grütter consulting

Power Sector Assessment




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1. Mexico

The following table shows the data on Mexico's electricity generation and consumption for the year 2021.

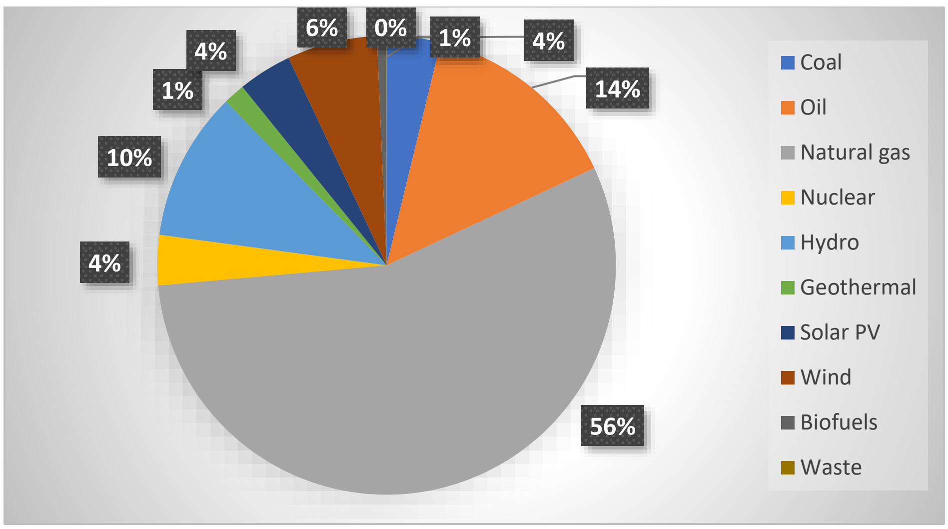
Table 1: Electricity generation and consumption in Mexico in 2021

Electricity generation in GWh	328,526
Electricity imports in GWh	8,447
Electricity exports in GWh	(6,028)
Electricity consumption in GWh	330,945

Source: IEA Database

2021 Mexico produced 22% of electricity based on renewables[1]. Natural gas is by far the largest source of electricity production, followed by oil and coal (see following figure).

Figure 1: Electricity Generation Mexico 2021

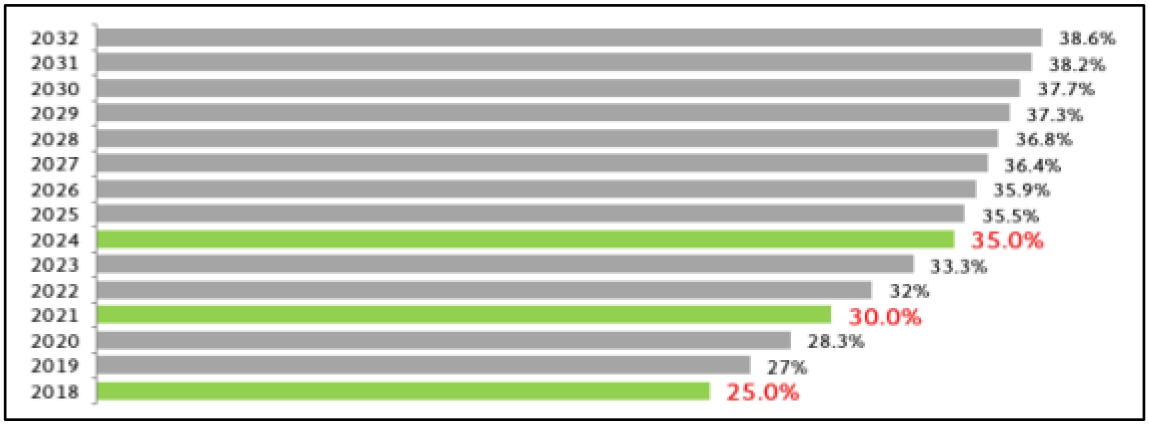


Source: IEA

The renewable energy target for 2025 is 35.5% and for 2030 37.7%. However, the actual renewable energy share for 2021 falls with 22% far short of the target for 2021 with 30% (see figure below).

[1] Including nuclear energy the share is 26%

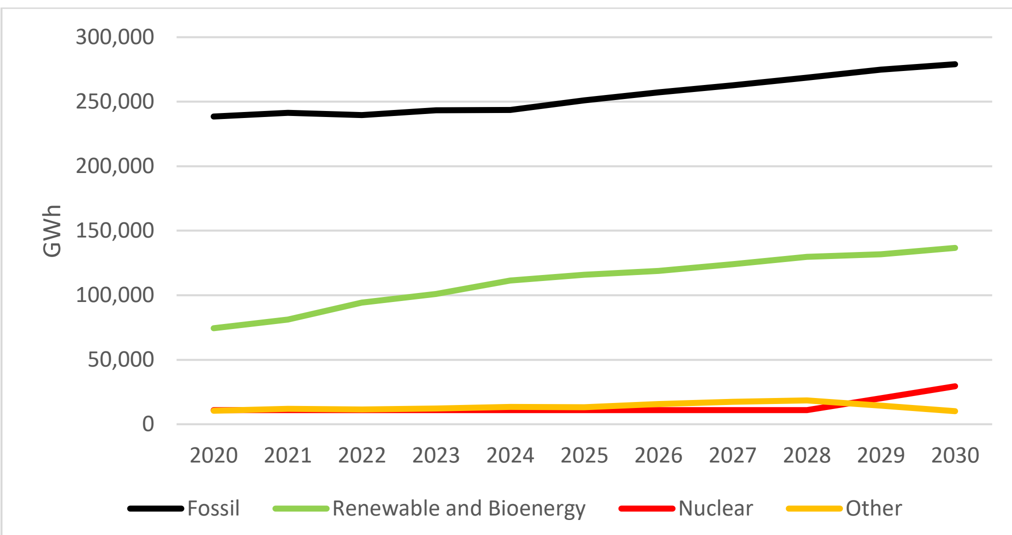
Figure 2: Renewable Energy Target Mexico (in % of generation)



Source: Elaborated by SENER and cited in (SENER, 2018)

Based on the projections of SENER 55% of the capacity addition until 2032 shall be renewable and the rest conventional technologies (SENER, 2018). The following figure shows the projected electricity generation of Mexico to 2030 relative to the energy sources. Based on the projections of SENER the carbon grid factor should slightly decrease by 2030.

Figure 3: Projected Electricity Generation per Source 2020 to 2030 Mexico (GWh)



Source: (SENER, 2018)

Production as well as consumption are expected to grow on average annually around 3.1%. In order to cover the growing demand and phasing out fossil energy, according to Mexico's updated NDC, the country is planning to build four new hydropower plants with a total capacity of 284 MW. Likewise, the country seeks to increase the generation capacity with photovoltaic, wind and geothermal power plants, and to promote renewable distributed generation. (SEMARNAT, 2022)

Electricity imports in Mexico have also increased over the last five years, as can be seen in the next table.

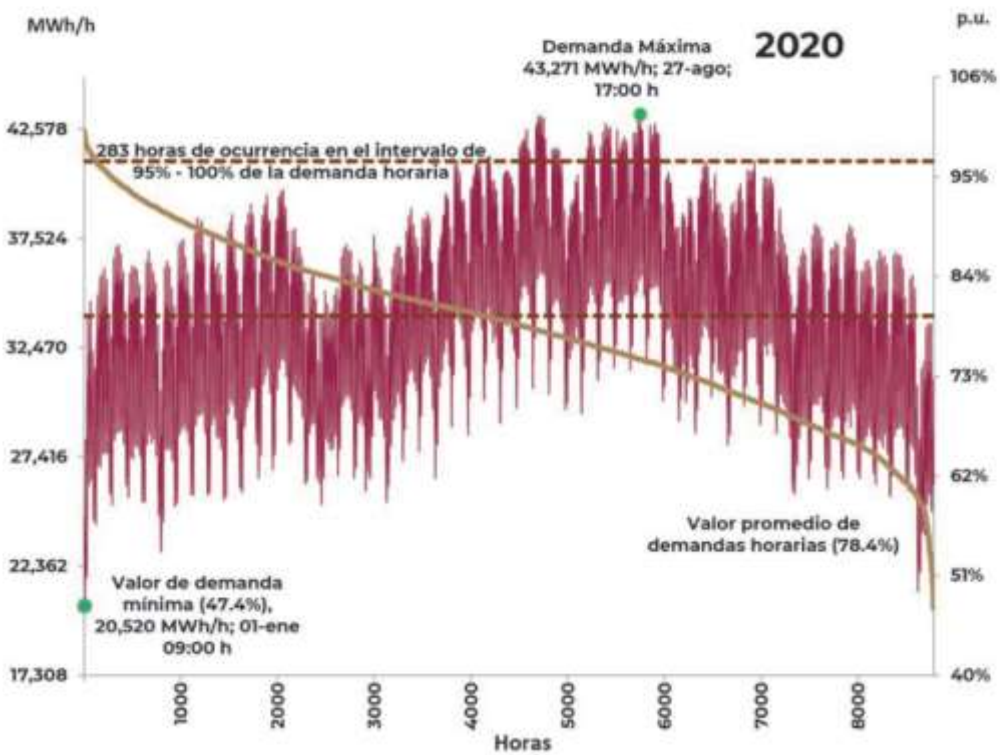
Table 2: Electricity imports in Mexico 2017-2021

Year	2017	2018	2019	2020	2021
Imports in GWh	2,151	3,673	3,907	9,965	8,447

Source: IEA Database

The electricity demand in 2020 showed a differentiated behavior throughout the year, with seasonal fluctuations between the summer months (years highest demand) and the winter months, where the demand is lower. This behavior is characteristic of the northern region of the country; in the center of the country; in the center of the country, this behavior is less marked. Maximum demand in summer months from May to August is significantly higher than in the rest of the year due to cooling. The maximum peak occurred in August 27th, 2020 at 17:00. (See Figure 4)

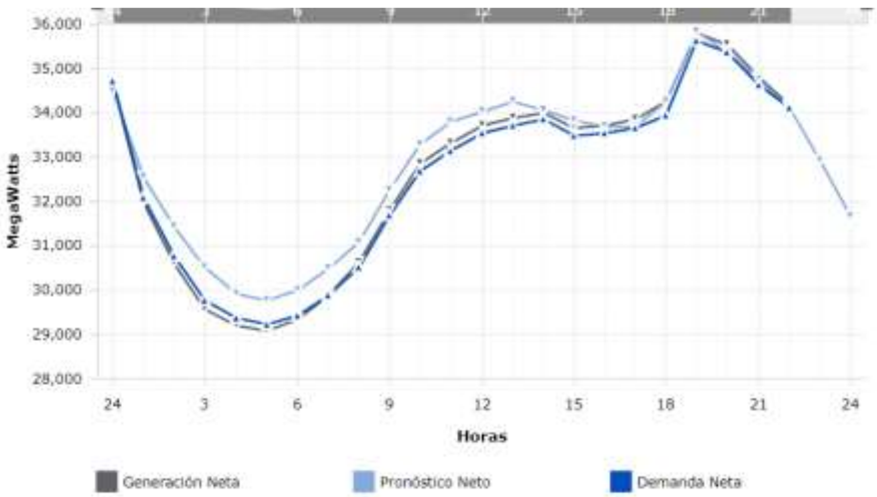
Figure 4: Demand Curve Mexico in 2020



Source: **(SENER, 2021)**

In a 24 hour period, the sistem experiences a maximum demand of 35,629 MW bewteen 18:00 and 19:00.

