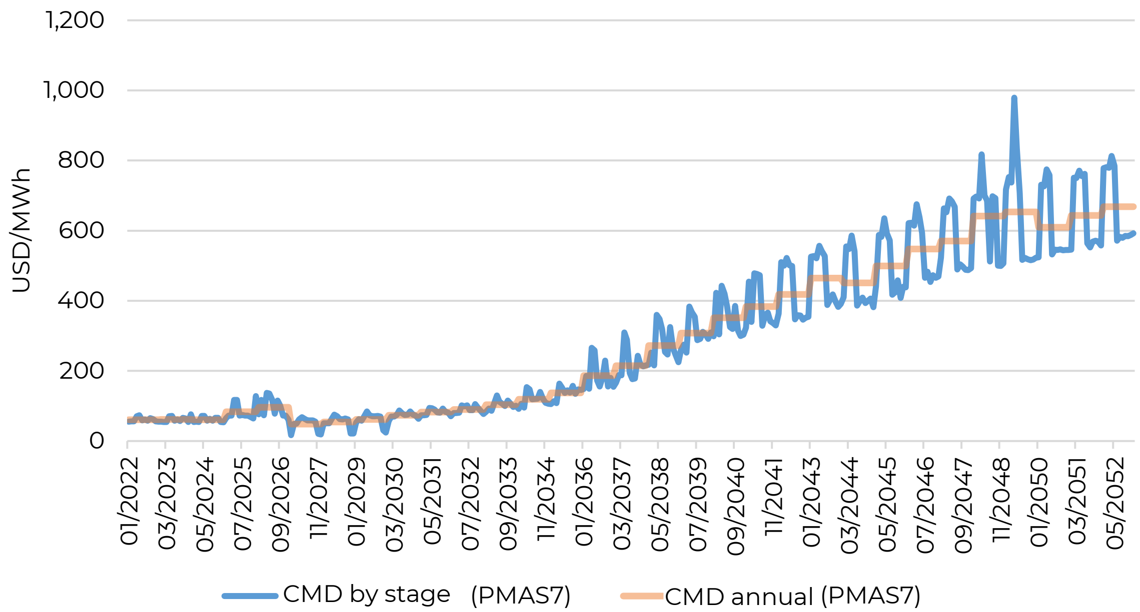
Source: Elaborated by UPEM.

Graph 73: Energy Dispatch of the PMAS7 scenario.



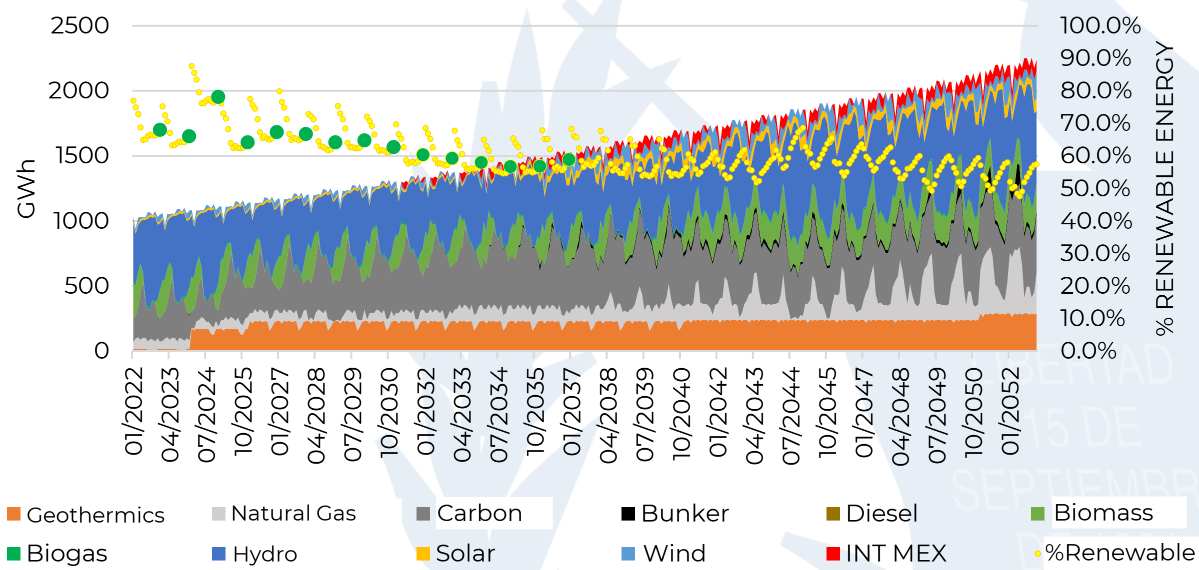
Source: Elaborated by UPEM.

Graph 74: Marginal Cost of Demand by stage and annual average, PMAS7 scenario.



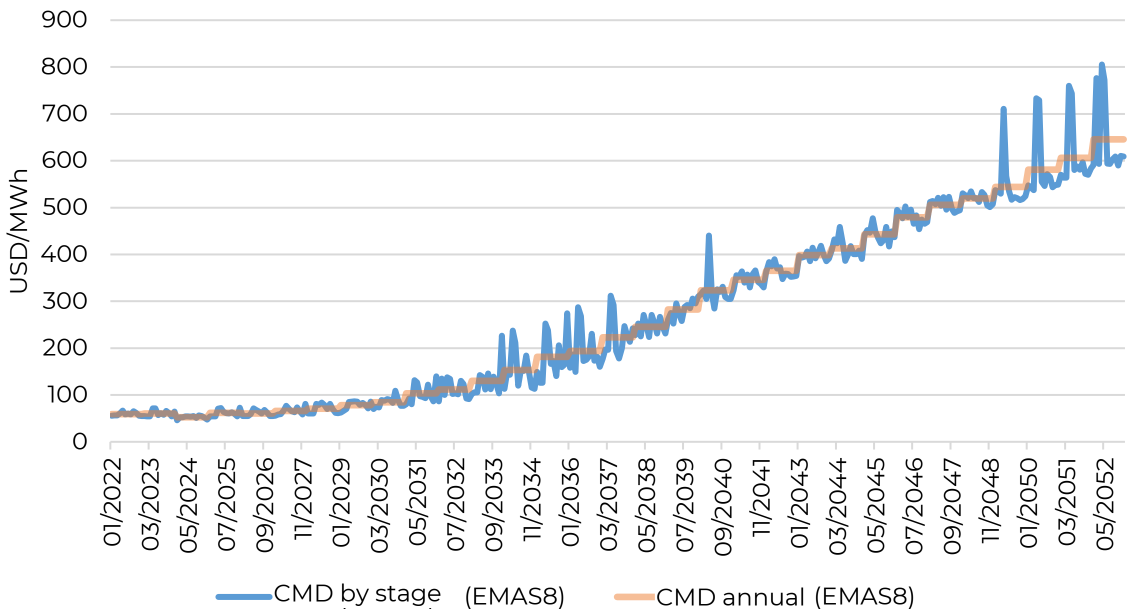
Source: Elaborated by UPEM.

Graph 75: Energy Dispatch of the EMAS8 scenario.



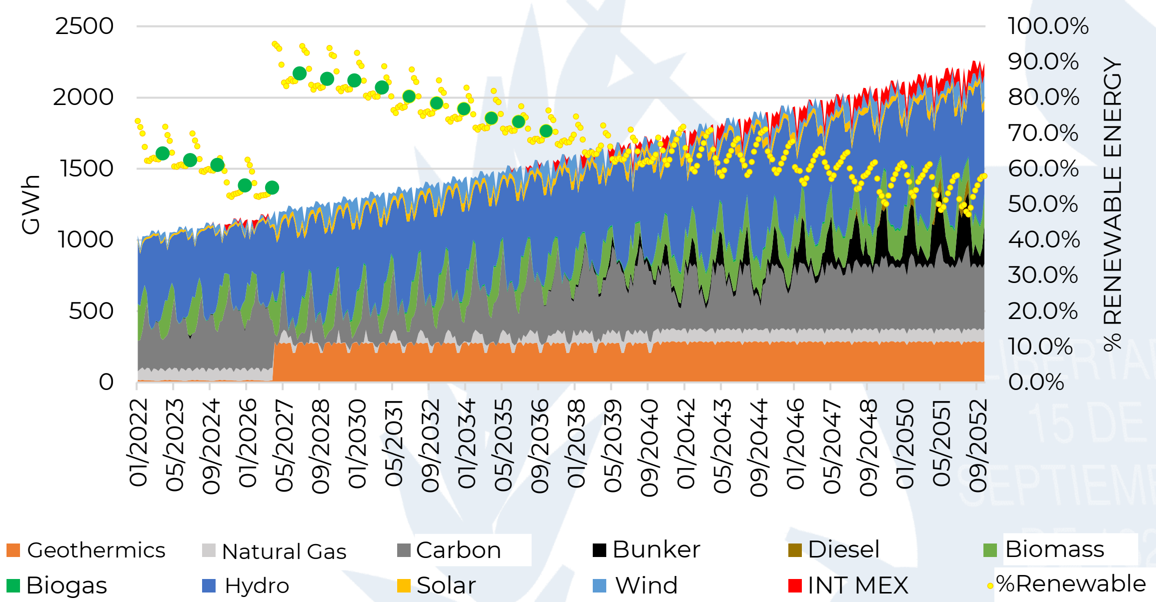
Source: Elaborated by UPEM.

Graph 76: Marginal Cost of Demand by stage and annual average, EMAS8 scenario.



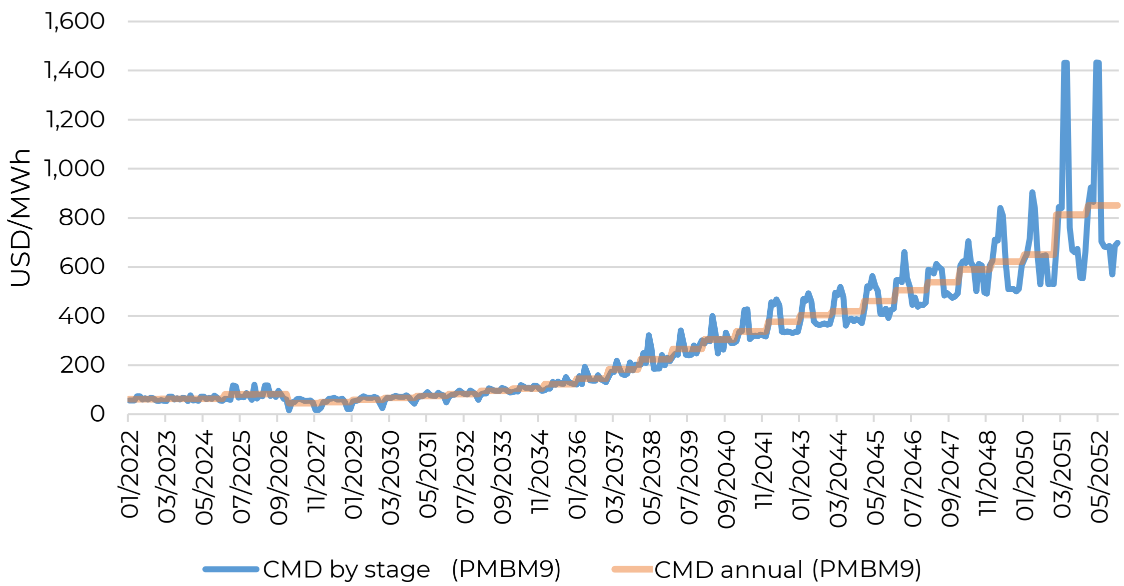
Source: Elaborated by UPEM.

Graph 77: Energy Dispatch of the PMBM9 scenario.



