MINISTÉRIO DE MINAS E ENERGIA
SECRETARIA DE PLANEJAMENTO E DESENVOLVIMENTO ENERGÉTICO

2031
TEN-YEAR ENERGY EXPANSION PLAN

Empresa de Pesquisa Energética

Ministério de Minas e Energia

11. Consolidation of Results

This chapter deals with the consolidation of the information presented throughout the report, following the methodology of the Brazilian Energy Balance. The values described in this chapter refer to expected forecasts and, therefore, may differ from any potential values informed throughout the document. For comparative analysis with the Brazilian energy history, consult the Brazilian Energy Balance.

At the end of the ten-year period, it is estimated that the domestic energy supply will reach approximately 384 million tons of oil equivalent (toe), which represents an average annual growth of 2.7%. Domestic electricity supply evolves at an average rate of 3.4% p.y., reaching 2031 with an estimated supply of 945 TWh.

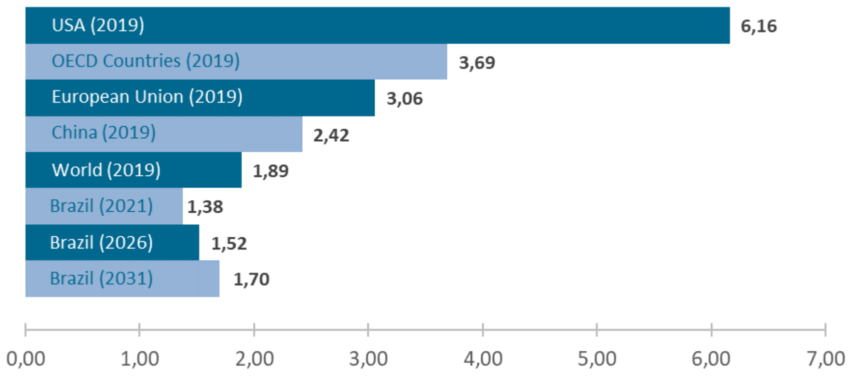
Final energy consumption is crucial for the evolution of domestic supply and, at the end of 2031, stands at around 317 million toe and with an average growth rate of 2.5% p.y. (**Table 11 - 1**).

Table 11 - 1: Indicators: economy and energy

Description		2021	2026	2031	Annual average variation		
					2021 to 2026	2027 to 2031	2021 to 2031
Resident Population	(10^6 inhab)	214.1	220.9	226.3	0.6%	0.5%	0.6%
GDP	(10^9 BRL)	4,190	4,811	5,577	2.8%	3.0%	2.9%
	per capita (10^3 BRL/inhab)	19.6	21.8	24.6	2.2%	2.5%	2.3%
Domestic Energy Supply	(10^6 toe)	295.0	336.1	384.4	2.6%	2.7%	2.7%
	per GDP (toe/10^3 BRL)	0.070	0.070	0.069	-0.2%	-0.3%	-0.2%
	per capita (toe/inhab)	1.38	1.52	1.70	2.0%	2.2%	2.1%
Domestic Electricity Supply	(TWh)	674.2	804.5	945.1	3.6%	3.3%	3.4%
	per GDP (kWh/10^3 BRL)	160.9	167.2	169.5	0.8%	0.3%	0.5%
	per capita (kWh/inhab)	3,149	3,641	4,184	2.9%	2.8%	2.9%
Final Power Consumption	(10^6 toe)	247.4	281.6	316.9	2.6%	2.4%	2.5%
	per GDP (kWh/10^3 BRL)	0.059	0.059	0.057	-0.2%	-0.6%	-0.4%
	per capita (kWh/inhab)	1.16	1.27	1.40	2.0%	1.9%	1.9%

Comparing the domestic supply of energy per capita in Brazil with the world average and its main countries, there is a great challenge to increase the availability of energy per inhabitant in Brazil. An increase from 1.38 toe/inhabitant in 2021 to 1.70 toe/inhab in 2031 is estimated, still lower than the world average of 1.89 toe/inhab in 2019 (**Chart 11 - 1**).

Chart 11 - 1: Domestic energy supply per capita



Regarding the internal energy supply (**Table 11 - 2**), renewable energies show an average annual growth of 2.9%, highlighting the average growth of 6.7% p.y. in the supply of other renewables (wind, solar, biodiesel and lixivium). Thus, it is estimated that the share of renewable energies in the Brazilian energy matrix will increase, reaching a level of 48% in 2031 (

Chart 11 - 2). Also noteworthy is the growth in the supply of natural gas, with a 14% share in 2031, and the reduction in the share of oil and its products in the total domestic supply of energy, from 34% in 2021 to 30% in 2031 (**Chart 11 - 3**).