Figure 5: Peak curve for 24h in Mexico on 10/12/2022



Source: https://www.cenace.gob.mx/graficademanda.aspx

Regarding power outages and grid failures, the Energy Regulating Commission (CRE) publishes a periodic report, the latest being from 2020. According to the report, the total number of disturbances registered in the National Electric System (SEN) in 2020 was 16,054. In the last 3 years reported, this total has registered a decrease at an average annual rate of 1.6%, however it remains at higher levels than those registered in 2017 when they totaled 15,878. Disturbances of high and minimum relevance present an increasing trend, while those classified in medium and low relevance register reductions in the last two years. According to the definitions established in the Grid Code, meteorological events, risk conditions and low frequency operating conditions, among others, are the most common causes of High relevance disturbances, while disturbances of less than 10 MW derived from transient tripping of capacitors, reactors and static compensators represent the main causes of minimum relevance disturbances.

With reference to the fundamental electrical variables established in the Grid Code, voltage and frequency, the SEN presented 56 frequency deviation events with a total load affectation of 8,795 MW, mostly registered in Baja California Sur. In relation to the established voltage band, in 2020 there were 92 voltage deviation events affecting load in the SEN. The total load affected reached 2,203 MW.

In the case of the General Distribution Networks (RDG) performance indexes, in 2020 there was a generalized improvement in the SAIDI of all distribution divisions in relation to 2019 and in its annual accumulated, the lowest value of the last 4 years was reported. In the case of SAIFI, only the Central East and Southeast divisions presented increases; even with these variations, the annual accumulated SAIFI of the 2020 RGD recorded the lowest value of the last 4 years reported. For CAIDI, 15 of the 16 distribution divisions registered an improvement compared to 2019 and only the East distribution division presented an increase, although it remains below its historical maximum. (Comisión Reguladora de Energía, 2020)

The total duration of the power outages (SAIDI) was 107.93 minutes in 2020. The following table shows the SAIDI values for all distribution units. (Comisión Reguladora de Energía, 2020)

Table 3 SAIDI per Distribution Division from the RDG, 2016-2020 (minutes)

No.	División de Distribución	2016	2017	2018	2019	2020	Tendencia	Variación 19-20 [1]
1	Baja California	23.43	20.82	20.58	21.41	20.72		-0.69
2	Noroeste	39.40	36.59	34.46	29.86	23.46		-6.40
3	Norte	22.44	20.74	19.22	18.67	17.21		-1.46
4	Golfo Norte	30.88	25.01	22.07	19.77	18.98		-0.79
5	Golfo Centro	41.77	38.64	40.50	35.47	31.47		-4.01
6	Bajío	24.63	23.69	22.48	21.44	19.59		-1.85
7	Jalisco	26.84	24.41	23.73	22.44	21.58		-0.86
8	Centro Occidente	21.58	19.14	18.94	18.31	16.37		-1.94
9	Centro Sur	27.31	26.73	25.77	24.75	20.44		-4.31
10	Centro Oriente	18.69	17.63	17.60	17.12	14.72		-2.40
11	Oriente	26.64	22.35	26.62	22.17	19.17		-3.00
12	Sureste	51.35	72.15	55.03	53.41	46.95		-6.47
13	Peninsular	19.12	18.38	19.24	17.24	15.05		-2.19
14	Valle de México Norte	30.54	27.67	26.11	25.47	24.39		-1.08
15	Valle de México Centro	28.19	22.53	20.82	18.37	14.35		-4.02
16	Valle de México Sur	45.19	38.09	31.83	27.79	20.81		-6.98

Source: (Comisión Reguladora de Energía, 2020)

The number of power outages (SAIFI) in 2020 was of 1.12. The next tables shows the SAIFI for every distribution network.

Table 4: SAIFI for every Distribution Network, 2016-2020 (events per user)

No.	División de Distribución	2016	2017	2018	2019	2020	Tendencia	Variación 19-20 [1]
1	Baja California	0.62	0.57	0.54	0.57	0.57		0.00
2	Noroeste	1.09	0.91	0.87	0.62	0.52		-0.10
3	Norte	0.73	0.58	0.48	0.43	0.42		-0.01
4	Golfo Norte	0.62	0.47	0.42	0.38	0.38		0.00
5	Golfo Centro	0.63	0.39	0.35	0.38	0.40		0.02
6	Bajío	0.41	0.39	0.35	0.35	0.33		-0.02
7	Jalisco	0.52	0.48	0.46	0.46	0.45		-0.01
8	Centro Occidente	0.47	0.40	0.38	0.35	0.35		-0.01
9	Centro Sur	1.07	0.70	0.53	0.58	0.56		-0.02
10	Centro Oriente	0.38	0.34	0.30	0.27	0.32		0.05
11	Oriente	0.54	0.38	0.31	0.33	0.28		-0.05
12	Sureste	1.07	0.90	0.61	0.64	0.68		0.04
13	Peninsular	0.60	0.53	0.51	0.45	0.43		-0.02
14	Valle de México Norte	0.85	0.72	0.72	0.65	0.64		-0.01
15	Valle de México Centro	0.90	0.71	0.66	0.55	0.43		-0.12
16	Valle de México Sur	0.99	0.86	0.74	0.70	0.58		-0.12

Source: (Comisión Reguladora de Energía, 2020)

The CAIDI is the average duration rate of end-user interruptions in the event of a failure of an element of the of the RGD. To evaluate the index, interruptions greater than five minutes are considered. In 202, the national total CAIDI was of 96.7 minutes. (Comisión Reguladora de Energía, 2020)

2. Argentina

The following table shows Argentina's electricity generation and consumption for the year 2020.

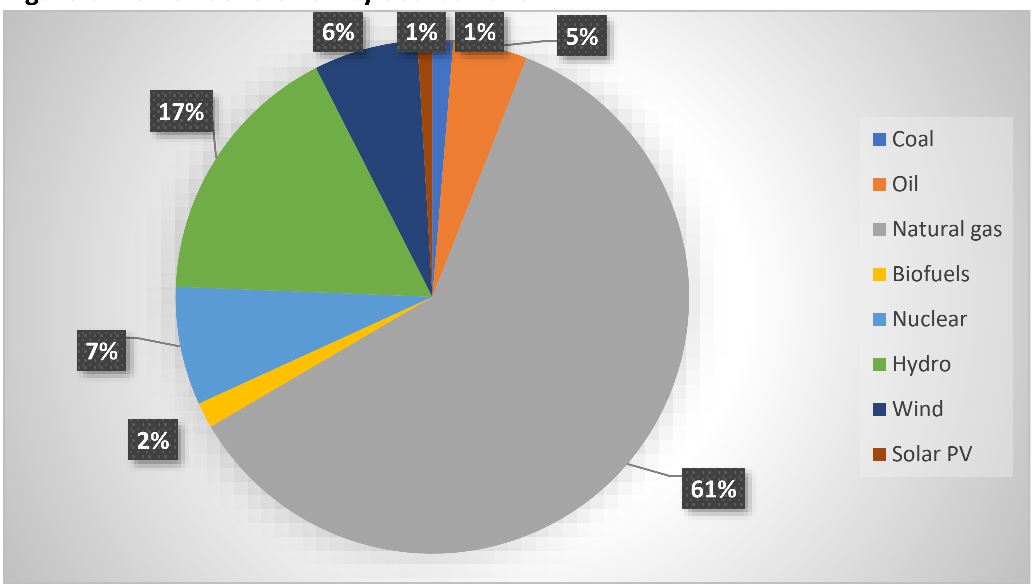
Table 5: Electricity generation and consumption in Argentina in 2020

Electricity generation in GWh	143,697
Electricity imports in GWh	7,802
Electricity exports in GWh	(3,089)
Electricity consumption in GWh	124,522

Source: IEA Dataase

In 2020, 26% of electricity was generated by renewables including hydropower (see figure below). Adding nuclear to the mix, the percentage is 33%.

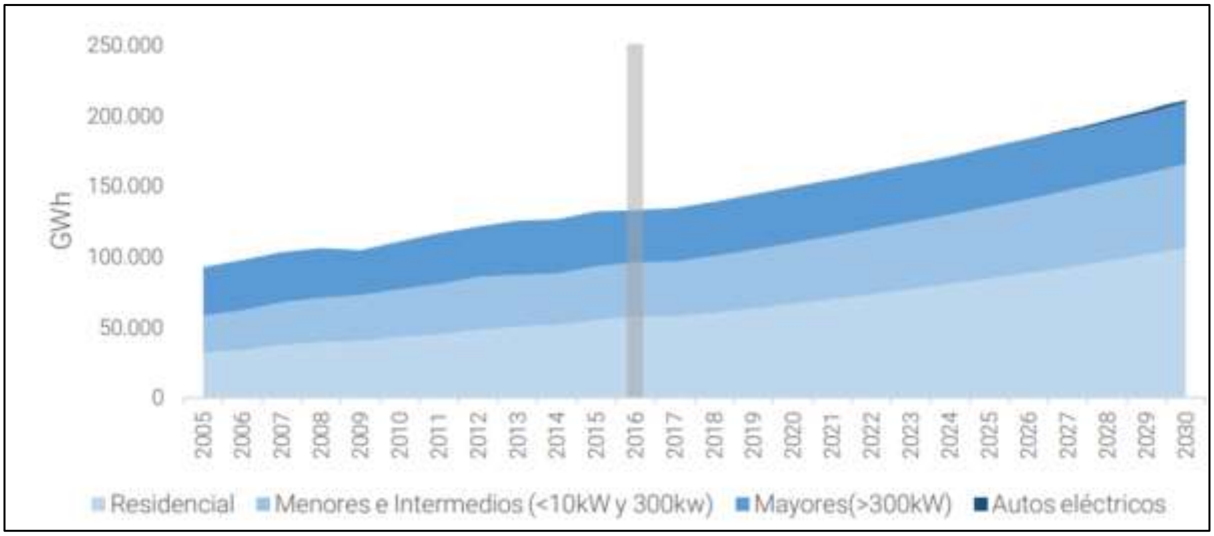
Figure 6: Power Generation by Source 2020



Source: IEA database

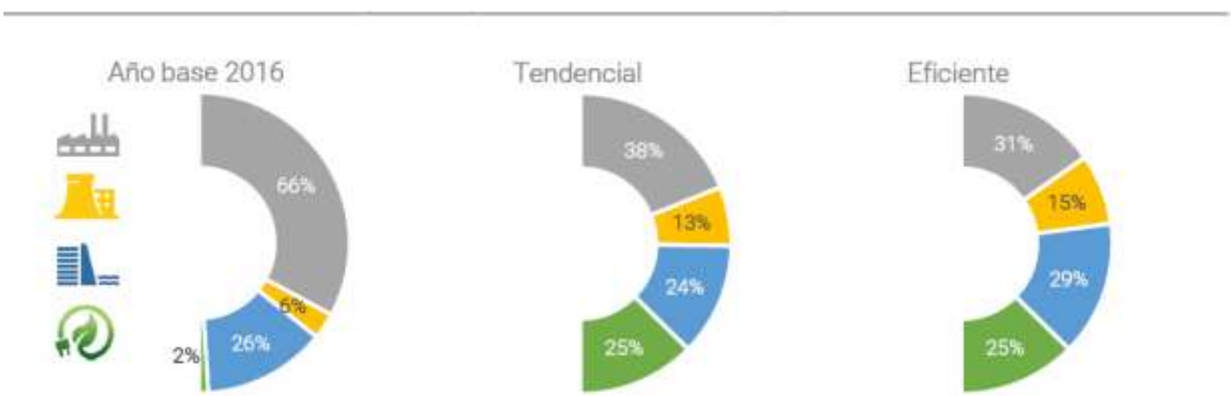
The following figure shows the projected demand increase in electricity usage for Argentina. In order to cover the demand, for 2030 a comparable the share of renewables including hydropower is expected to increase to 49%, nuclear from 6 to 13% and thermal to decrease from nearly 70% to 38%. (MINEM, 2017)

Figure 7: Projected Electricity Consumption Argentina (GWh)



Source: (MINEM, 2017)

Figure 8: Expected share of renewables under different scenarios



Source: (MINEM, 2017)

Electricity imports have remained relatively constant over the last five years, and have seen a decrease in the year 2020 as can be seen in the next table.