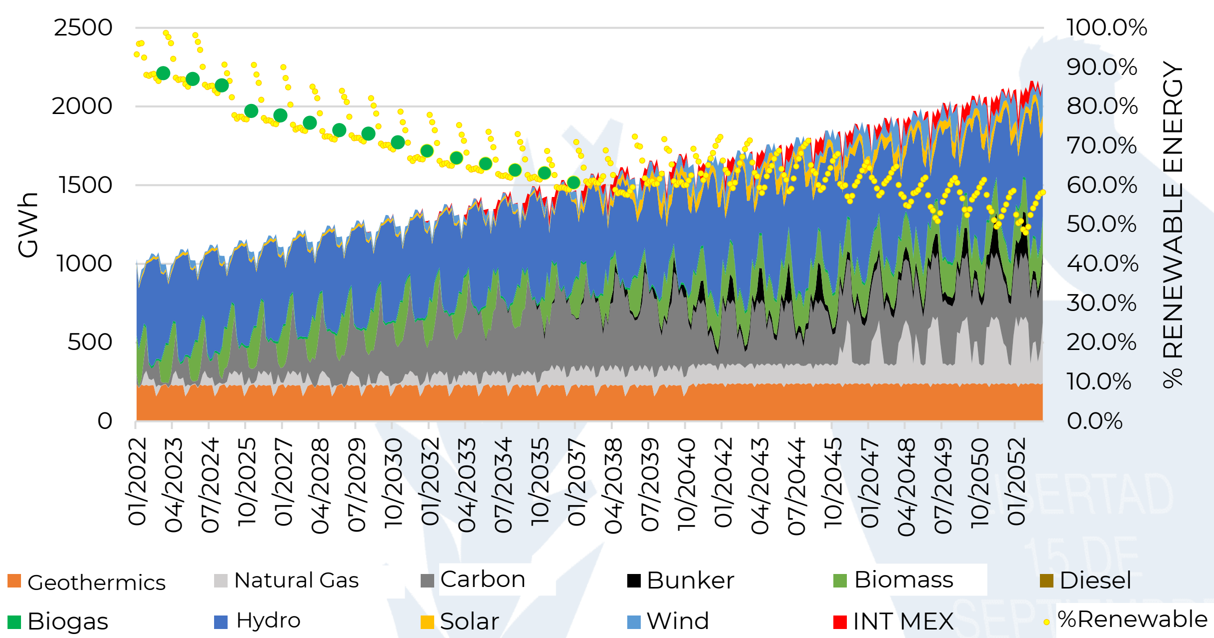
Source: Elaborated by UPEM.

Graph 78: Marginal Cost of Demand by stage and annual average, PMBM9 scenario.



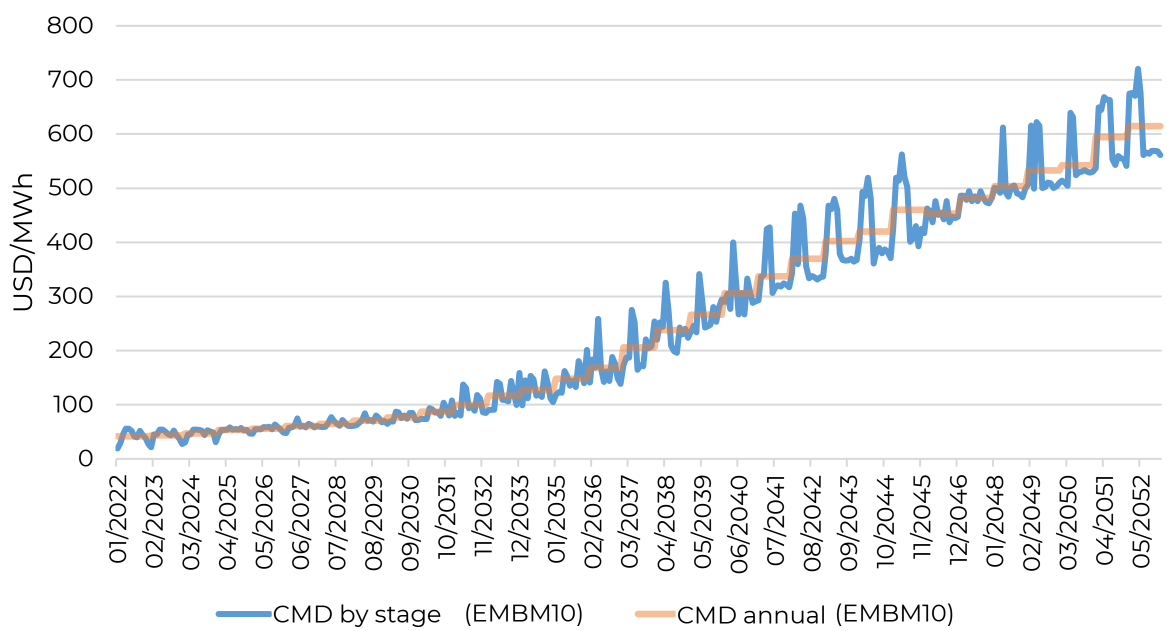
Source: Elaborated by UPEM.

Graph 79: Energy Dispatch of the EMBM10 scenario.



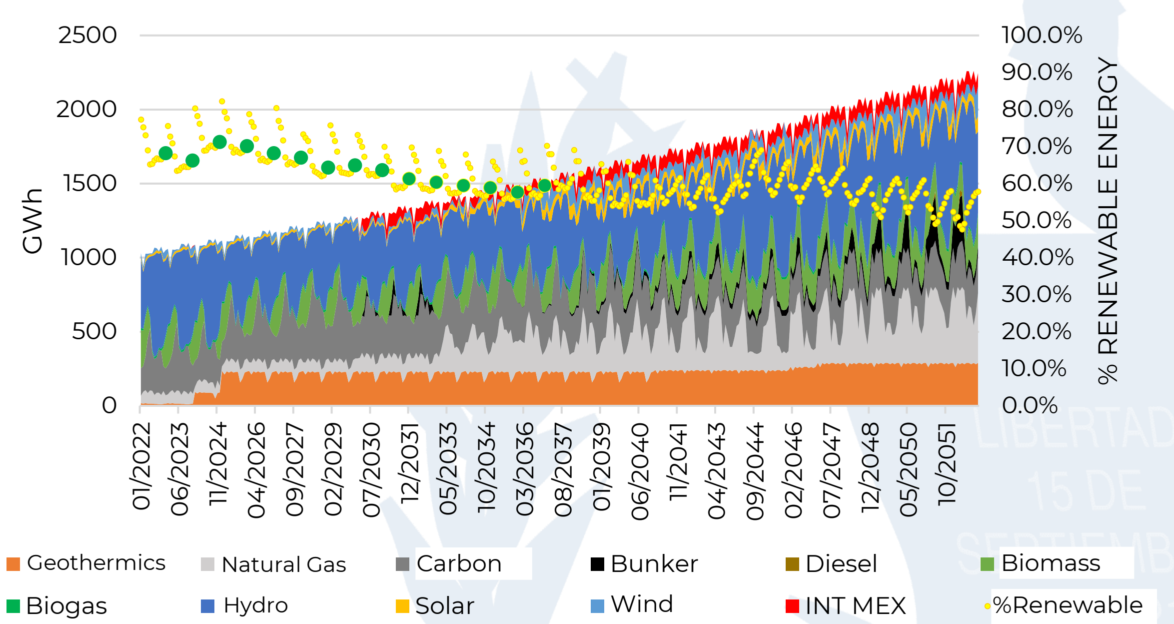
Source: Elaborated by UPEM.

Graph 80: Marginal Cost of Demand by stage and annual average, EMBM10 scenario.



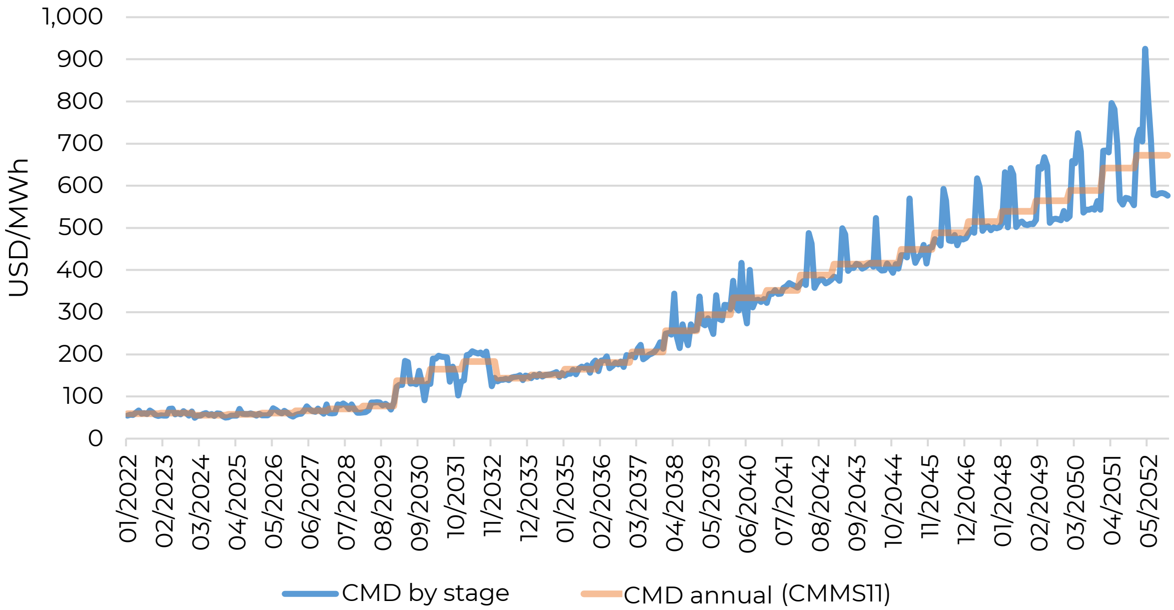
Source: Elaborated by UPEM.

Graph 81: Energy Dispatch of the CMMS11 scenario.



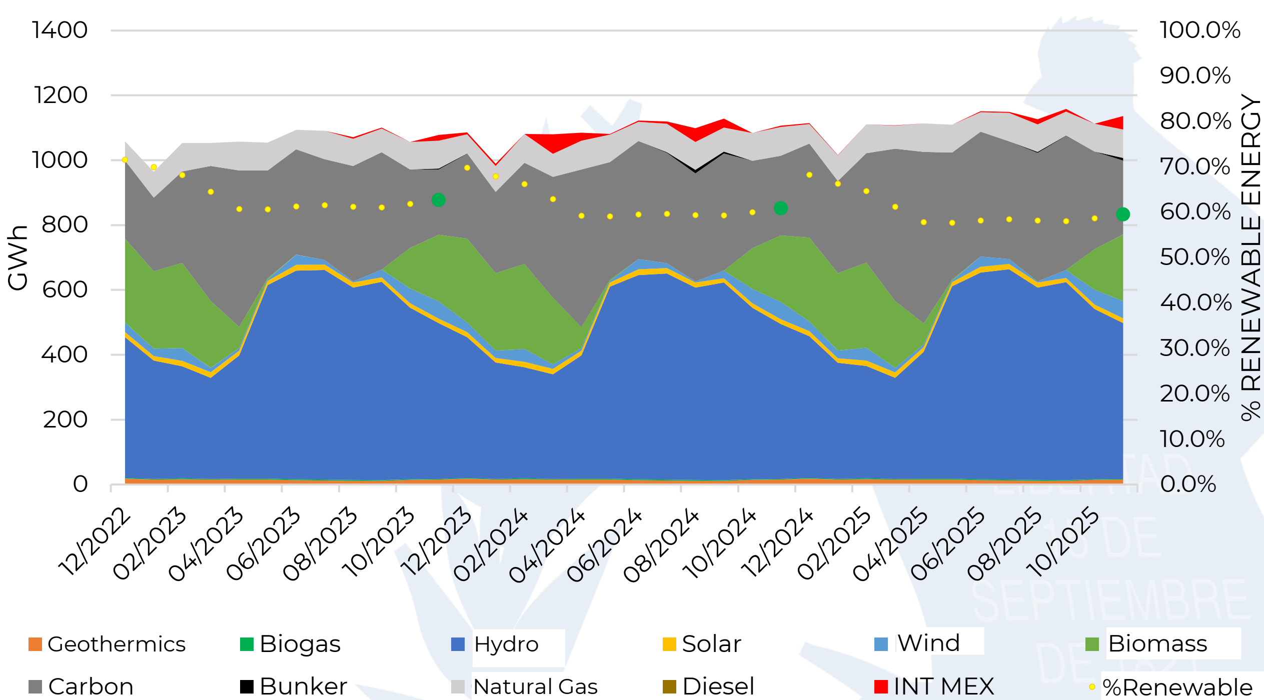
Source: Elaborated by UPEM.

Graph 82: Marginal Cost of Demand by stage and annual average, CMMS11 scenario.