Table 11 - 2: Evolution of the domestic energy supply in the ten-year timeframe

	2021		2026		2031		2021-2031
	Thousand toe	%	Thousand toe	%	Thousand toe	%	Average Variationn (%
Non-Renewable Energy	**156,412**	**53**	**168,074**	**50**	**200,409**	**52**	**2.5**
Oil and Oil Products	100,089	34	107,575	32	116,335	30	1.5
Natural Gas	36,063	12	39,034	12	54,862	14	4.3
Coal and Coal Products	15,478	5	16,264	5	19,064	5	2.1
Uranium Products	3,871	1	3,728	1	8,807	2	8.8
Other Non-Renewables	1,000	0	1,473	0	1,341	0	3.0
Renewable Energy	**138,602**	**47**	**167,992**	**50**	**184,016**	**48**	**2.9**
Hydraulic and Electricity	36,102	12	42,498	13	43,587	11	1.9
Firewood and Charcoal	26,213	9	28,441	8	27,811	7	0.6
Sugar Cane Products	51,644	18	60,013	18	65,608	17	2.4
Other Renewables	24,643	8	37,040	11	47,010	12	6.7
Total	**295,014**	**100**	**336,065**	**100**	**384,425**	**100**	**2.7**

Chart 11 - 2: Brazilian energy matrix: renewable and non-renewable energy

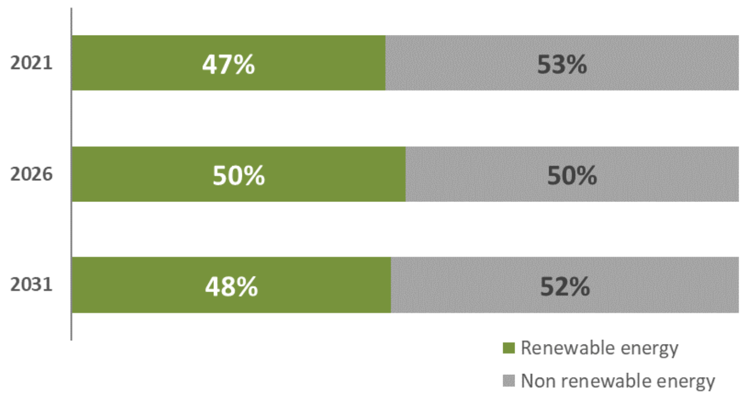
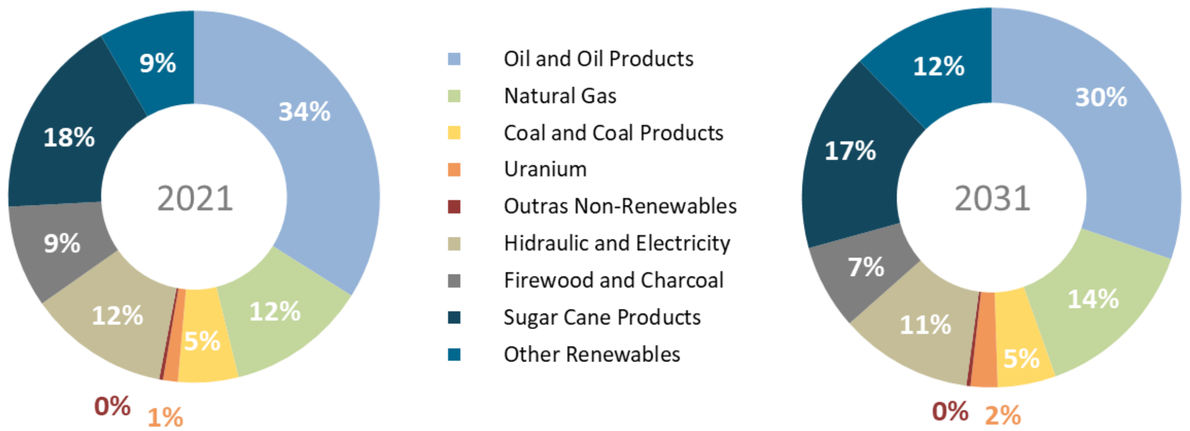


Chart 11 - 3: Evolution of the composition of the internal energy supply by source



For electricity supply, Brazil maintains the predominance of generation based on renewable sources (hydraulic, biomass, wind and solar), with a level of renewability of 84% over the ten-year timeframe. Estimates for electricity generation, including self-production and distributed generation, are presented in **Table 11 - 3**.