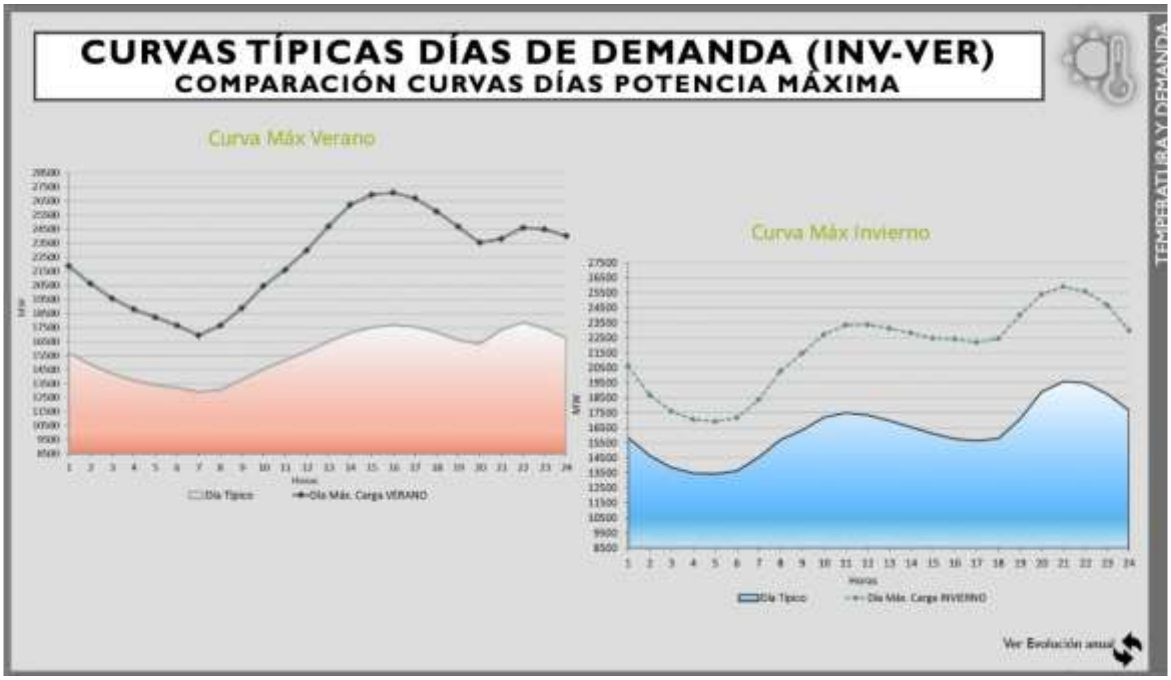
Table 6: Electricity Imports in Argentina, 2016-2020

Year	2016	2017	2018	2019	2020
Imports in GWh	9,851	10,531	9,842	10,948	7,802

Source: IEA Database

The following figure shows the maximum demand curves in Argentina compared to a typical day for both seasons, summer and winter.

Figure 9: Demand curve for Argentina in 2021 (in MW)



Source: (CAMMESA, 2022)

The system has a pronounced peak between 13:00 and 17:00 and a smaller evening peak at 21:00-22:00 in summer. In winter, this shifts to one peak from 20:00-22:00

There are approximately 30 electric distribution companies in Argentina. The two largest companies are EDENORTE and EDESUR, which distribute in the Federal Capital and Greater Buenos Aires. The data presented in this report are for these two companies. The National Electricity Regulator (ENRE) elaborates periodic (semestral) evaluations[2] (ENRE, 2022)

Table 7 : SAIFI and SAIDI for EDENOR and EDESUR 2021[3]

EDENOR	Sem 50	sem 51	
	mar 21 - ago 21	sep 21 - feb 22	**Annual Average 21-22**
SAIFI (number of events per user)	2.24	2.83	**2.535**
SAIDI (horas)	6.03	7.07	**6.55**
EDESUR	Sem 50	sem 51	
	mar 21 - ago 21	sep 21 - feb 22	**Annual Average 21-22**

[2] https://www.energia.gob.ar/contenidos/

[3] The table shows the total number of events, including force majeure events.

SAIFI (number of events per user)	2.5	3.06	**2.78**
SAIDI (horas)	7.05	10.19	**8.62**

Source: Own calculations based on: (ENRE, 2022)

3. Costa Rica

The following table shows Costa Rica's electricity generation and consumption in the year

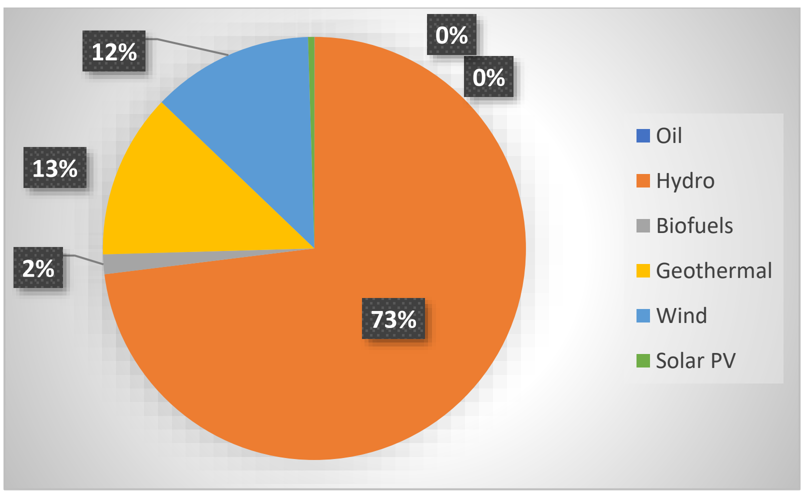
Table 8: Electricity generation and consumption in Costa Rica in 2021

Electricity generation in GWh	12,716
Electricity imports in GWh	6
Electricity exports in GWh	(-1,009)
Electricity consumption in GWh	10,363

Source: IEA Database

2019 Costa Rica produced 99.2% of electricity based on renewables (see following figure).

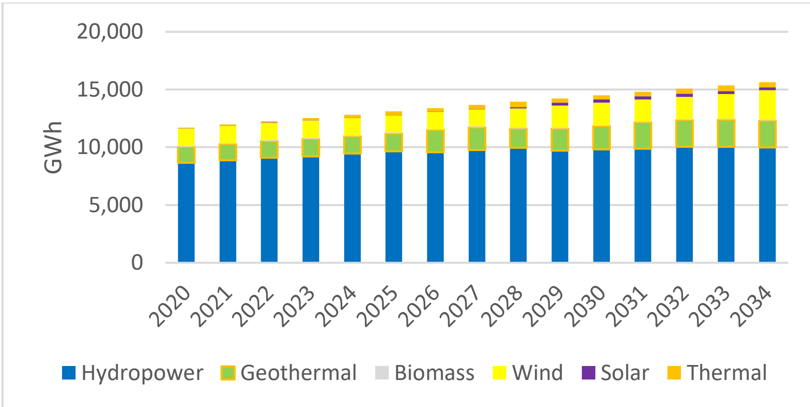
Figure 10: Electricity Generation Costa Rica 2021



Source: IEA Database

The average share of renewables in the last 5 years has been 99%. Projections estimate that the share of renewables will remain constant at 98% also for the future (see following figure).

Figure 11: Projected Electricity Generation per Source 2020 to 2034 Costa Rica (GWh)



Source: (ICE, 2019)

Production as well as consumption are expected to grow on average annually around 2% (ICE, 2019). Energy interchange (exports/imports) have averaged in the last decade only 1% with on average more exports of electricity than imports (ICE, 2020). Electricity generation is projected to be sufficient to cover 100% of national demand by 2034 (ICE, 2019). There is no clear trend over the last 5 years regarding electricity imports. It peaked at 340 GWh in 2019, a relatively dry year, and went down to 6 GWh in 2021 (as can be seen in the following table).

Table 9: Electricity Imports in Costa Rica, 2017-2020

Year	**2017**	**2018**	**2019**	**2020**	**2021**
Imports in GWh	32	66	340	118	6

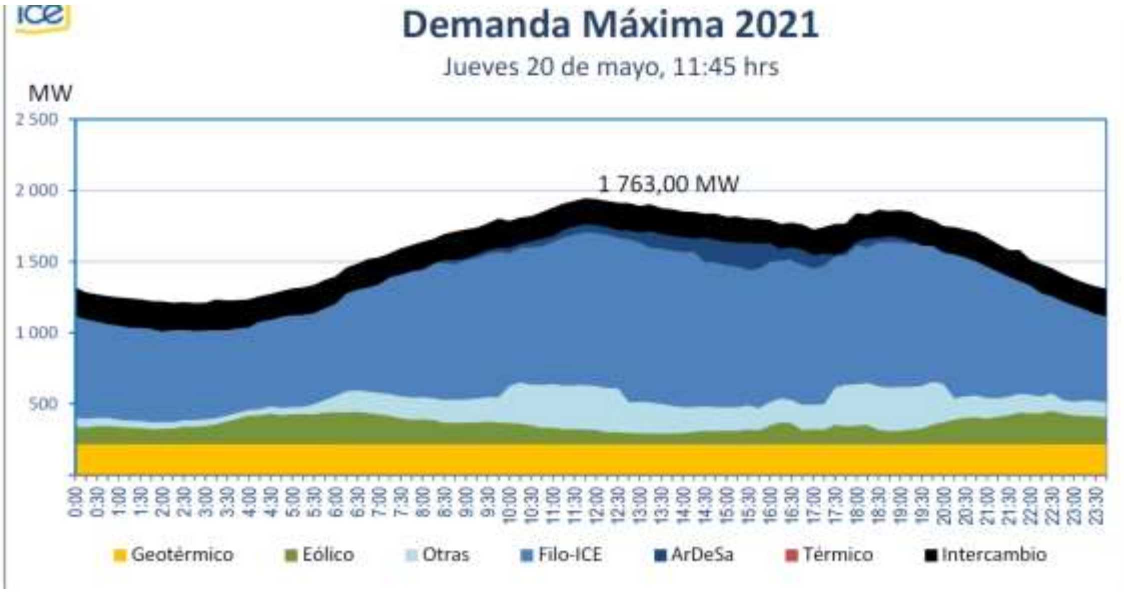
Source: IEA Database

The following figure shows the typical demand curve during the day in Costa Rica as well as for one specific day. Even peak demand can be covered in general 100% through renewables.