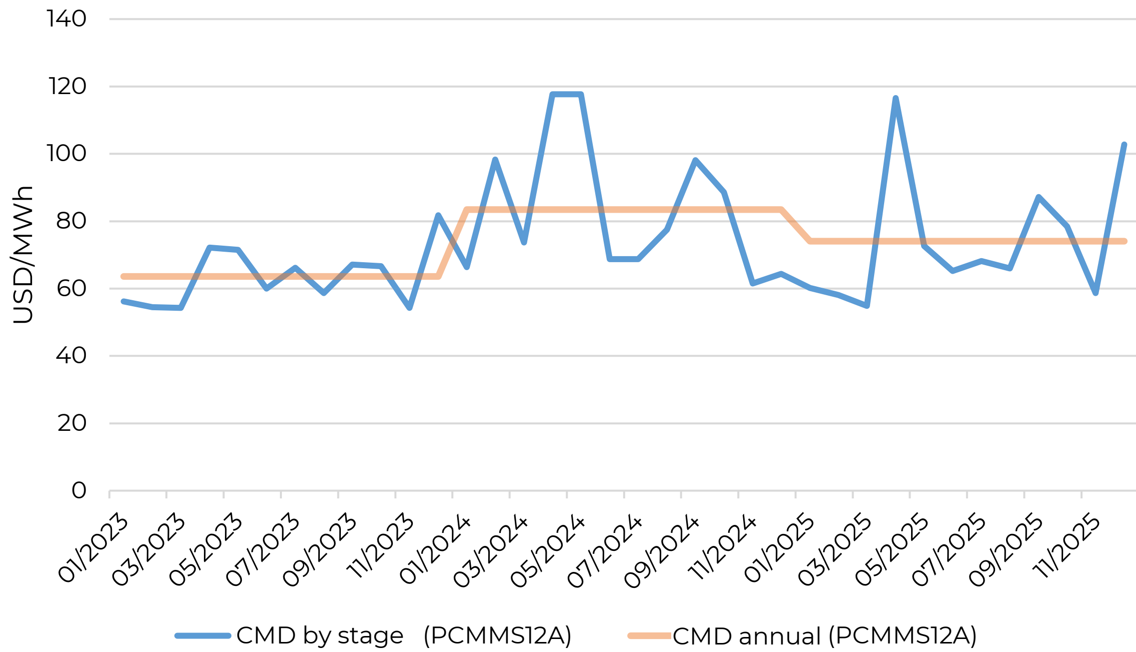
Source: Elaborated by UPEM.

Graph 83: Energy Dispatch of CMMS 12A scenario.



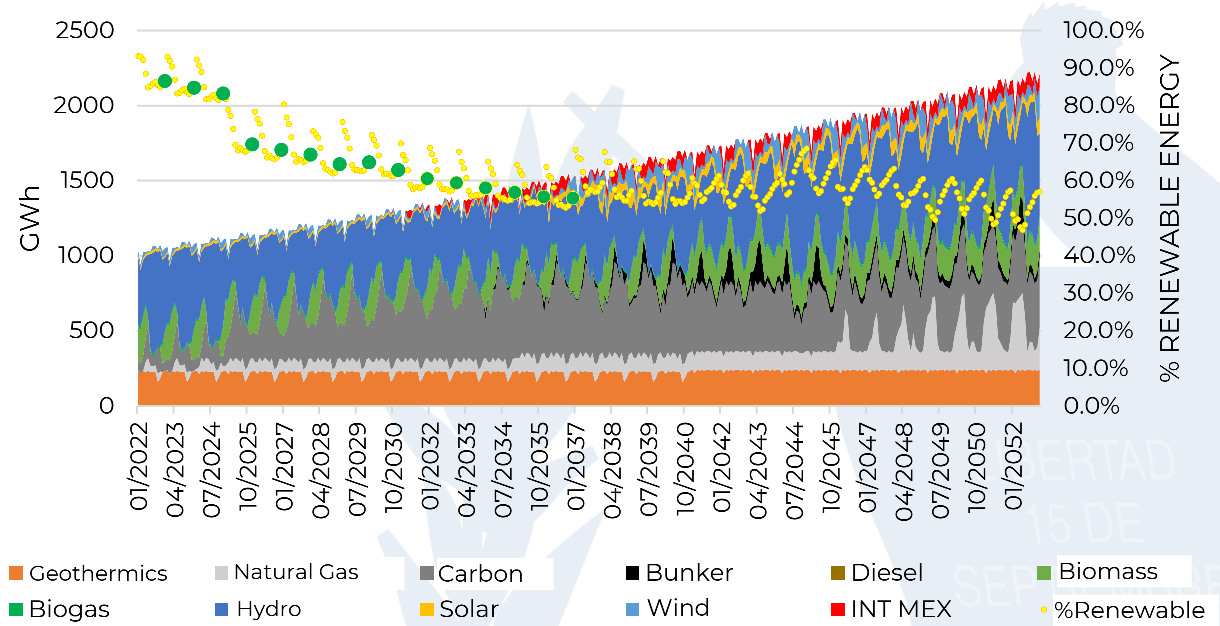
Source: Elaborated by UPEM.

Graph 84: Marginal Cost of Demand by stage and annual average, CMMS12A scenario.



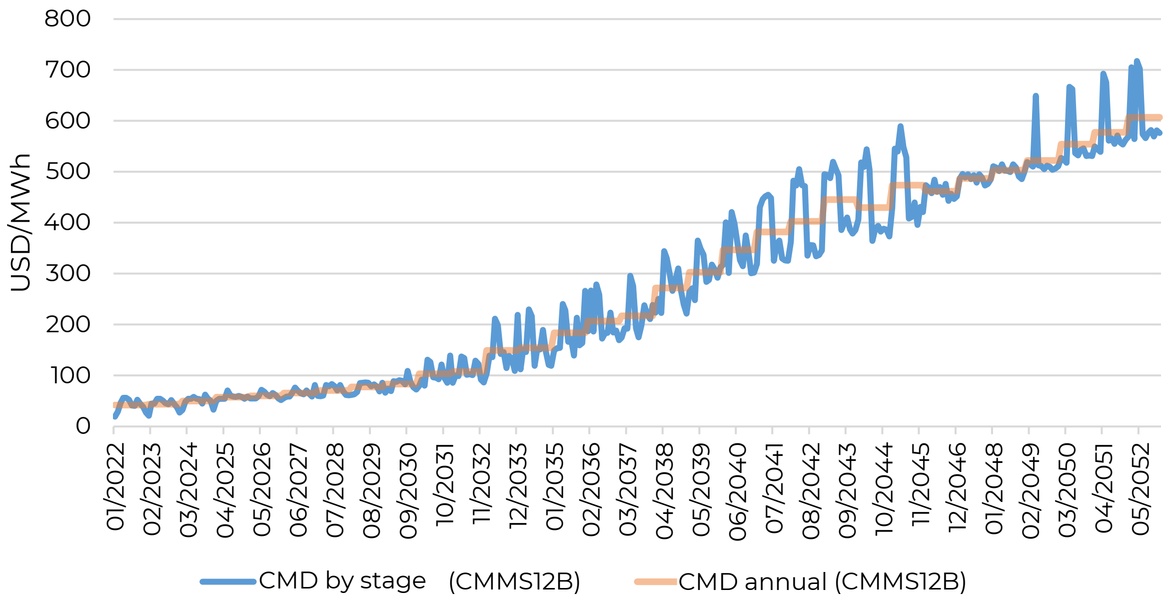
Source: Elaborated by UPEM.

Graph 85: Energy Dispatch of the CMMS12B scenario.



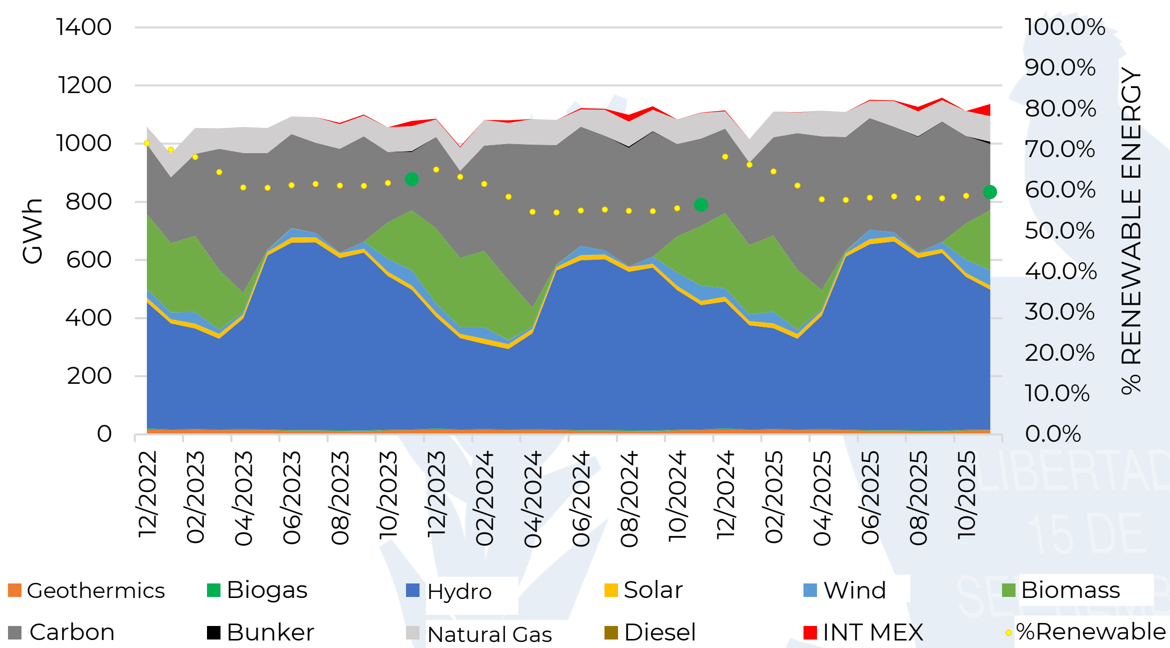
Source: Elaborated by UPEM.

Graph 86: Marginal Cost of Demand by stage and annual average, CMMS12B scenario.



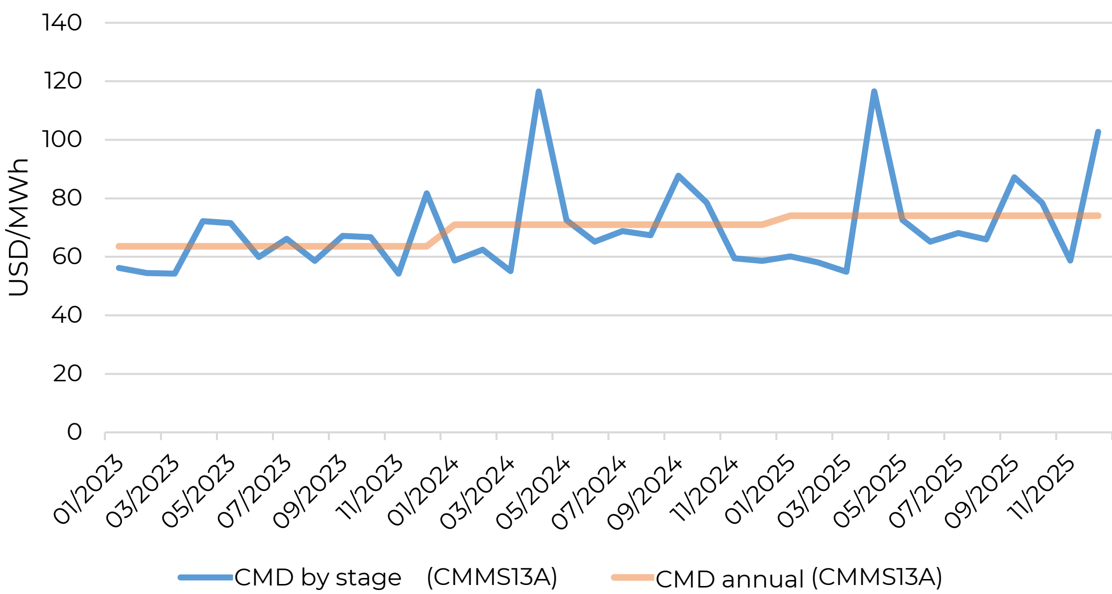
Source: Elaborated by UPEM.

Graph 87: Energy Dispatch of the CMMS13A scenario.



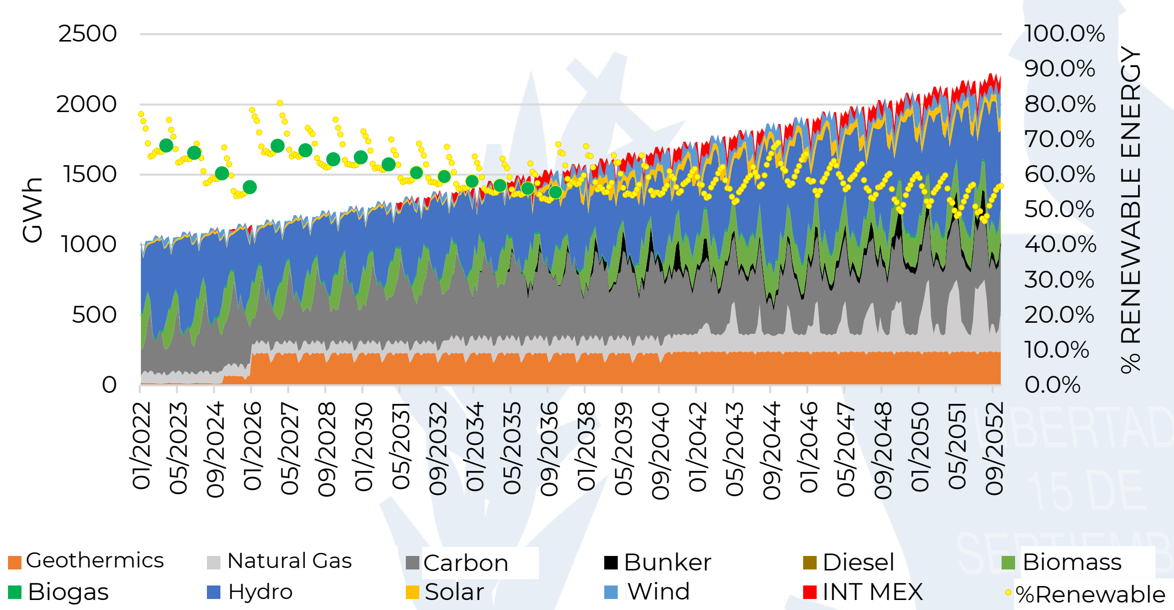
Source: Elaborated by UPEM.