Table 11 - 3: Total electricity generation

Centralized Generation	2021		2026		2031	
	TWh	%	TWh	%	TWh	%
Hydraulic(1)	416	62	490	61	502	53
Natural Gas	50	7	25	3	67	7
Coal	9	1	7	1	6	1
Nuclear	14	2	14	2	33	4
Biomass	36	5	44	5	44	5
Wind	67	10	96	12	114	12
Solar (centralized)	7	1	15	2	22	2
Others(2)	9	1	11	1	15	2
Subtotal (meet Load)	608	90	701	87	804	85
Self-production & Distributed Generation	**2021**		**2026**		**2031**	
	TWh	**%**	**TWh**	**%**	**TWh**	**%**
Biomass (biomass, sugarcane bagasse, lixivium and firewood)	30	4	40	5	56	6
Solar	9	1	29	4	45	5
Wind	0.1	0	0.5	0	1.3	0
Hydraulic	4	1	4	1	5	1
Non-renewables	24	4	29	4	34	4
Subtotal (self-prod. & GD)	67	10	103	13	141	15
Total	674	100	805	100	945	100

Notes: (1) Includes portion imported from Itaipu.

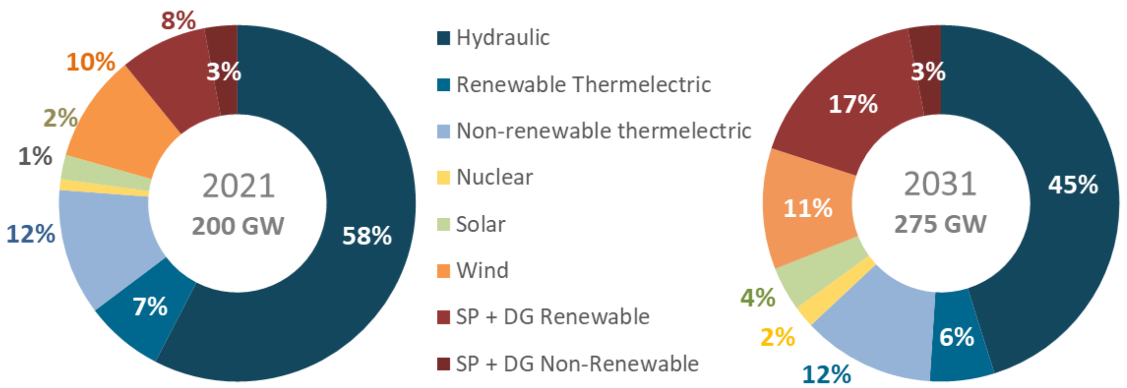
(2) Includes diesel oil from Isolated Systems. Includes MSW.

In terms of installed capacity (**Chart 11 - 4**), a greater diversification of the Brazilian electricity matrix can be observed over the period, with the reduction in the hydroelectric share being offset by the growth in the installed capacity of wind and solar sources. Also noteworthy is the growth in the share of renewable sources in self-production and distributed generation, from 8% to 17%, increasing the total installed capacity of renewable sources in the electricity matrix.

Therefore, it is estimated that the installed capacity of Brazilian electricity generation will reach the level of renewability of 83% in 2031 (

Chart 11 - 5).

Chart 11 - 4: Evolution of the composition of total installed capacity by source



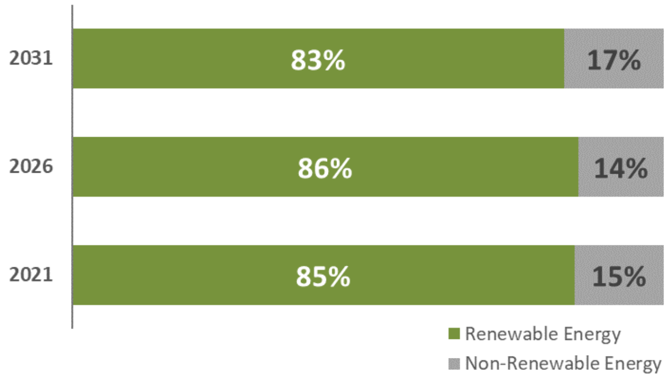
Note: Includes UHE Itaipu Portion belonging to Paraguay.