Figure 12: Demand Curve Costa Rica 2020-2021

Source: (ICE, 2021)

Figure 13: Maximum Demand Day in 2021



Source: (ICE, 2021)

The system has a peak at midday and early evening (peak power prices are from 10-12.30 and from 17.30-20.00). Peak demand is managed also with differential pricing. The system has limited monthly variations.

The medium voltage networks are usually powered from a substation in which High Voltage (HV, 138 or 230 kV) is transformed to MV (34.5, 24.9 or 13.8 kV). These substations typically connect several MV feeders. In San José these feeders are typically constructed in a so called meshed topology. This has the advantage that in case of a power outage due to faults in these feeders or substations, parts of feeders can be switched-over to other feeders. Consequently, after a fault in a MV feeder or an HV/MV substation, the supply to all customers could be restored within typically a few hours. On average, a customer in Costa Rica is without power 8,0 times per year (=SAIFI) and the average duration of an outage is 1 hour and 7 minutes (=CAIDI)[4]. SAIDI in 2021 was 8,6 hours. The figures are similar for network operator CNFL that operates a network in the metropolitan area and are rather constant since 2013. The technical standard on electricity network quality of Costa Rica[5] aims for an improvement of this the reliability to not more than 7 interruptions per year (=SAIFI) with a total duration of not more than 6 hours/year (=SAIDI). (Aresep, 2021)

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[4] Chapter 1 of 'Informe de evaluación de la calidad del suministro eléctrico Sector Distribución 2019' by Aresep. CAIDI is calculated by dividing SAIDI (or DPIR in Spanish, 9:24 hours/year) by SAIFI (FPI, 8,3 times/year)

[5] Article 62 of "Supervisión de la calidad del suministro eléctrico en baja y media tensión" (AR-NT-SUCAL)

4. Dominican Republic

The following table shows the electricity generation and consumption in the Dominican Republic in the year 2020.

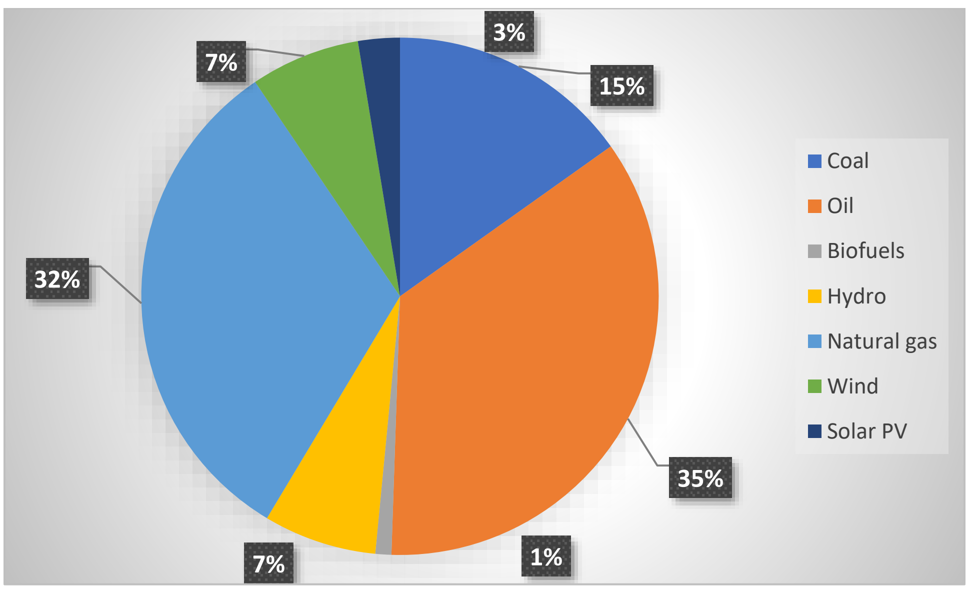
Table 10: Electricity generation and consumption in the Dominican Republic in 2020

Electricity generation in GWh	16,629
Electricity imports in GWh	-
Electricity exports in GWh[6]	-
Electricity consumption in GWh	15,559

Source: IEA Database

In 2020 the share of renewables in total electricity generated was around 17% (see following figure). Oil, natural gas and coal are the main generation sources. The country intends to produce its electricity with 30% renewable sources by 2030. This means that further 2,400 MW need to be installed. Figure 19 and Figure 20 show the potential mix of the renewables. (CNE - RD, 2022)

Figure 14: Electricity Generation Dominican Republic in 2020



Source: IEA database

The Dominican Republic has abundant solar and wind resources. 26 Micro-hydropower also offers some remaining potential in certain parts of the country (IRENA, 2016). The projected growth of electricity consumption is estimated at 3.2% annually (Comision Nacional de Energia, 2014) (however, the actual consumption figure of 2018 already surpasses the projected 2020 consumption figure i.e. the growth rate seem sub-estimated).

The recently published National Energy Plan, anticipates two different scenarios for the electricity demand that are shown in the next graphs. One scenario is called the trend scenario and the other one the alternative scenario. The first scenario foresees a growth rate of 4% and the second one of 11%. This

[6] Dominican Republic does not export or import electricity

growth is related to different GDP scenarios. The growth rate of the GDP in the Dominican Republic in 2021 was of 12.3% according to World Bank Data. [7]However, the PEN did not state to which GDP growth rate each scenario was related to.

Figure 15: Forecasted electricity demand under a trend scenario

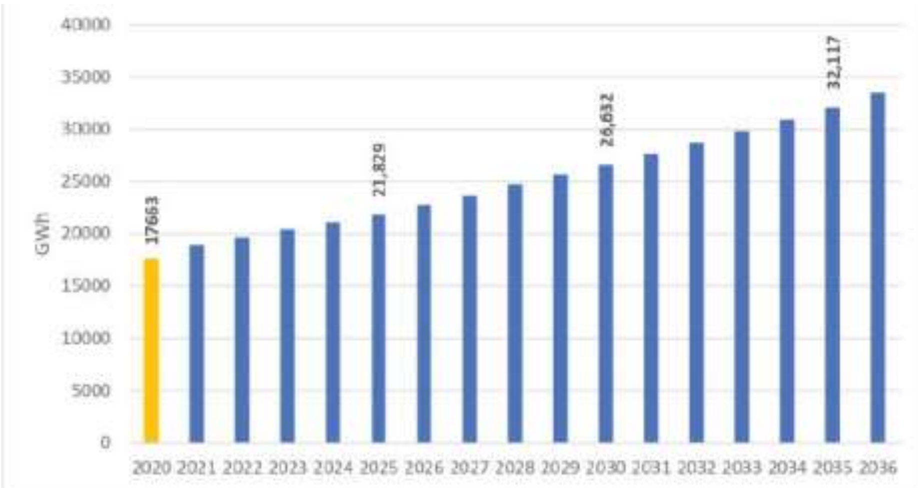
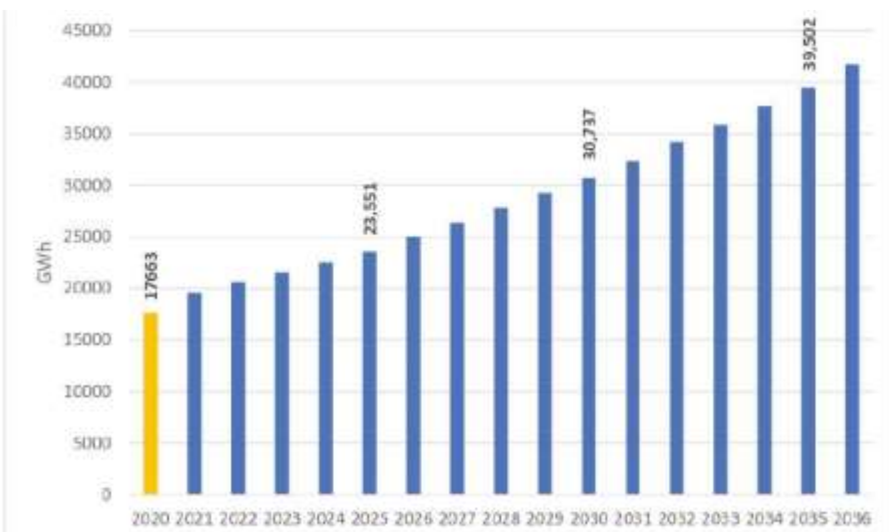


Figure 16: Forcasted electricity demand under an alternative scenario



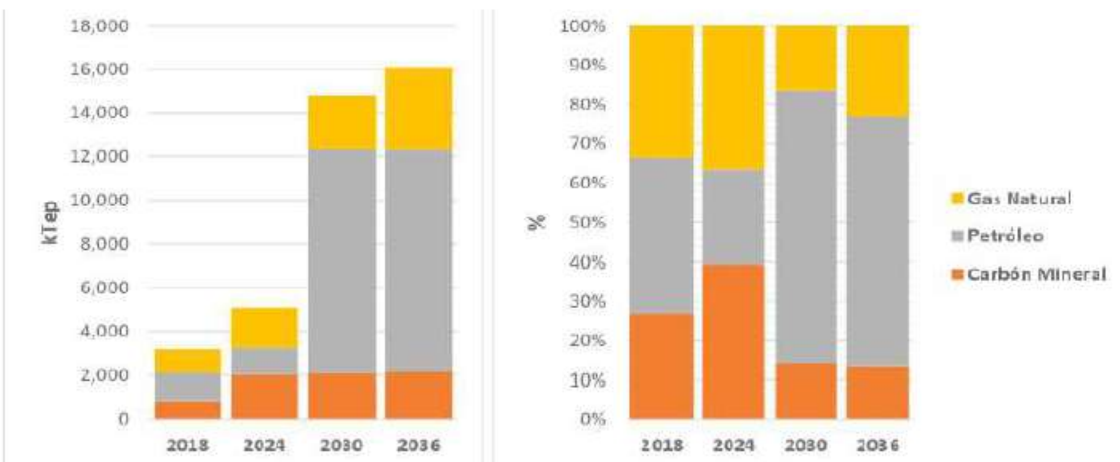
Source: (CNE - RD, 2022)

Even though the Dominican Republic does not import electricity, it does import all of the primary energy source to produce it an remains a heavily fuel dependant country. The National Energy Plan 2022-2036 (CNE - RD, 2022) provides projections of the fuel imports under the two different economic growth scenarios (trend and alternative) and are shown in the next graphs.