Graph 88: Marginal Cost of Demand by stage and annual average, CMMS13A scenario.



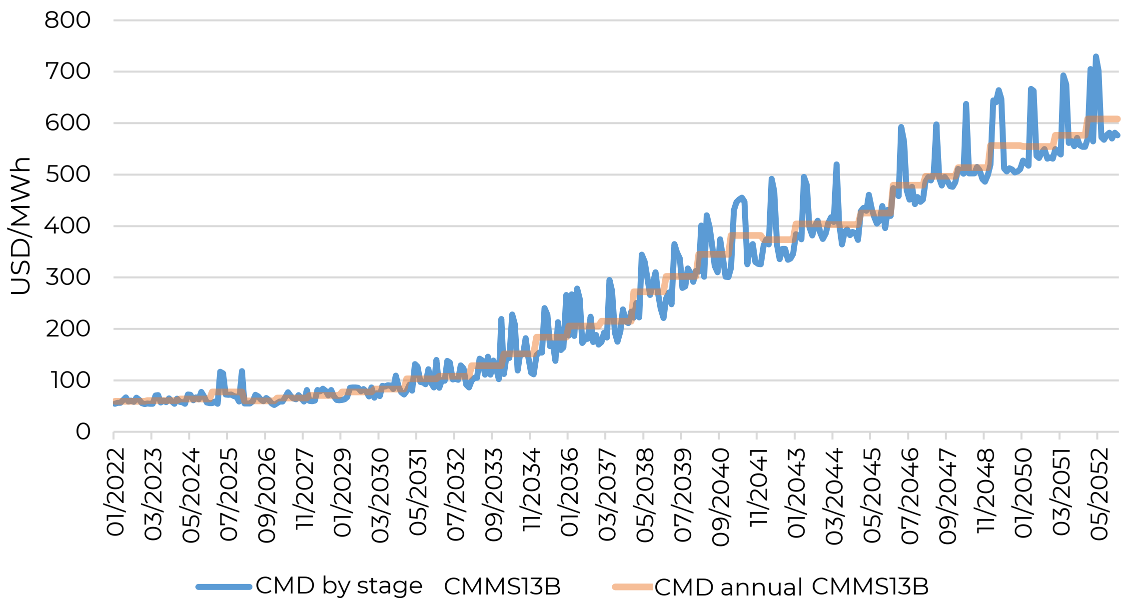
Source: Elaborated by UPEM.

Graph 89: Energy Dispatch of the CMMS13B scenario.



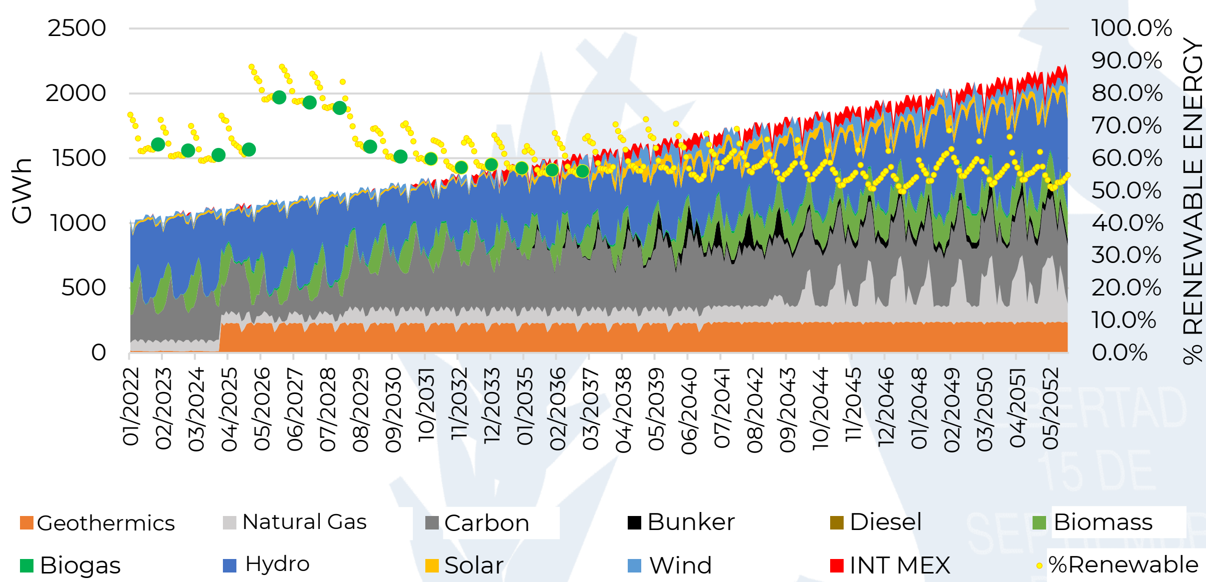
Source: Elaborated by UPEM.

Graph 90: Marginal Cost of Demand by stage and annual average, CMMS13B scenario.



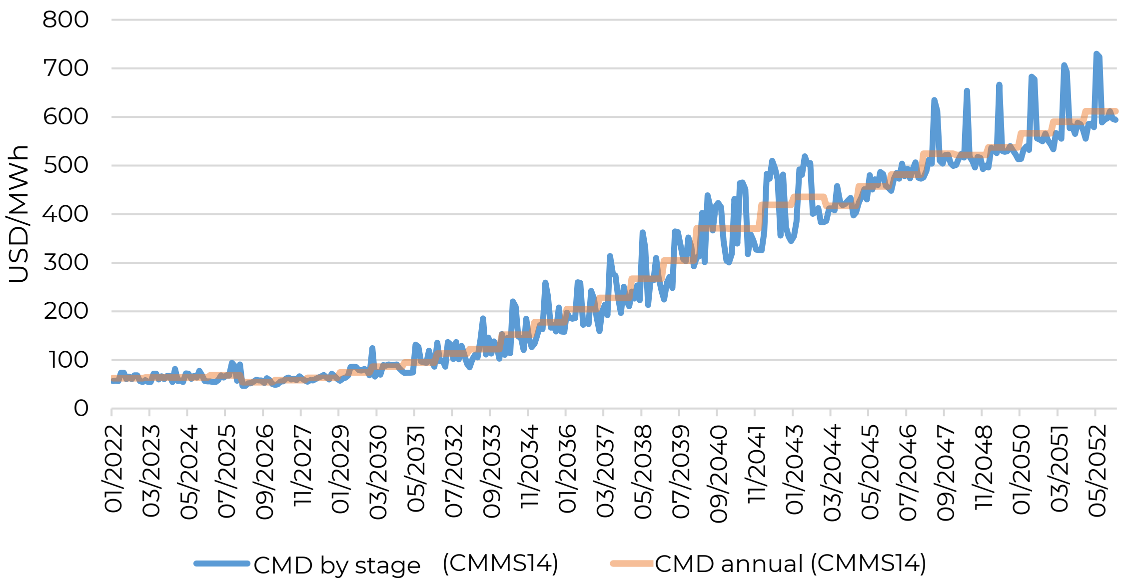
Source: Elaborated by UPEM.

Graph 91: Energy Dispatch of the CMMS14 scenario.



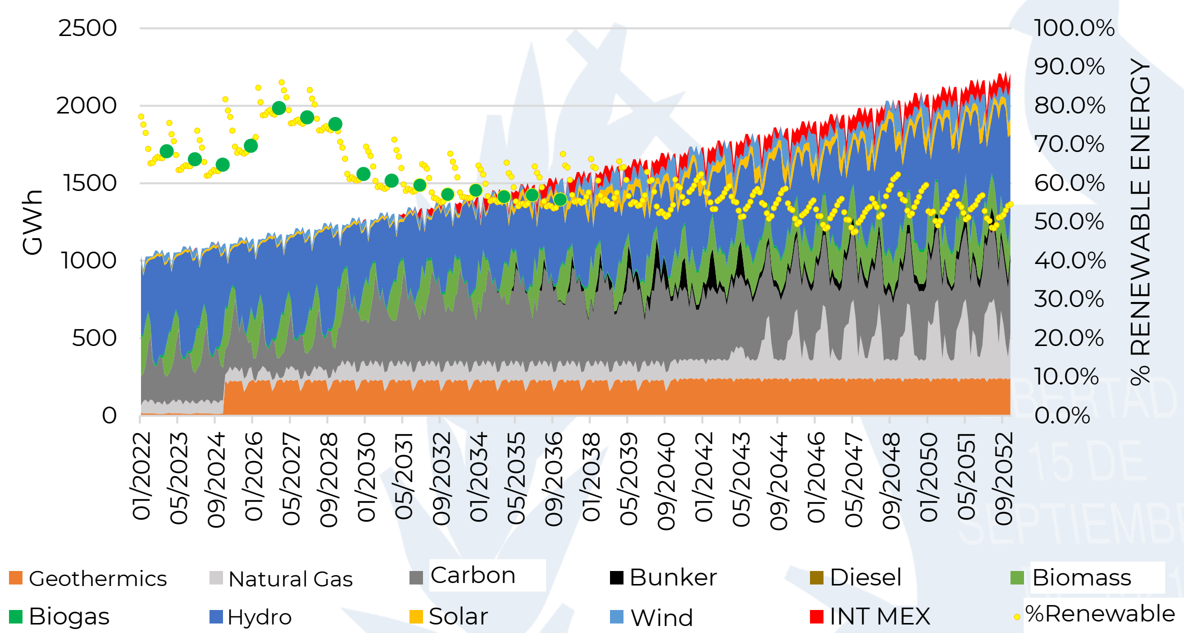
Source: Elaborated by UPEM.

Graph 92: Marginal Cost of Demand by stage and annual average, CMMS14 scenario.



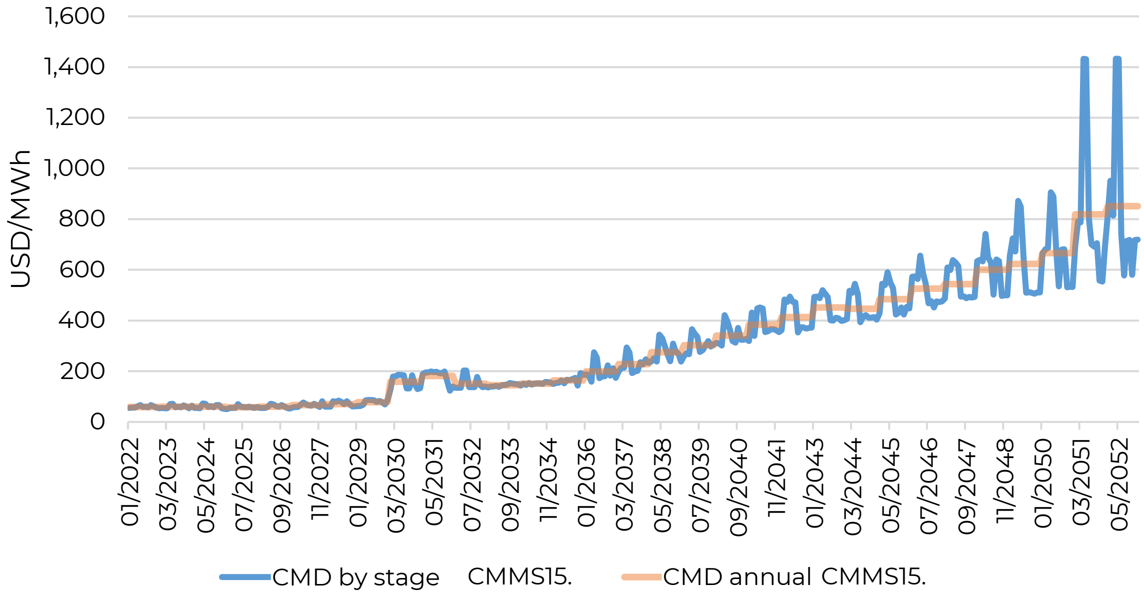
Source: Elaborated by UPEM.

Graph 93: Energy Dispatch of the CMMS15 scenario.