[7] https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=DO

Figure 17: Forcasted fuel imports under a trending scenario

Figure 18: Forcasted fossil fuel imports under an alternative scenario



Source: (CNE - RD, 2022)

Figure 19: Primary energy production under a trend scenario

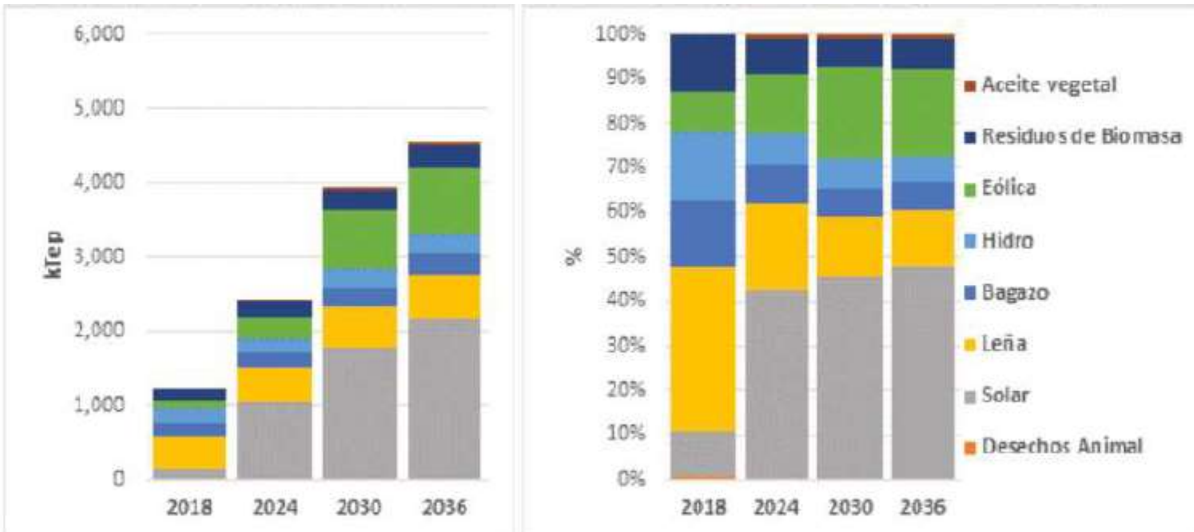
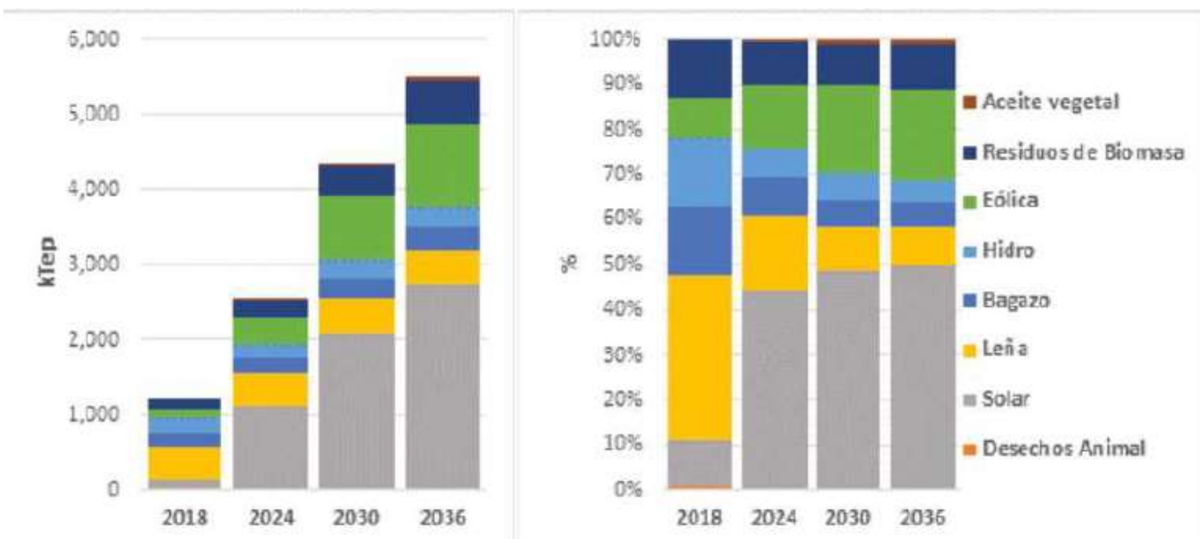


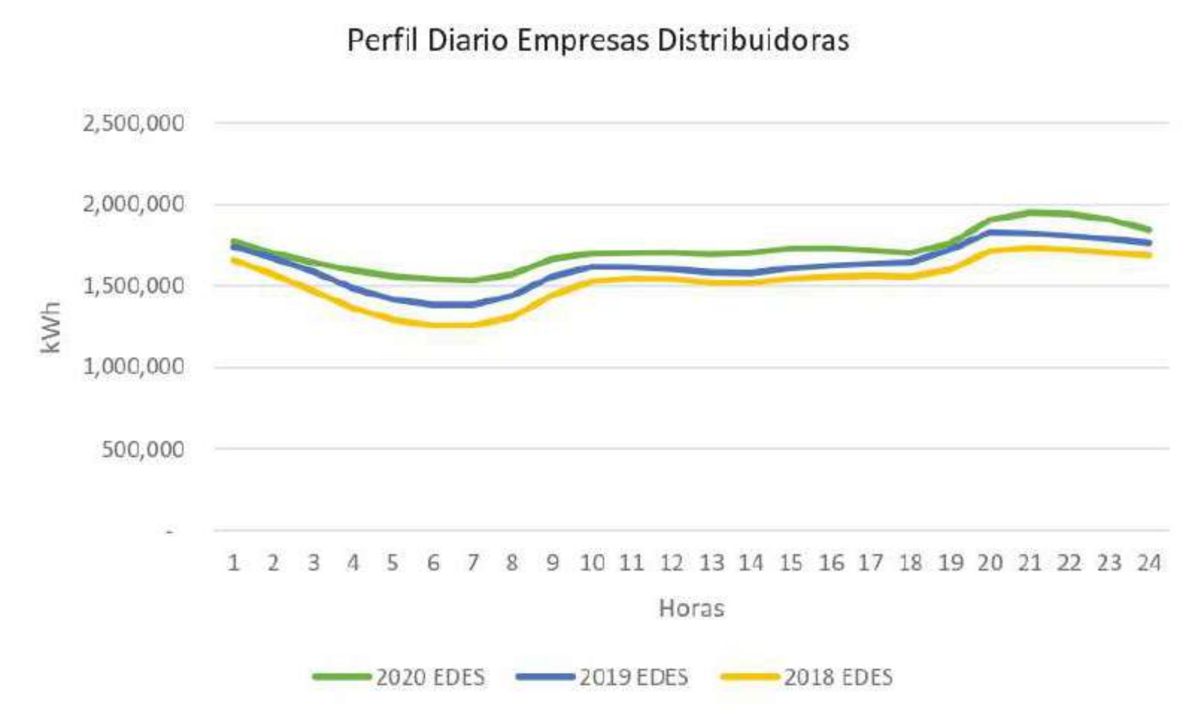
Figure 20: Primary energy production under and alternative scenario



Source: (CNE - RD, 2022)

The following graph shows the daily electricity demand curve from 2018-2020. The curve stays telatively flat during the whole day, with a slight increase between 19:00 and 21:00.

Figure 21: Daily electricity demand curve for Dominican Republic



Source: (CNE - RD, 2022)

Regarding interruptions, considering a class A circuit (24-hour service), an average of 80 interruptions are recorded annually, 70.43% of which are caused by faults or breakdowns in the distribution networks and tripping for unknown causes. Among the main causes are jumper openings, failures in connectors and clamps that join conductors.

Table 11: SAIFI and SAIDI for Dominican Republic 2021

Indicator (average in 2020)	EDESUR	EDEESTE	EDENORTE
SAIFI (number of events per user)	18.81	21.89	17.84
SAIDI (in hours)	26.12	29.67	18.16
CAIDI (in hours)	1.38	1.28	0.99

Source: Based on interviews conducted in 2021

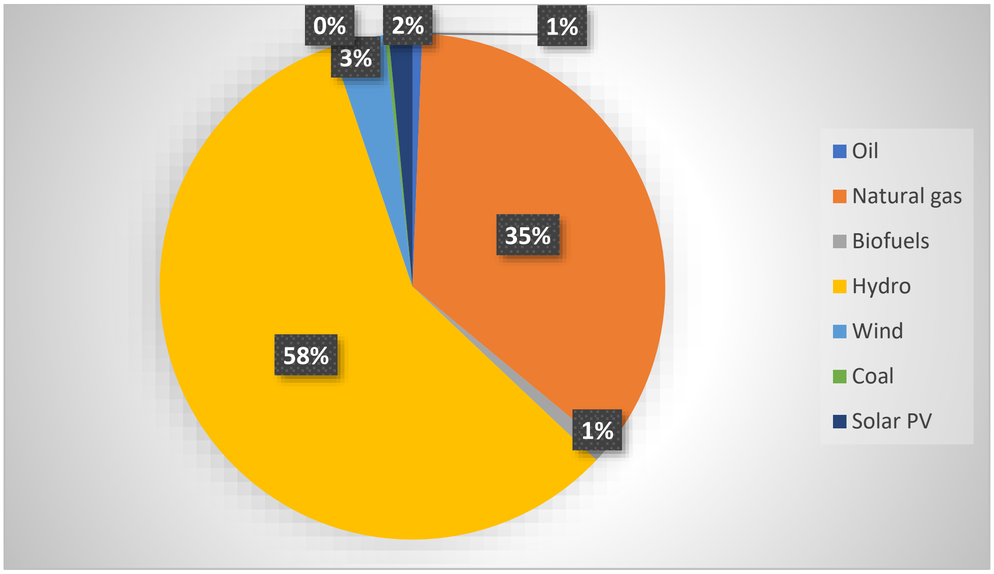
5. Peru

Table 12: Electricity generation and consumption in Peru in 2020

Electricity generation in GWh	52,778
Electricity imports in GWh	37
Electricity exports in GWh	
Electricity consumption in GWh	52,815

In 2020 64% of electricity, of a total generation of 52,000 GWh, was generated by renewables (see figure below).

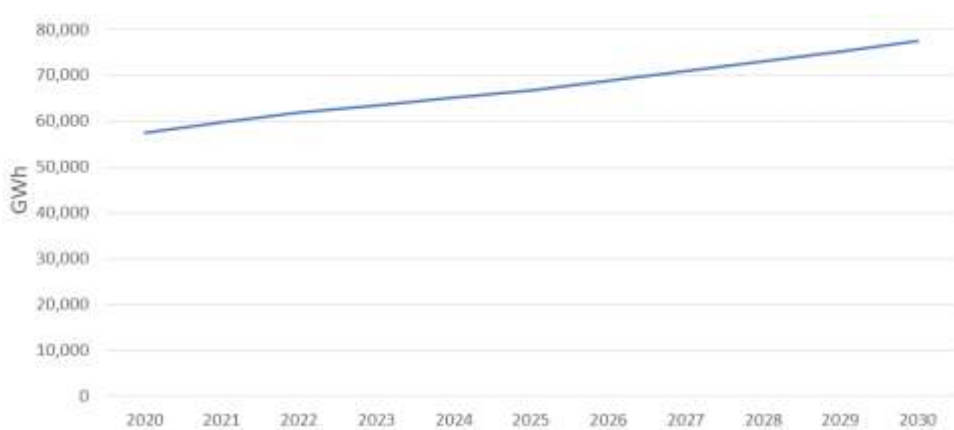
Figure 22: Power Generation by Source 2020



Source: IEA database

Based on MINEM Peru has a very large not yet exploited renewable energy potential basically for wind (>22,000 MW exploitable), geothermal (3,000 MW potential) and solar PV (The documents consulted on this topic mention some areas of the country, which are not exhaustive inventories, with 6.8 to 8.5 kWh/m^2). The average growth rate of energy consumption is 3% per year, see Figure 23.

Figure 23: Projected Electricity Consumption Peru (GWh)



Source: MINEM, Plan energetico nacional 2014-2025; used for data until 2025; same growth rate assumed by author from 2026 to 2030.

Figure 24: Projected production of electricity by source under a 4.5% GDP Scenario in Peru

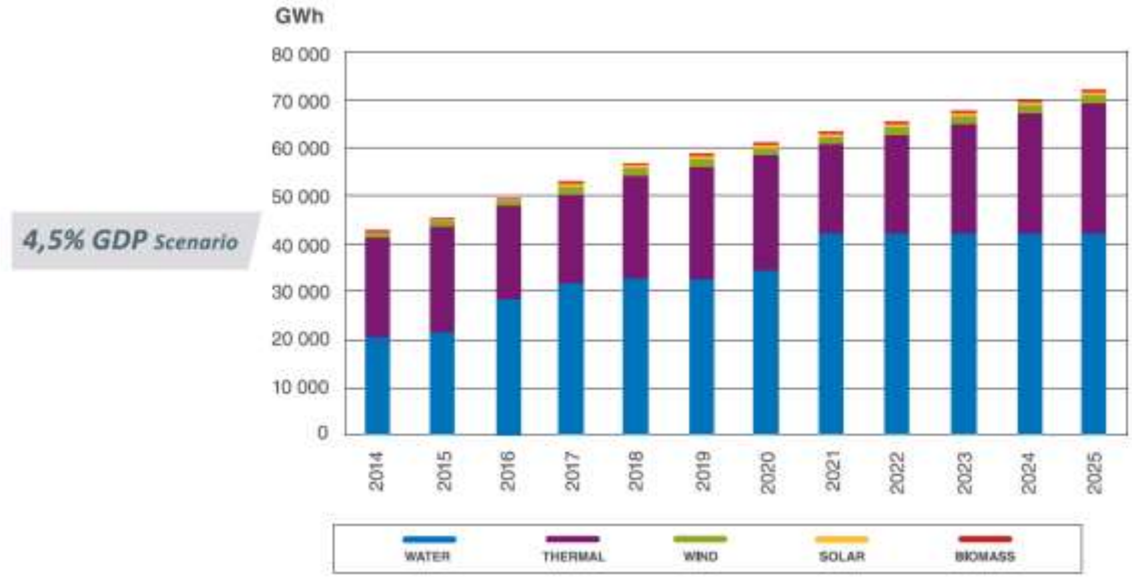
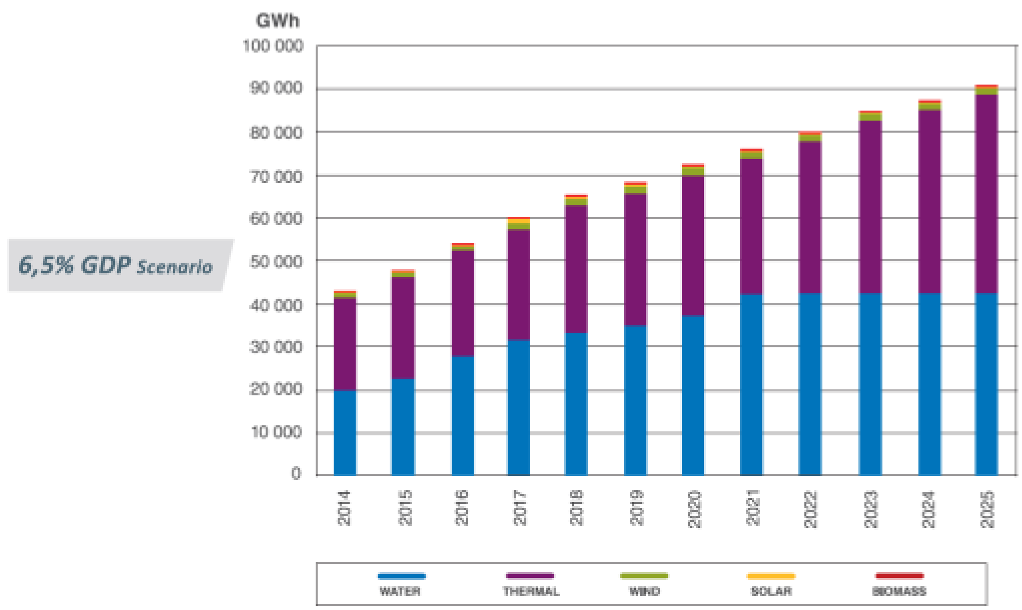


Figure 25: Projected electricity production by source under a 6.5% GDP growth Scenario in Peru



Source: (MINEM-Pe, 2014)

Electricity imports are very low compared to the total electricity production. The following table shows the electricity imports over the last 5 years.

Table 13: Electricity Imports in Peru, 2017-2020

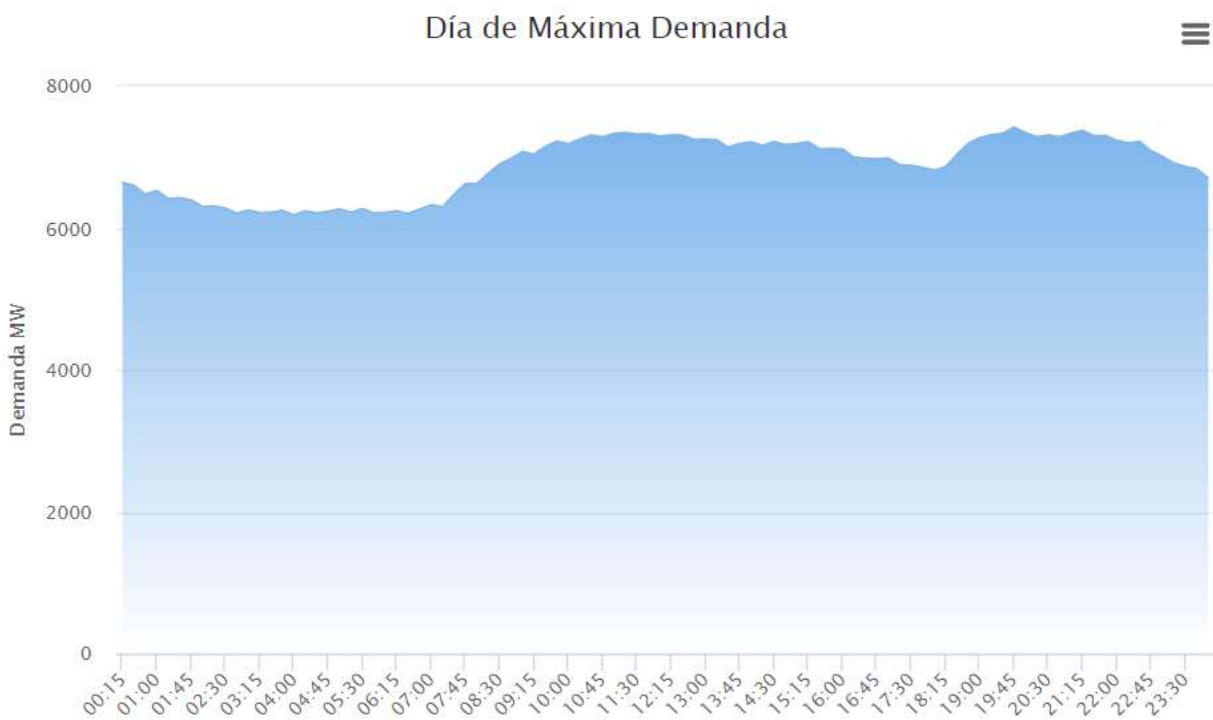
Year	2016	2017	2018	2019	2020

Imports in GWh	22	17	21	60	37

Source: IEA Database

The following figure shows a typical demand curve in Peru.

Figure 26: Demand Curve, 26.11.2022



Source: https://www.coes.org.pe/Portal/portalinformacion/demanda?indicador=maxim

The curve peaks at 19:45 with a maximum demand of 7,426 MW. A similar value can be seen around noon. The values remain above 7,000 MW from 9:00 a.m. to 16:00.

The medium voltage (MV) networks in Lima are operated at a Voltage level of 10 kV. In older areas and areas with high load density (60% of the MV networks) the MV networks consist of underground cables. Overhead lines are typically used in peripheral and industrial areas (40% of the MV networks).

The MV lines and cables use a large variety of conductors resulting in a wide range of nominal capacities of the MV feeders. The underground MV feeders could typically accommodate a total load of up to approximately 5 MW[8], while the overhead lines can accommodate up to approximately 8 MW. Although the feeders with the highest capacity ratings may technically be able to facilitate charging sites in the 500 kW – 5 MW range, many feeders applied in Lima are a lot smaller and would only be able to facilitate charging sites at the lower end of the 500 kW – 5 MW range. It is further reported that the currently

[8] The MV feeders have a capacity of 3 MVA to more than 7MVA. Assuming that the feeders are operated up to 80% with a power factor of 0.9, the load per feeder should be in the range of 2-5 MW.

available capacity on existing MV feeder varies and that load on the MV networks is still increasing. In some areas MV feeders are fully loaded.

Typically, the network operator does not connect loads of more than about 500 kW[9] to the 10 kV network in Lima. For the charging sites considered in this section, this means that the MV network would only facilitate the smallest sites. Larger sites may need to be connected directly to a 60 kV substation (see below).

The MV networks are usually powered from a substation in which High Voltage (HV, 60 kV) is transformed to MV (10 kV). The MV side of these substations typically connects several MV feeders. The MV network consists of both radial system and meshed systems. In meshed systems, feeders starting from one HV substations can be connected via switching actions to other feeders powered from the same or other HV substations. This has the advantage that in case of a power outage due to a fault in a feeder line or cable or a substation, the power supply can be restored via another route. In Lima, these are usually manual switching actions while in exceptional cased the operation is automated. Consequently, after a fault in a MV feeder of a meshed system or an HV/MV substation, the supply to all customers could be restored within typically a few hours. Supply restorations on radial system will take typically longer since the MV feeder needs to be repaired first.

On average, a customer in Lima was in 2016 without power 5.4 times per year (=SAIFI) and the average duration of an outage was 3 hour and 16 minutes (=CAIDI)[10]. It is reported that by 2020, these figures have been slightly improved. The technical standard for quality of electrical services[11] includes targets for the network quality: Customers at MV networks may expect 4 interruptions per semester (SAIFI = 8 interruptions per year) and a total of 7 hours without power per semester (SAIDI -14 hours/year).

In addition to these reliability targets, the technical standard for quality of electrical services also defines a target voltage quality, including limits for voltage level, harmonic distortion, and voltage dips in MV networks. The limits are in line with internationally applied standards (e.g. IEC) and should be sufficient to connect charging equipment without problems. The technical standard adds requirements on monitoring and reporting on these aspects of voltage quality, which are also in line with international standards (e.g. IEC-61000-4-30). In practice, only the voltage level in both MV and LV is monitored and reported[12]: approximately 10% of the measurements are outside the target range. It is further reported that in some areas and at certain load levels, also other voltage quality issues may appear.

In addition, the technical standard describes an extensive mechanism that provides the network operator with financial incentives to improve the both the reliability figures mentioned above and the voltage quality.