Source: Elaborated by UPEM.

Graph 94: Marginal Cost of Demand by stage and annual average, CMMS15 scenario.

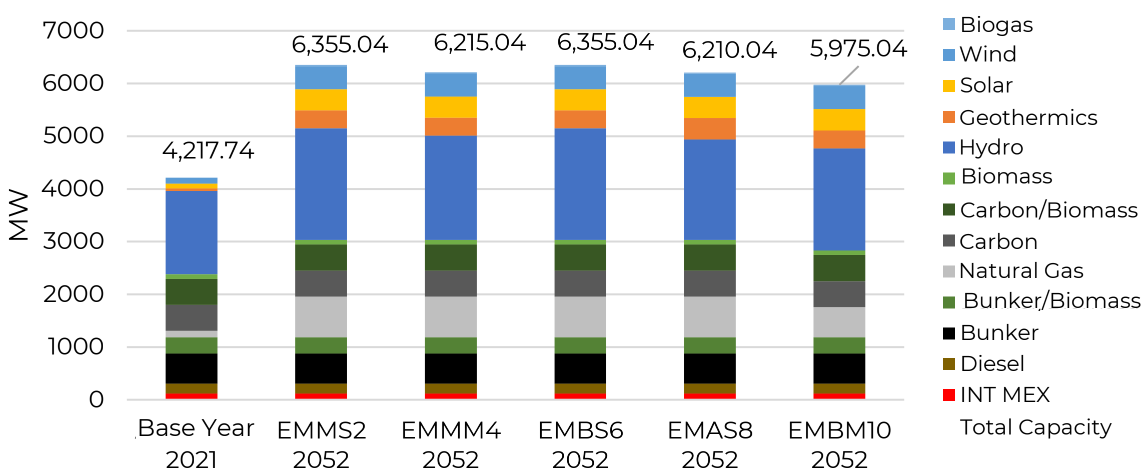


Source: Elaborated by UPEM.

9.3 COMPOSITION OF THE INSTALLED CAPACITY MATRIX

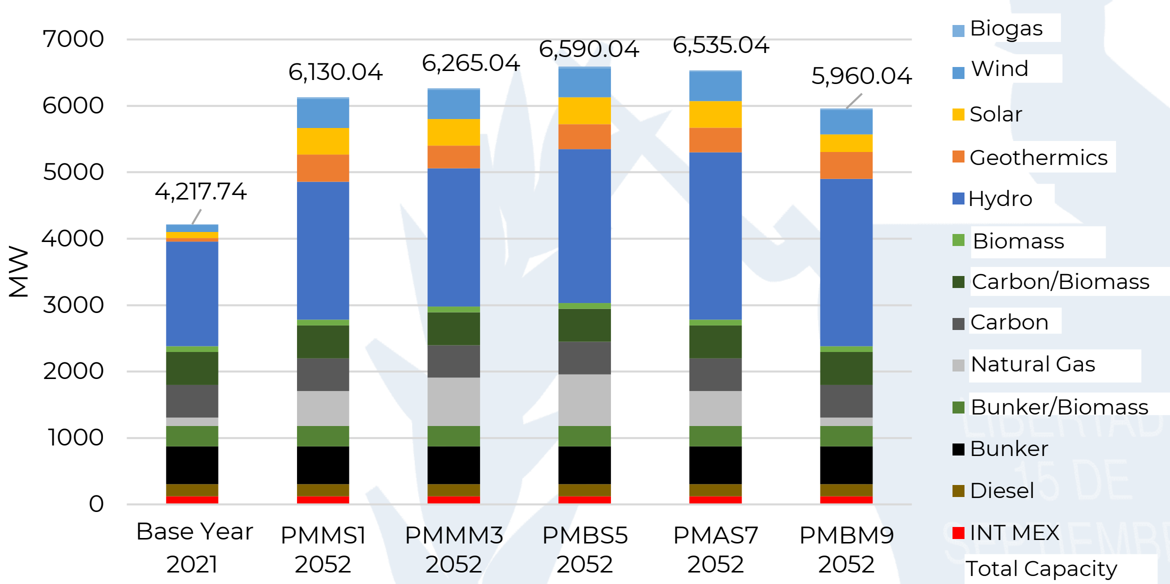
The following graphs show the comparison of installed capacity in each of the scenarios proposed versus the current one.

Graph 95: Comparison of Installed Capacity of each BAU scenario.



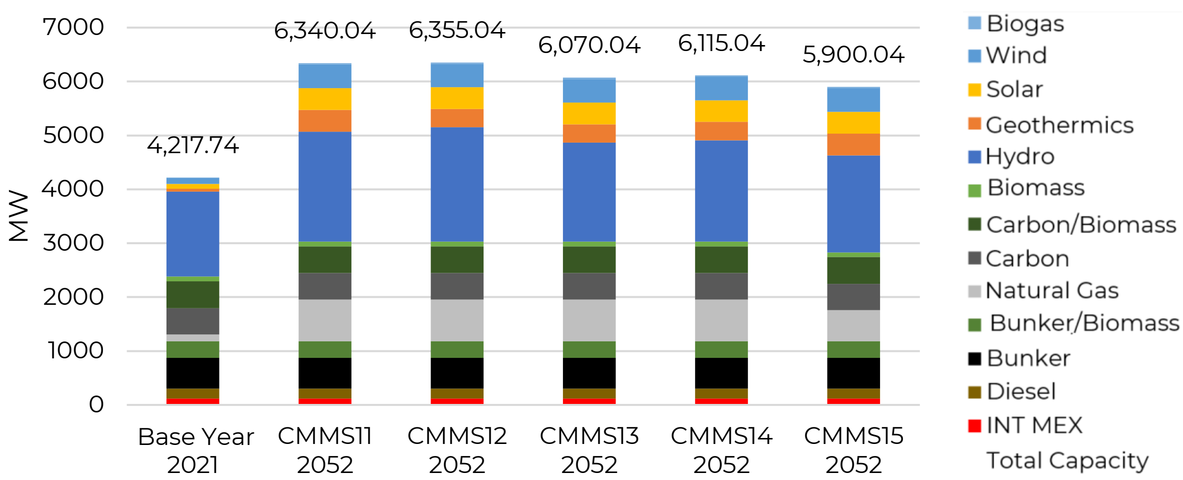
Source: Proprietary Production, SDDP-OPTGEN.

Graph 96: Comparison of Installed Capacity of each scenario complying with Public Policies.



Source: Proprietary Production, SDDP-OPTGEN.

Graph 97: Comparison of Installed Capacity for each contingency scenario.

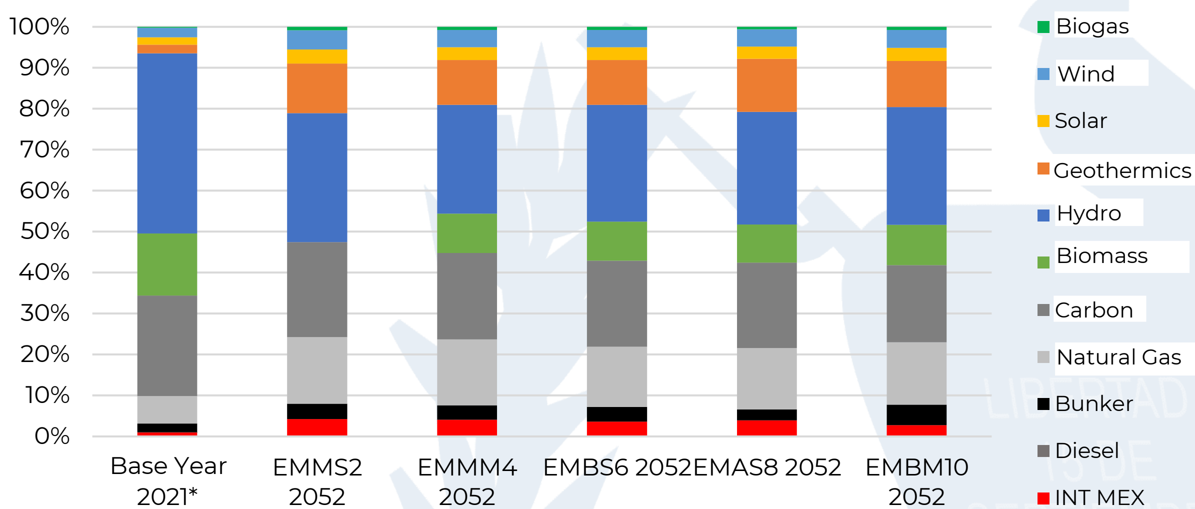


Source: Proprietary Production, SDDP-OPTGEN.

9.4 ELECTRIC GENERATION MATRICES [GWh].

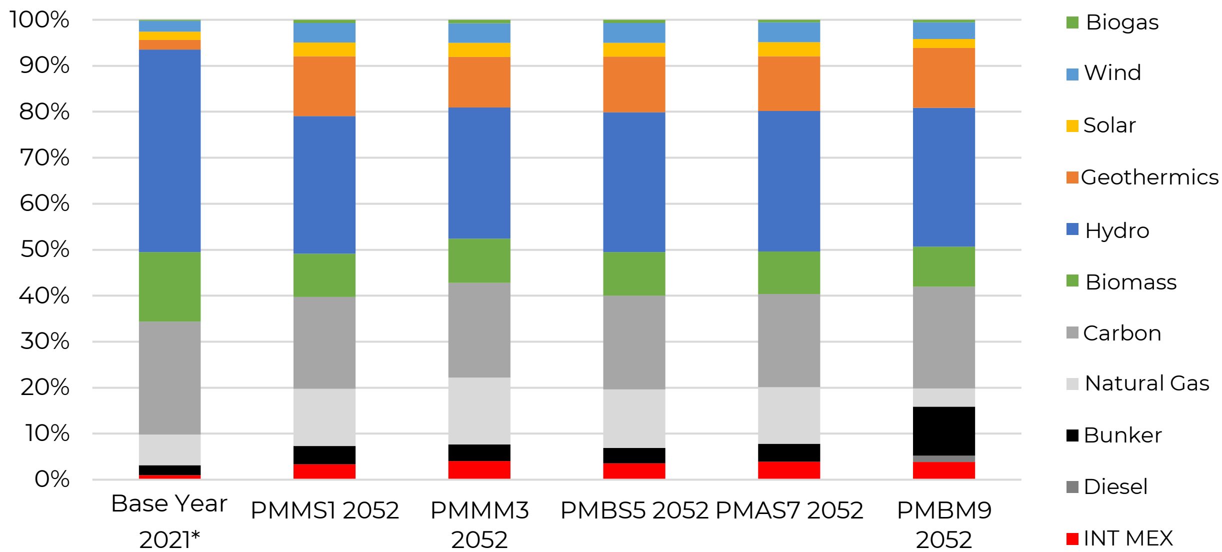
The following graphs compare the electricity generation matrix that will be achieved in each of the scenarios evaluated against the current one.

Graph 98: Electricity generation matrices for each BAU scenario.



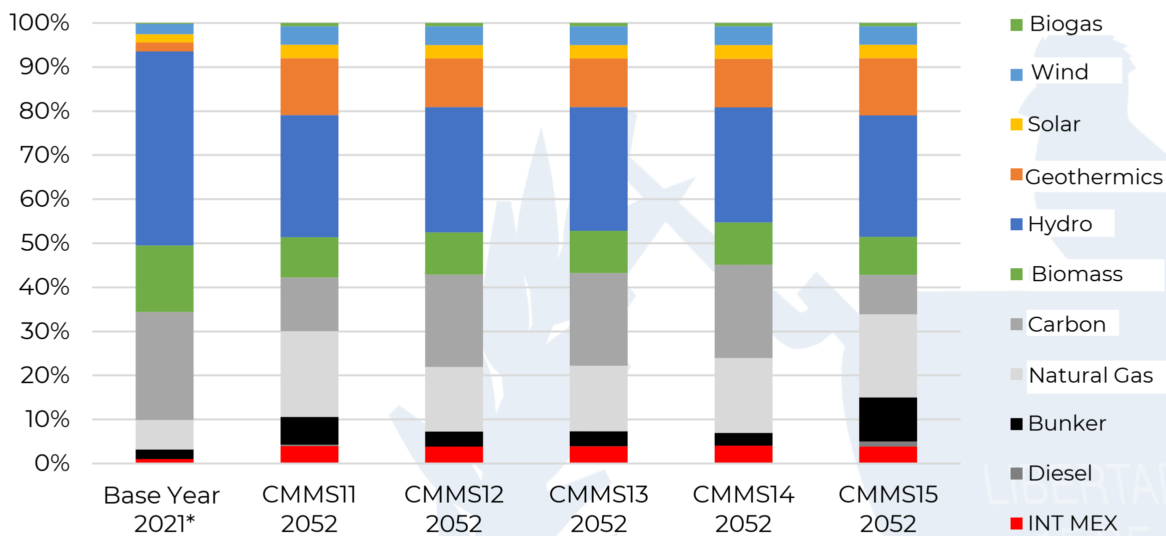
*August 2021. Source: Proprietary Production, SDDP-OPTGEN.