[9] The technical limit is 630 kVA. Taking into account a power factor this translates in loads of 500 to 600 kW.
[10] Source: OSINERGMIN. CAIDI is calculated by dividing SAIDI (17:42 hours/year) by SAIFI (5.4 times/year). The values indicated correspond to distribution systems that include MV/LV networks.
[11] La Norma Técnica de Calidad de los Servicios Eléctricos (NTCSE), Decreto Supremo Nº 020-97-EM (Actualizado al 13 de Setiembre de 2010 DS 020-1997- EM – Urbana), chapter 6 (responsibility of Osinergmin, an independent agency of the Ministry of Energy and Mines, which has supervisory and sanctioning powers to enforce compliance with the Technical Standard for the Quality of Services)
[12] Some power distribution companies also monitor other parameters, but they are not public.

6. Brazil

The following table shows the electricity production and consumption in Brazil

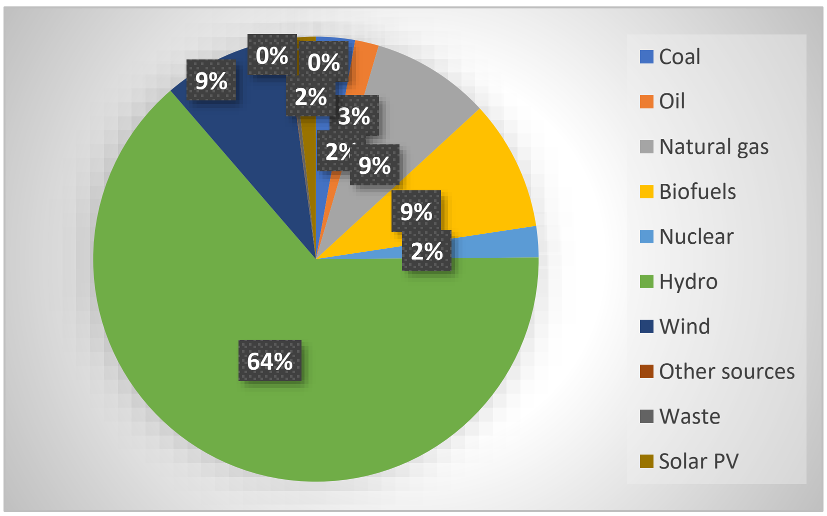
Table 14: Electricity generation and consumption in Brazil in 2020

Electricity generation in GWh	621,198
Electricity imports in GWh	25,113
Electricity exports in GWh	(395)
Electricity consumption in GWh	509,323

Source: IEA Database

In 2020 84%[13] of electricity was generated by renewable and 18% by fossil sources (see graph below).

Figure 27: Power Generation by Source in 2020



Source: IEA Database

Regarding the growth of electricity demand, the studies of the National Energy Plan address the wide range of uncertainty regarding technologies, habits, behaviors, business models, regulation, among others in the 2050 horizon by means of 2 e scenarios and summarized by means of 2 trajectories for the evolution of potential energy consumption (calculated before energy efficiency gains).

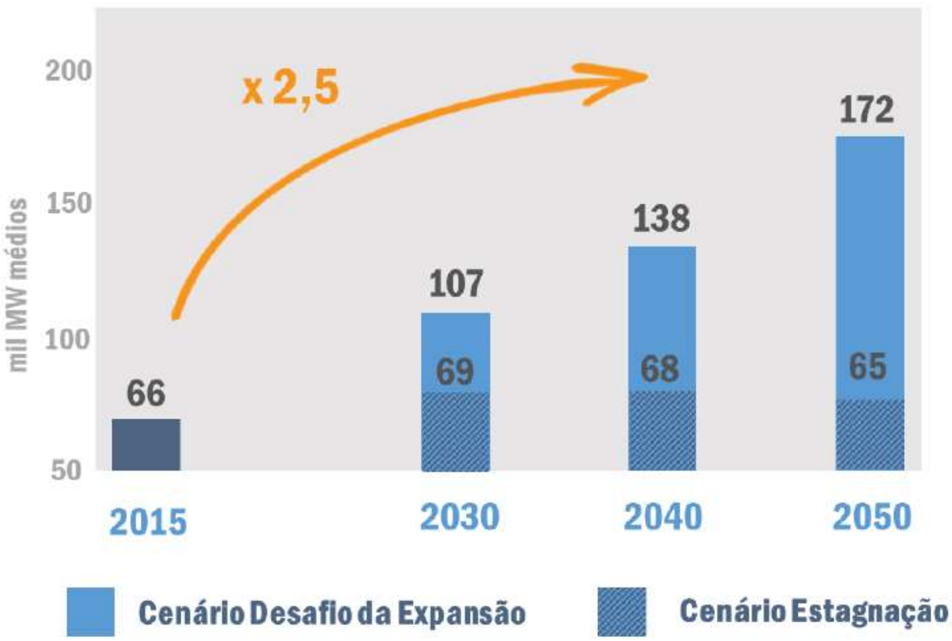
The upper borderline scenario is characterized by the challenge of preparing for the future in a context of strong expansion of gross demand and how to position oneself strategically to meet this demand. Therefore, it was named the Expansion Challenge. Sensitivity analyses related to key issues for the design of the long-term expansion strategy for the national energy sector are also conducted for this scenario.

In the Stagnation scenario (because it reflects a trajectory in which per capita energy consumption remains around the 2015 level), the expansion of gross energy demand is not the central element of energy policy, although it still has a role in pointing the way to an energy matrix that is more adequate to the goals of moderation and technical and environmental sustainability.

[13] 87% counting nuclear

The Expansion Challenge scenario presents an average growth rate of 2.2% p.a., reaching 2050 with a little more than double the final consumption of 2015, with more accelerated growth in the first fifteen years, with an average rate above 2.5% p.a. In the Stagnation scenario, growth in final energy consumption increases by just over 10% over the analysis horizon. These growth rates are associated, among others, with the economic and demographic growth perspectives. The next figure shows the growth rate in these scenarios.

Figure 28_ Forcasted electricity demand under different scenarios



Source: (MME, 2020)

Brazils electricity imports have seen a downward trend over the last 5 years as can be seen in the next table.

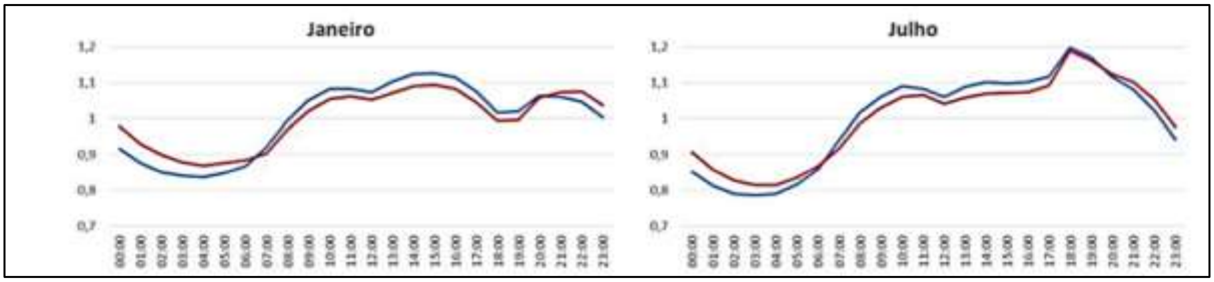
Table 15: Electricity Imports in Brazil, 2017-2020

Year	**2016**	**2017**	**2018**	**2019**	**2020**
Imports in GWh	41,313	36,511	34,980	25,156	25,113

Source: IEA Database

The following graphs shows the typical demand curve in Brazil.

Graph 1: Typical demand curve in Brazil

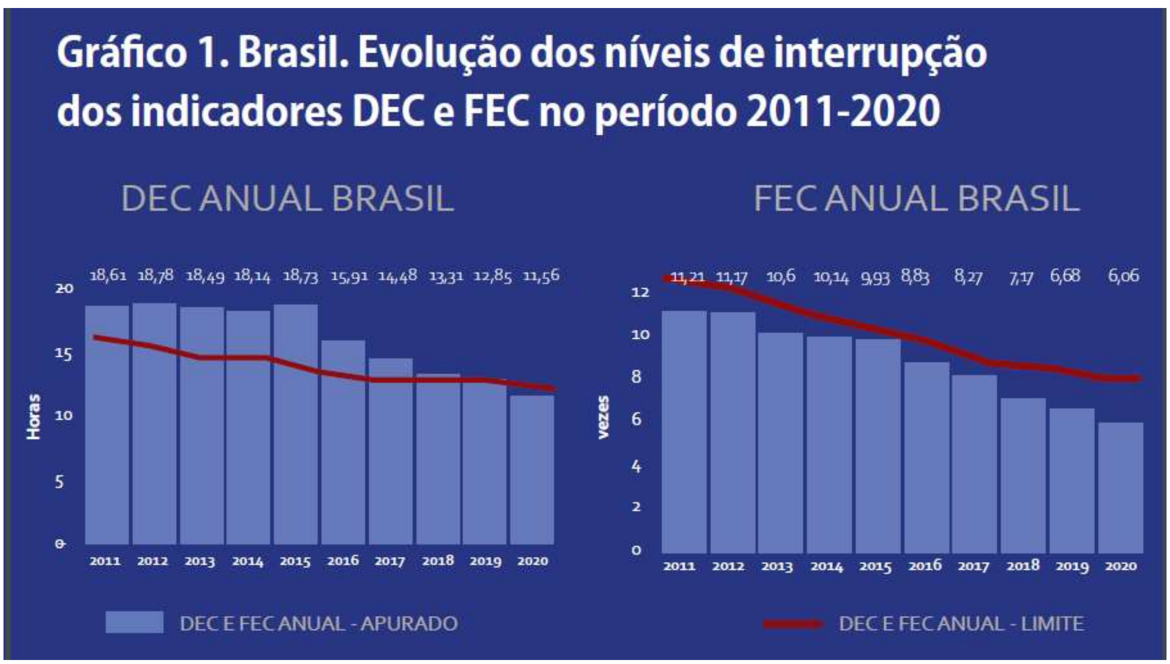


Source: EPEe

The system has during summer months a peak between 1 and 4 PM and in winter an evening peak at 6PM.

The following graph shows the evolution of the SAIDI (DEC in Portuguese) and SAIFI (FEC in Portuguese) over the last 10 years. Both indicators have improved significantly, reaching values of 11,56 hours for SAIDI and 6,06 interruptions per year in 2020.

Figure 29: Evolution of SAIDI and SAIFI indicators in Brasil - 2011-2020.



Source: (Arsesp, 2022)

7. Colombia

The following table shows de electricity generation and consumption in Colombia for the year 2021.

Table 16: Electricity generation and consumption in Colombia in 2021

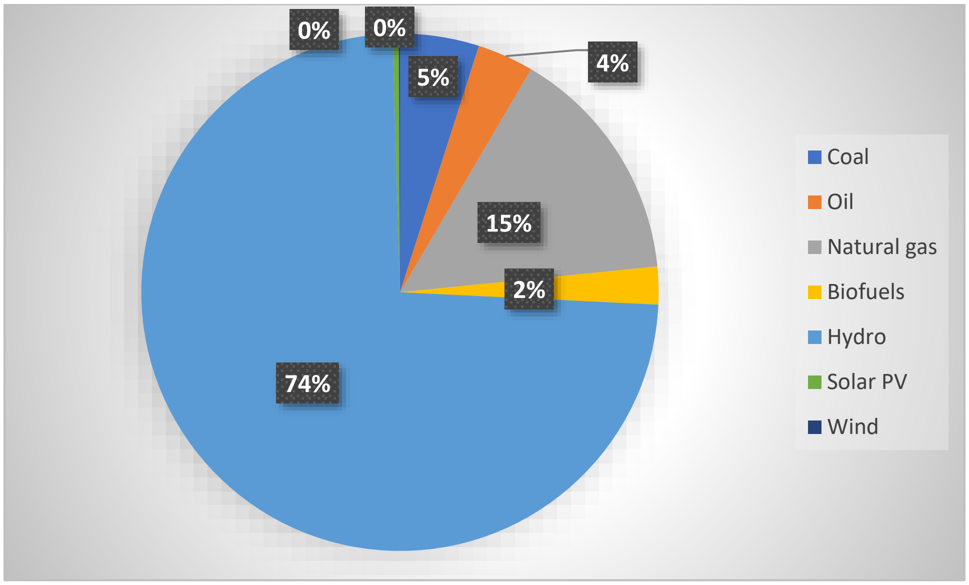
Electricity generation in GWh	82,007
Electricity imports in GWh	181

Electricity exports in GWh	(396)
Electricity consumption in GWh	74,116

Source: IEA Database

In 2021 there was around 76% share of renewables in total electricity generated was slightly above 70% (see following figure).

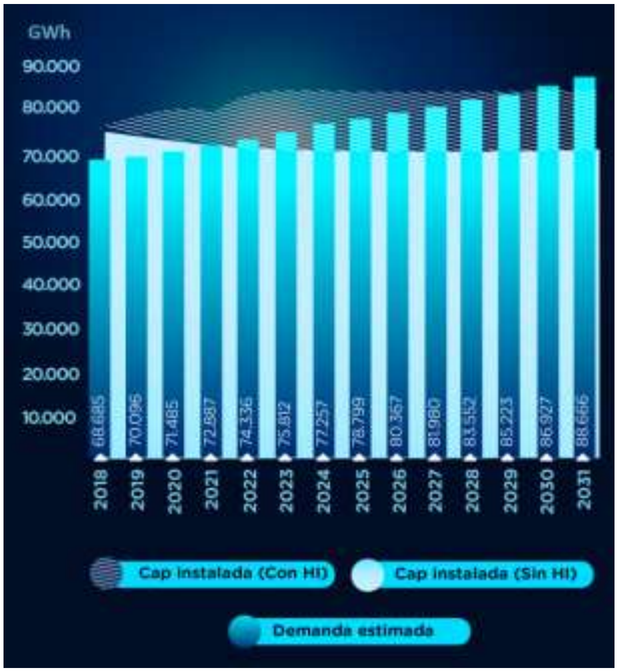
Figure 30: Electricity Generation Colombia 2021



Source: IEA Database

The following figure shows expected demand and supply until 2031. Electricity demand is projected to grow annually by 2%b between 2020 and 2030.

Figure 31: Projections Electricity Demand and Generation Colombia to 2031



Source: (Arango, 2019) Retrieved from Grupo Bancolombia: https://www.grupobancolombia.com/wps/portal/empresas/capital-inteligente/especiales/especial-energia-2019/panomara-energetico-colombia

Colombia still has a considerable non-exploited renewable energy capacity in terms of hydroelectric, solar and wind power (Arango, 2019).

There is no clear trend when it comes to the electricity imports in Colombia, as can be seen in the next table.

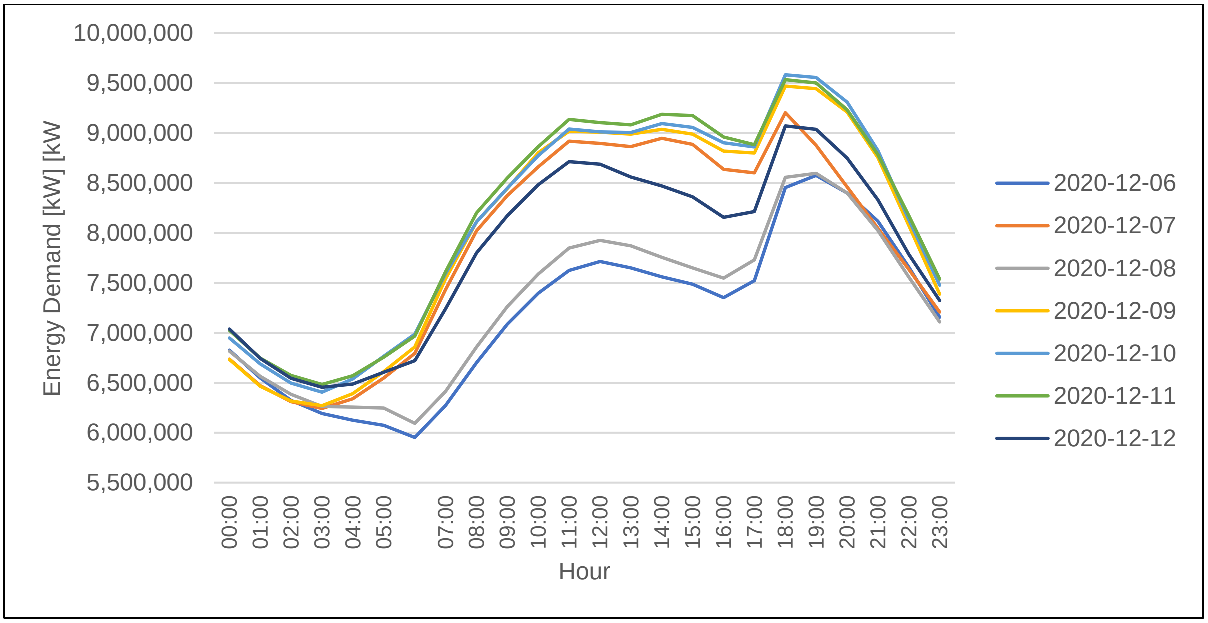
Table 17: Electricity Imports in Colombia, 2017-2021

Year	**2017**	**2018**	**2019**	**2020**	**2021**
Imports in GWh	78	122	312	1302	181

Source: IEA Database

The following figure shows the typical demand curve during the day in Colombia.

Figure 32: Demand Curve Colombia



Source: XM. (2020h). *Demand_for_OR_2020*.
http://portalbissrs.xm.com.co/dmnd/Paginas/Historicos/Historicos.aspx.

The system has a peak in the early evening (from 5-9 PM).

The MV networks in Colombia mainly consist of overhead lines. Only in special cases underground cables are installed[14]. In the large Columbian cities, a distinction is made between 'industrial' and 'non-industrial' MV networks. The most common voltage levels for non-industrial networks are 13.2 kV and 13.8 kV. For industrial networks the most common voltage level is 34.5 kV[15]. It is noted that - dependent on the location and size of the load - also industries could be connected to 13.2 kV networks.

Because of the relatively high voltage level of the 'industrial' MV networks on 34.5 kV, the capacity of the feeders is relatively high. The MV feeders could typically accommodate a total load of 10 to 17 MW[16]. Consequently, charging sites of 500 kW – 5 MW would normally not require dedicated MV feeders, but will likely share the MV feeders with other customers. This may be different for the MV feeders on 13.2 kV or 13.8 kV in 'non-industrial' MV networks. If not already completely loaded, these feeders may be able to facilitate charging sites at the lower end of the 500 kV – 5 MW range. However, larger charging sites may require a dedicated feeder.

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[14] For example where construction regulations prohibit the installation of aerial networks, such as crossings of parks, traffic distributors and parking lots in commercial areas. Also in sectors as underground urban distribution, historical conservation areas, bridges, near heliports or airports (see: https://www.cens.com.co/Portals/2/Documentos/Norma_Actualizada/CAPITULO%203_Redes%20de%20Media%20y%20Baja%20Tensión%20CENS%20-%20Norma%20Técnica%20-%20CNS-NT-03.pdf).
[15] In Antioquia 44 kV
[16] The MV feeders have a capacity of 16 MVA to 27 MVA and are operated up to 70%. Considering an assumed power factor 0.9, the active load per feeder should be in the range of 10 - 17MW.

The medium voltage networks are usually powered from a substation in which High Voltage (HV) is transformed to MV (34.5 kV, 13.8 kV or 13.2 kV). The MV side of these substations typically connects several MV feeders. These feeders are constructed in a so called ring topology and are operated radially. This means that feeders starting from one HV substations may be connected via switching actions to other feeders powered from the same or other HV substations. This has the advantage that in case of a power outage due to a fault in a feeder line or cable or a substation, the power supply can be restored via another route. Consequently, after a fault in a MV feeder or a HV/MV substation, the supply to all customers could be restored within typically a few hours.

In addition to this, MV feeders in Colombia are usually divided into typically three sections by so-called reclosers. In case of a fault in a feeder, these reclosers help to limit the number of customers affected and may limit the duration of the power interruption.

On average, a customer in Bogotá was in 2018/2019 without power 18 to 20 times per year (=SAIFI). The number of interruptions per customer (SAIFI) for other cities was larger, e.g. customers in Medellín faced almost double the number of power interruptions. The average SAIFI for Colombia was 53 interruptions per year. The average duration of an outage for the customers in Bogotá was in 2018/2019 about 45 minutes (=CAIDI)[17] and was similar to the Colombian average. It is noted that although the duration of a fault is reasonably short, the number of power interruptions is high. The main causes are specific for overhead networks and include lightning, storms and birds. In Bogotá these issues are being mitigated by undergrounding the networks while in Medellín the overhead lines are being isolated. [18]

The distribution company Enel-Codensa, which operates in Bogotá-Cundinamarca, has reported that thanks to an investment of over USD 200,000 for the modernization of their electric infrastructure, it has been able to improve their SAIFI and SAIDI indicators as follows:

Table 18: Grid quality indicators for ENEL Colombia

Indicator	2021	2020	Variation in %
SAIDI in minutes	487	557	-12.5
SAIFI in numbers	8.1	8.9	-8,5

Source

The Colombian regulation of power quality[19] describes the target voltage quality, including limits for voltage level, flicker, harmonic distortion, and voltage dips in MV networks. The limits in this regulation are in line with internationally applied standards (e.g. IEEE 519 for harmonic distortion) and should be sufficient to connect charging equipment without problems. The regulation adds requirements on monitoring and reporting on these aspects of voltage quality, which are also in line with international standards (e.g. IEC-61000-4-30).

As of today – December 2022- there are 1,485 electric buses operating in Bogotá. All of them recharge overnight in six different bus depots, the largest of them being Fontibón III and Usme II. They are operated by the company Enel X with their business unit Enel-Codensa. Enel has invested around USD 60,000 in 2021 in the charging system of the electric buses operating in the Integrated Transport System (SITP) in

[17] CAIDI is calculated by dividing SAIDI by SAIFI.
[18] Source: Interviews held in 2020.
[19] D-CREG 032 de 2012 Calidad de la potencia.

Bogotá. According to an interview given by the Enel Colombia's Manager, when it comes to tackle the growing electricity demand for the Bogotá Region, he refers to the "Bogota-Region 2030" plan, that plans an investment of more than MUSD 430 for Enel-Codensa's expansion plan for substations and high voltage projects. It seeks to strengthen, over a period of 10 years, the electricity infrastructure in Bogota and Cundinamarca, through the construction of more than 30 substations and their associated transmission lines, which will increase the installed power from 10,500 to 14,700 megavolt amperes (MVA).

These substations will be strategically located, as part of the population, economic and industrial growth of the region and to enable the massification of electric mobility.[20]

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