Graph 99: Electricity generation matrices for each public policy scenario.



*August 2021. Source: Proprietary Production, SDDP-OPTGEN.

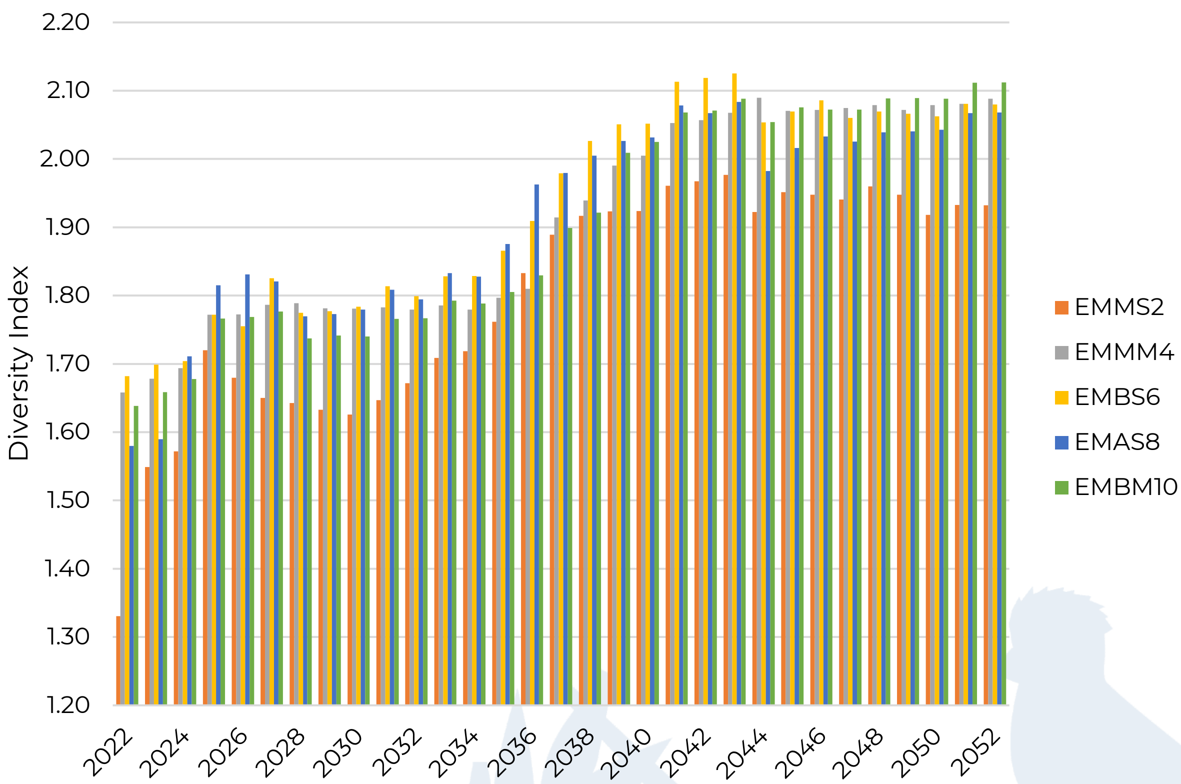
Graph 100: Electricity generation matrices for each contingency scenario.



*August 2021. Source: Proprietary Production, SDDP-OPTGEN.

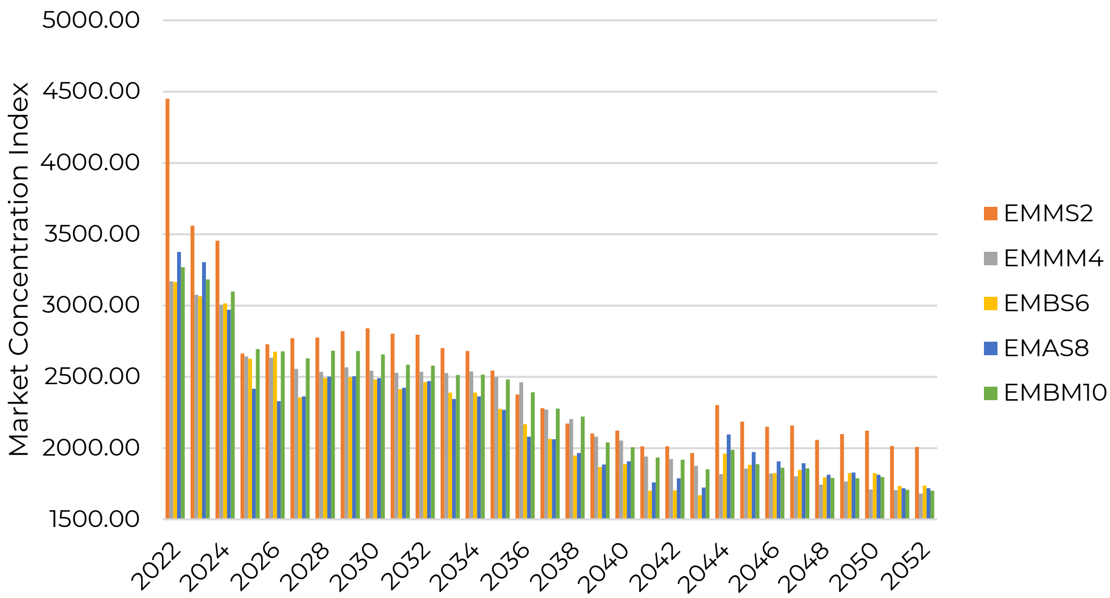
9.5 INDICATORS OF DIVERSIFICATION OF THE ELECTRICITY GENERATION MATRIX

Graph 101: Shannonn Wienner Diversification Index for BAU scenarios.



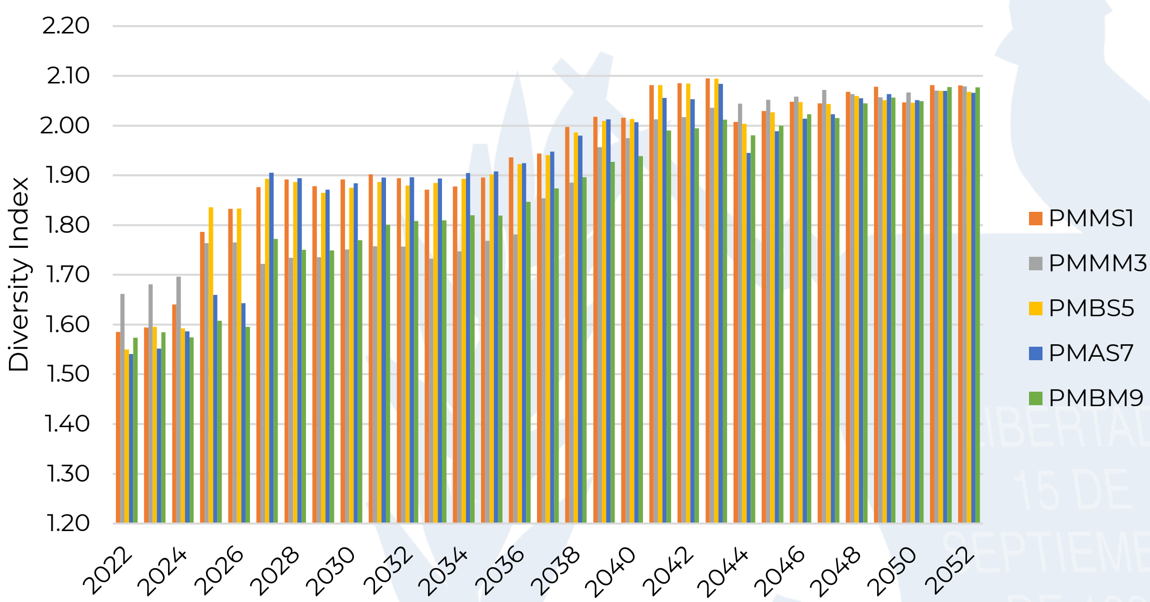
Source: Proprietary Production, SDDP-OPTGEN.

Graph 102: Herdendahl Hirshman Concentration Index for BAU scenarios.



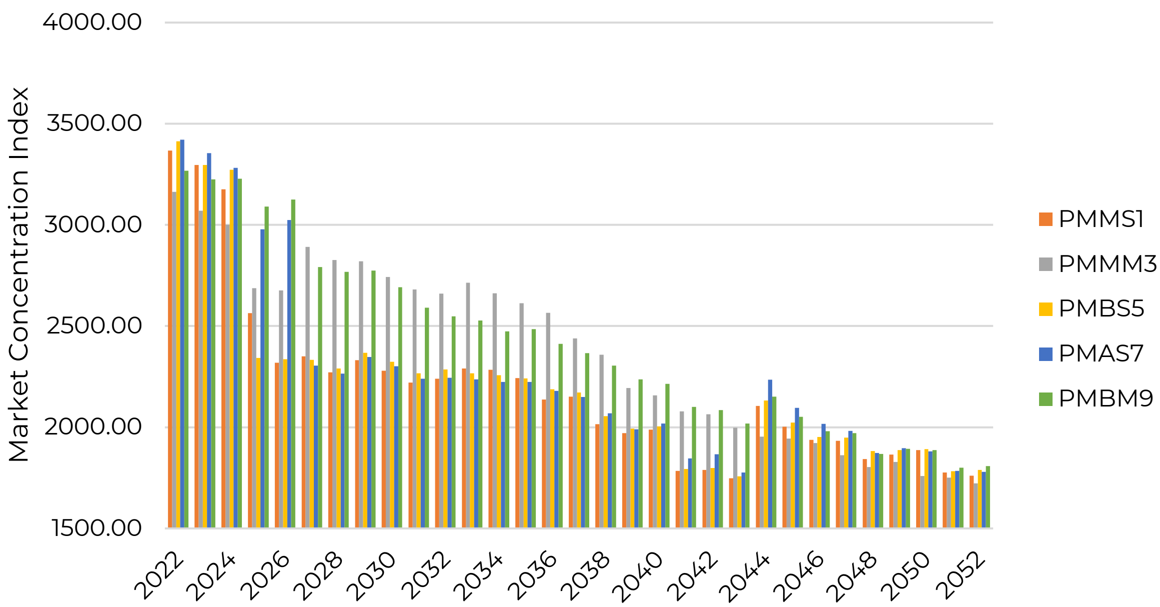
Source: Proprietary Production, SDDP-OPTGEN.

Graph 103: Shannonn Wienner Diversification Index for Public Policy Compliance Scenarios.



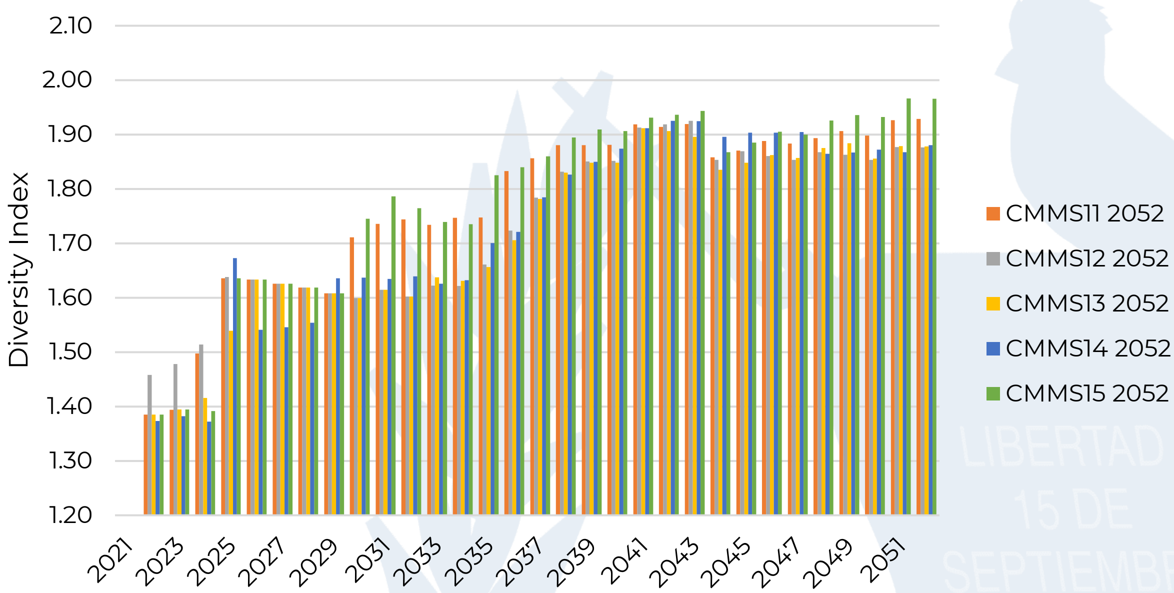
Source: Proprietary Production, SDDP-OPTGEN.

Graph 104: Herdendahl Hirshman Concentration Index for Public Policy compliance scenarios.



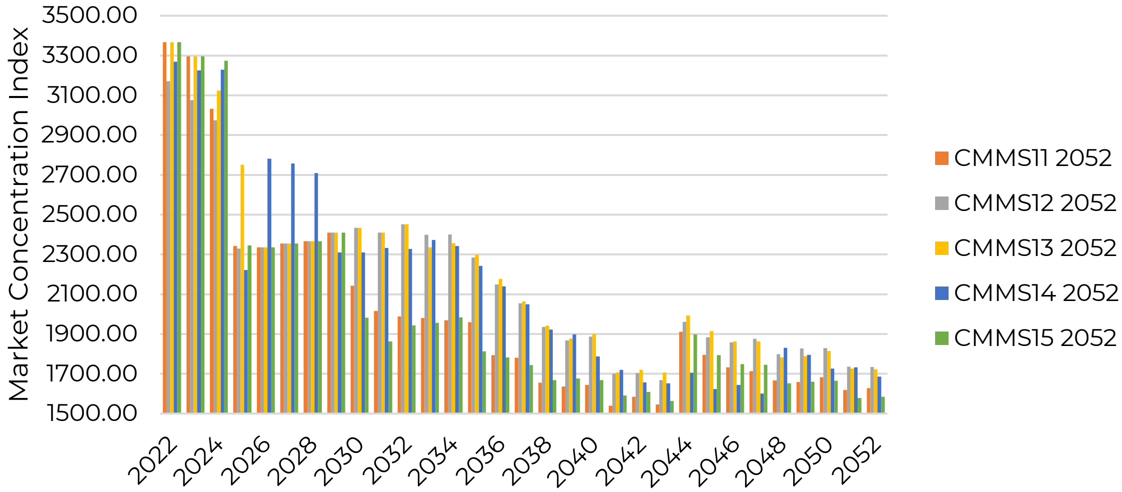
Source: Proprietary Production, SDDP-OPTGEN.

Graph 105: Shannonn Wienner Diversification Index for contingency scenarios.



Source: Proprietary Production, SDDP-OPTGEN.

Graph 106: Herdendahl Hirshman Concentration Index for contingency scenarios.

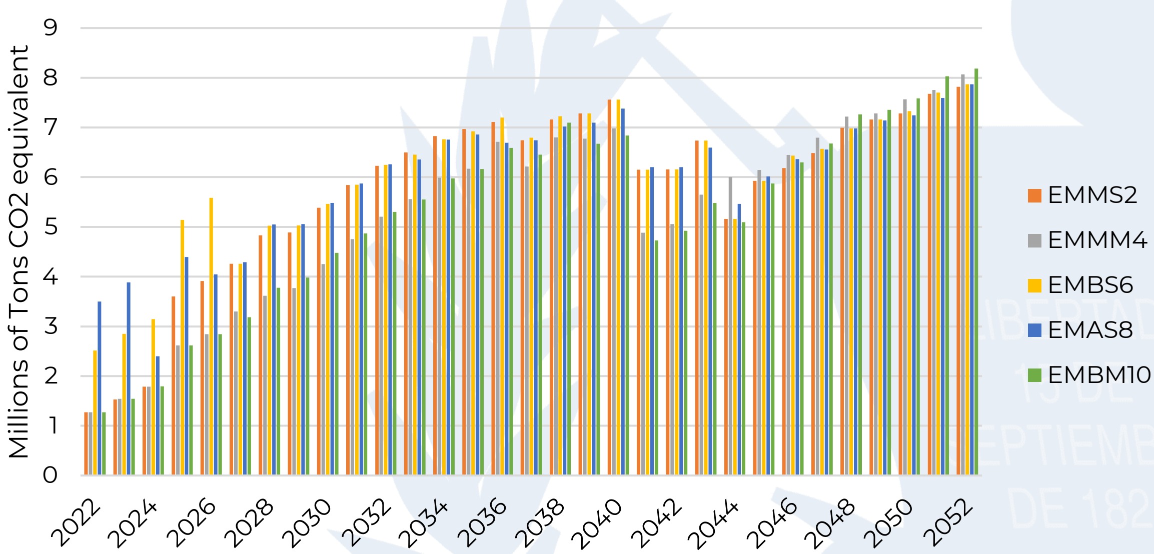


Source: Proprietary Production, SDDP-OPTGEN.

9.6 ANNUAL CO_2 EQUIVALENT EMISSIONS

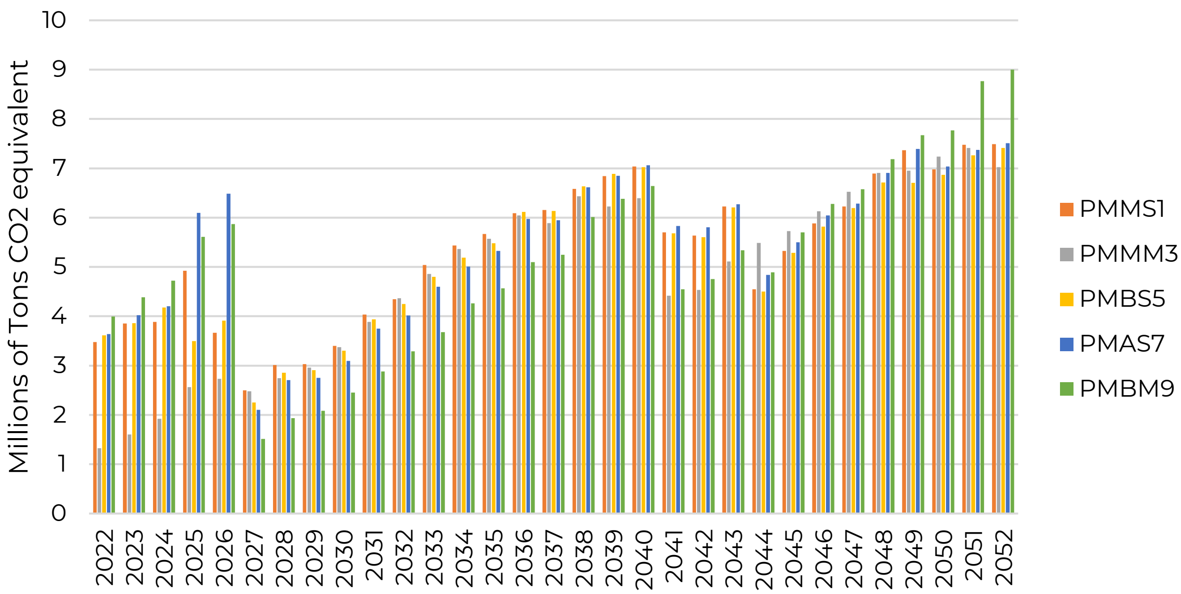
The greenhouse gas emissions provided by each of the scenarios indicated in the legends are quantified below.

Graph 107: Greenhouse Gas Emissions for each BAU scenario.



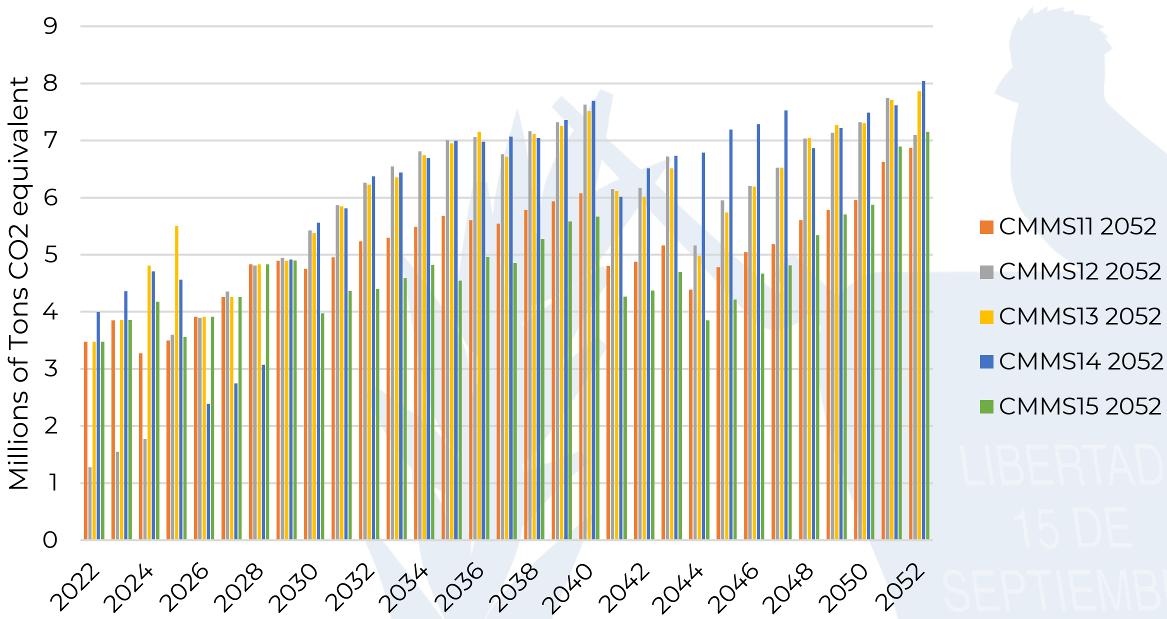
Source: Proprietary Production, SDDP-OPTGEN.

Graph 108: Greenhouse Gas Emissions of each scenario compliance with Public Policies.



Source: Proprietary Production, SDDP-OPTGEN.

Graph 109: Greenhouse Gas Emissions for each contingency scenario.



Source: Proprietary Production, SDDP-OPTGEN.

9.7 TOTAL FUEL CONSUMPTION BY SCENARIO

For each scenario evaluated, the table with the total fuel consumption in the study period is attached, as shown in the following table.

Table 20: Fuel consumption for the period 2022-2052 in the various scenarios.

	US Gal	US Gal	MMBTU	Metric Ton
Scenario	Diesel	Bunker	Natural Gas	Carbon
EMMS2	0	686,365	398,771	58,061
EMMM4	0	619,524	385,073	52,982
EMBS6	0	758,579	394,089	61,031
EMAS8	0	350,302	433,108	61,222
EMBM10	0	653,122	387,851	52,546
PMMS1	7,861	862,330	296,126	53,751
PMMM3	26,444	991,138	266,554	49,488
PMBS5	24,048	1,018,197	259,513	54,452
PMAS7	0	543,064	285,424	54,226
PMBM9	144,784	1,587,702	231,438	58,309

Source: Proprietary Production, SDDP-OPTGEN.

Table 21: Fuel consumption for the period 2022-2052 in the various contingency scenarios.

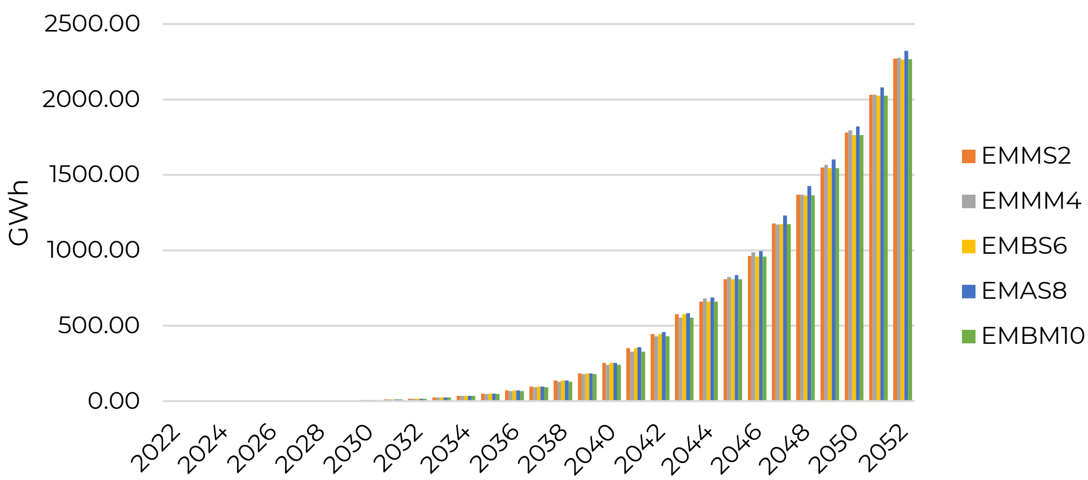
	US Gal	US Gal	MMBTU	Metric Ton
Scenario	Diesel	Bunker	Natural Gas	Carbon
CMMS11	8,313	710,074	697,650	42,126
CMMS12	0	686,668	401,336	57,950
CMMS13	0	592,165	430,099	61,217
CMMS14	0	622,828	474,371	60,815
CMMS15	63,748	1,264,648	822,350	32,500

Source: Proprietary Production, SDDP-OPTGEN.

9.8 TOTAL DEFICIT RISK (GWh)

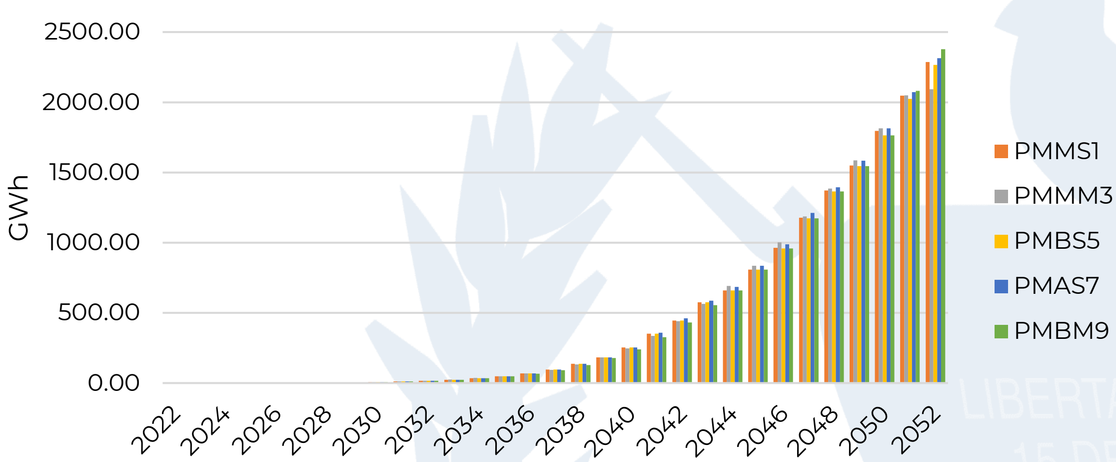
The risk of deficit is the energy that for various reasons cannot be supplied to the demand points, usually due to lack of installed capacity, network restrictions or other technical reasons.

Graph 110: Electric power deficit for each BAU scenario.



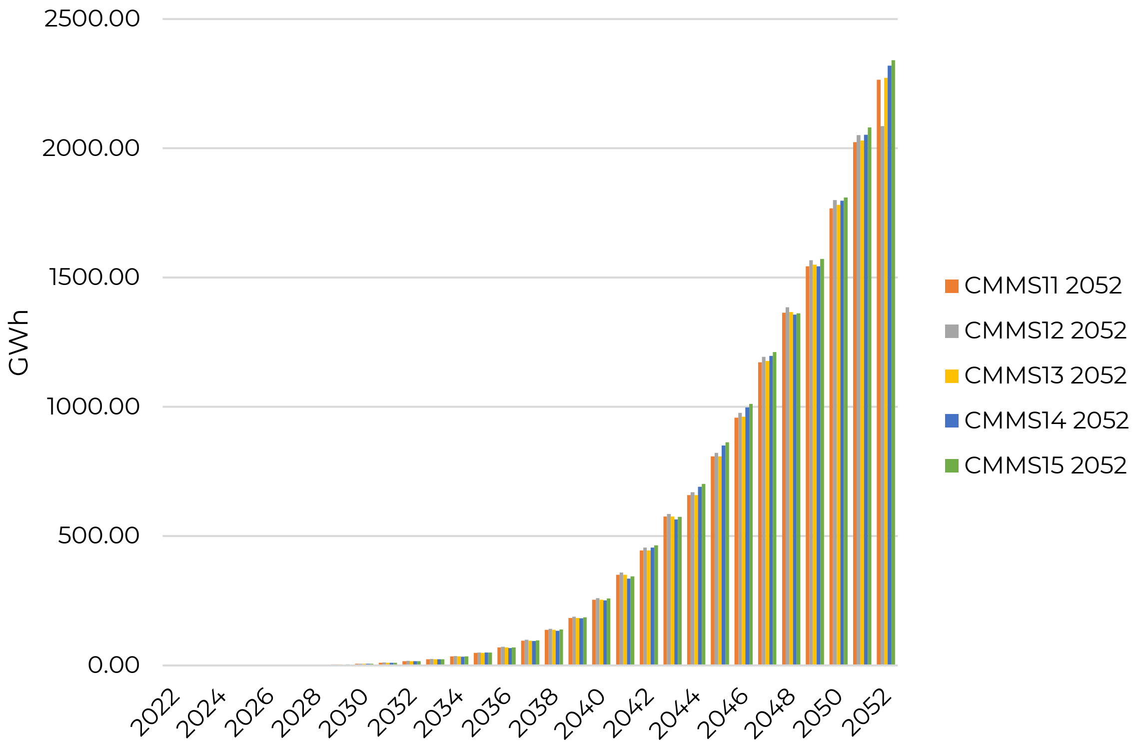
Source: Proprietary Production, SDDP-OPTGEN.

Graph 111: Electricity deficit of each Public Policy compliance scenario.



Source: Proprietary Production, SDDP-OPTGEN.

Graph 112: Electric power deficit for each contingency scenario.



Source: Proprietary Production, SDDP-OPTGEN.

10 CONCLUSIONS

- When evaluating 10 scenarios, 5 BAU and 5 public policy scenarios, under the premises of three fuel price increase scenarios, two hydrology scenarios (dry and medium) and a medium demand scenario, being these the most probable premises, it is observed that there is a risk of deficit as of 2030, however, such risk tends to increase as of 2042, reaching values close to 2,400 GWh for each scenario evaluated in 2052. The deficit risk is related to the energy that for different technical reasons cannot be delivered to the demand points, such as grid restrictions or others.

- The premise taken under the public policy concept was to promote an 80% share of renewable energies by the year 2027; in the scenarios for which this premise was considered, an average of 82% of renewable energy was achieved.

- The investments incurred for the public policy scenarios are on average 563 MUSD more expensive than the investments for the B.A.U. scenarios. In other words, this is the additional investment that the system will need to meet 80% renewable energy by 2027.

- In the contingency scenarios for which certain installed capacity of coal-fired plants is permanently taken out of operation, new capacity of plants using natural gas and geothermal resources is installed, and generation is increased in a representative manner with bunker, natural gas, carbon and interconnection with Mexico.

  In contingency scenarios for which a certain capacity of hydroelectric plants is temporarily taken out of operation, in a specific year, new plant capacity is installed using resources from: Biogas, geothermal and hydroelectric: Biogas, geothermal and hydro and generation is increased in a representative manner with resources of natural gas, carbon and interconnection with Mexico.

  For the contingency scenario in which coal thermal capacity is temporarily taken out of operation in a specific year, the contingency is compensated with existing capacity, thus increasing generation through natural gas and interconnection with Mexico.

- The above demonstrates the need for new or existing plants to reserve base power generation capacity to guarantee the supply of electricity in the event of contingencies or plant closures.

- When evaluating the investment costs incurred for the various contingency scenarios, it is observed that the most expensive scenarios are those in which coal-fired plants are taken out of operation, such is the case of the CMMS11 and CMMS12 scenarios, whose total investment costs are: 5,999.15 and 5,947.15, respectively.

- CO_2e emissions in 2027, for the scenarios that drive 80% renewable generation (PP scenarios), are reduced by 44% compared to the BAU scenarios.

- Total CO_2e emissions, over the study horizon, on average, show a reduction of 15,952,923 MT, representing a 9% reduction for the PP scenarios with respect to the BAU scenarios.

- In the contingency scenarios, in which certain coal plant capacity is taken out of operation (CMMS11, CMMS12 and CMMS15), a reduction of 1,438,188 MT of CO2e emissions is observed with respect to the BAU scenarios.

- Of the ten most likely scenarios, the PMMM3 scenario shows the lowest spot price and the PMAS7 scenario shows the highest spot price, taking into consideration the sum of the annual spot price averages over the period 2022 - 2052. In general, the opportunity price of electricity tends to increase for all scenarios, due to the relationship with the projected increase in international fuel costs.

- The sum of the annual averages of the spot price in the contingency cases, in the study period, are higher than the BAU and PP scenario prices.

11 RECOMMENDATIONS

- In order to meet the goals and objectives of the energy policy, it is advisable to make investments especially in solar projects with power reserves and generation projects with geothermal resources, either through private investments or state investments through INDE. Geothermal energy is a technology with a stable operation, considered as a base plant that uses renewable resources, so it does not depend on international fuel costs, in addition this type of plant has a long useful life.

- Take into account the available resource of natural gas in Guatemala, for the installation or expansion of power generation plants in the short or medium term, since this resource is considered clean compared to other non-renewable resources, and is also considered as basic plants, this would contribute to an energy transition to a cleaner matrix. Also take into account this resource to cover contingencies that may affect the supply of electricity in the system.

- The generation plants necessary for an economically efficient operation of the NIS need transmission lines to transport the generation to the consumption centers. It is recommended to consider the results present in the expansion of national transmission.

- It is advisable to define reserve plants to supply contingencies due to failures, plant closures or climate change, considering the impact on the generation system, since adaptation to climate change is key for a country so vulnerable to natural phenomena.

12 BIBLIOGRAPHY.

- Administrador del Mercado Mayorista. Informe Estadístico 2010. AMM, 2010.
- Administrador del Mercado Mayorista. Informe Estadístico 2011. AMM, 2011.
- Administrador del Mercado Mayorista. Informe Estadístico 2012. AMM, 2012.
- Administrador del Mercado Mayorista. Informe Estadístico 2013. AMM, 2013.
- Administrador del Mercado Mayorista. Informe Estadístico 2014. AMM, 2014.
- Administrador del Mercado Mayorista. Informe Estadístico 2015. AMM, 2015.
- Administrador del Mercado Mayorista. Informe Estadístico 2016. AMM, 2016.
- Administrador del Mercado Mayorista. Informe Estadístico 2017. AMM, 2017.
- Administrador del Mercado Mayorista. Informe Estadístico 2018. AMM, 2018.
- Administrador del Mercado Mayorista. Informe Estadístico 2019. AMM, 2019.
- Administrador del Mercado Mayorista. Informe Estadístico 2020. AMM, 2020.
- Ministerio de Energía y Minas. Balance Energético 2001. MEM, 2002.
- Ministerio de Energía y Minas. Balance Energético 2002. MEM, 2003.
- Ministerio de Energía y Minas. Balance Energético 2003. MEM, 2004.
- Ministerio de Energía y Minas. Balance Energético 2004. MEM, 2005.
- Ministerio de Energía y Minas. Balance Energético 2005. MEM, 2006.
- Ministerio de Energía y Minas. Balance Energético 2006. MEM, 2007.
- Ministerio de Energía y Minas. Balance Energético 2007. MEM, 2008.
- Ministerio de Energía y Minas. Balance Energético 2008. MEM, 2009.
- Ministerio de Energía y Minas. Balance Energético 2009. MEM, 2010.
- Ministerio de Energía y Minas. Balance Energético 2010. MEM, 2011.
- Ministerio de Energía y Minas. Balance Energético 2011. MEM, 2012.
- Ministerio de Energía y Minas. Balance Energético 2012. MEM, 2013.
- Ministerio de Energía y Minas. Balance Energético 2013. MEM, 2014.
- Ministerio de Energía y Minas. Balance Energético 2014. MEM, 2015.
- Ministerio de Energía y Minas. Balance Energético 2015. MEM, 2016.
- Ministerio de Energía y Minas. Balance Energético 2016. MEM, 2017.
- Ministerio de Energía y Minas. Balance Energético 2017. MEM, 2018.
- Ministerio de Energía y Minas. Balance Energético 2018. MEM, 2019.
- Ministerio de Energía y Minas. Balance Energético 2019. MEM, 2020.
- Banco de Guatemala. Producto Interno Bruto trimestral. [en línea]. https://www.banguat.gob.gt/inc/main.asp?id=84369&aud=1&lang=1. [Consulta: 2021].

- Comisión Nacional de Energía Eléctrica. Pliegos tarifarios. [en línea]. http://www.cnee.gob.gt/Calculadora/pliegos.php. [Consulta: 2021].
- Ministerio de Energía y Minas. Plan Nacional de Eficiencia Energética 2019 – 2032. MEM, 2019.
- Ministerio de Energía y Minas. Plan Nacional de Energía 2017 – 2032. Guatemala: MEM, 2017.
- Ministerio de Energía y Minas. Política Energética 2013 – 2027. Guatemala: MEM, 2013.
- Ministerio de Energía y Minas. Política Energética 2019 – 2050. Guatemala: MEM, 2018.
- Ministerio de Energía y Minas. Política de Electrificación Rural 2019 – 2032. Guatemala: MEM, 2018.

GOBIERNO *de*
GUATEMALA