Table 11 - 4: Development of total installed capacity in Brazil

SOURCE	2021	2026	2031	2021	2026	2031
		GW			%	
CENTRALIZED	**179**	**195**	**220**	**90%**	**84%**	**80%**
RENEWABLES	154	167	181	77%	72%	66%
NON-RENEWABLES	25	27	39	13%	12%	14%
SELF-PRODUCTION	**13**	**15**	**18**	**6%**	**7%**	**6%**
RENEWABLES	8	9	10	4%	4%	4%
NON-RENEWABLES	5	6	7	3%	3%	3%
DISTRIBUTED GENERATION	**8**	**23**	**37**	**4%**	**10%**	**14%**
RENEWABLES	8	23	37	4%	10%	14%
NON-RENEWABLES	0	0	0	0%	0%	0%
TOTAL AVAILABLE	**200**	**233**	**275**	**100%**	**100%**	**100%**
RENEWABLES	170	199	229	85%	86%	83%
NON-RENEWABLES	30	34	46	15%	14%	17%

Note: Includes UHE Itaipu Portion belonging to Paraguay.

Chart 11 - 5: Electric generation installed capacity: renewable versus non-renewable



Note: Includes UHE Itaipu Portion belonging to Paraguay.

Over the next 10 years, the significant growth in primary energy production accentuates energy surpluses in the domestic energy matrix, reaching 129 million toe in 2031, which will be equivalent to about 23% of Brazil's total energy production (**Table 11 - 5**).

Table 11 - 5: Development of primary energy supply

Description	2021	2026	2031	2021-2026	2027-2031	2021-2031
	Thousand toe			Variation (% p.y.)		
Total Energy Demand (A)	295,566	368,151	421,213	4.5	2.7	3.6
Final Consumption	261,331	297,159	333,118	2.6	2.3	2.5
Losses[(1)]	34,235	70,991	88,096	15.7	4.4	9.9
Primary Energy Production (B)	323,328	458,613	550,172	7.2	3.7	5.5
Surplus Energy (B)-(A)	27,762	90,462	128,959	26.6	7.3	16.6

Note: (1) Unused energy, reinjection and losses in transformation, distribution and storage.

Table 11 - 6 shows the evolution of energy supply in the oil chain, where there is an important increase in crude oil production, with an average annual growth of 5.9%. Therefore, there is a detachment in relation to the energy demand of petroleum products, which presents 1.7% of average annual growth. Thus, at the end of the decade, there is a surplus energy of 145 million toe in the Brazilian oil chain, which is the main responsible for the significant energy surplus of the Brazilian energy matrix on the timeframe of the plan.

Table 11 - 6: Development of the supply of oil and products

Description	2021	2026	2031	2021-2026	2027-2031	2021-2031
	Thousand toe			Variation (% p.y.)		
Oil Product Demand (A)	**112,481**	**121,140**	**133,274**	**1.5**	**1.9**	**1.7**
Final Consumption	106,328	114,140	125,215	1.4	1.9	1.6
Transformation (1)	6,153	7,000	8,059	2.6	2.9	2.7
Oil Production (B)	**151,791**	**229,141**	**278,115**	**8.6**	**4.0**	**6.2**
Raw Oil	150,834	220,240	267,296	7.9	3.9	5.9
Liquid Natural Gas (2)	957	1,197	1,908	4.6	9.8	7.1
Biodiesel (3)	0	7,704	8,911	-	3.0	-
Surplus Energy (B)-(A)	**39,310**	**108,000**	**144,841**	**22.4**	**6.0**	**13.9**

Notes: (1) Includes electricity generation, petrochemical plants and coke ovens
(2) Natural gas liquids from gas pipelines and UPGN
(3) Vegetable oils for biodiesel production.

Table 11 - 7 presents the forecast natural gas balance, highlighting the growth, in the last five years, in UPGN[1] processing. On the other hand, in the same five-year period, there was a reduction in imports. Thus, the expansion of supply from UPGN reaches 85 million m³/day and proves to be an alternative to external dependence on fuel.

As for consumption, it is worth mentioning the increase in the consumption of natural gas in the residential sector and as a raw material (non-energy consumption) for the manufacture of fertilizers and the production of hydrogen in oil refineries, with average annual rates of 4.8% and 5.3%, respectively. Thus, it is estimated that the final consumption of natural gas will increase, on average, by 3.0% p.y. in the next ten years, reaching around 65 million m³/day in 2031.

[1] Natural Gas Processing Plants (UPGN in Portuguese acronym)

Table 11 - 7: Dry natural gas balance

Description	2021	2026	2031	2021-2026	2027-2031	2021-2031
	Thousand m³/d			Variation (% p.y.)		
Expected Total Supply	79,086	72,432	100,329	-1.7	6.7	2.4
UPGN	51,465	52,652	85,559	-0.5	10.2	5.2
Import	27,621	19,780	14,770	-6.5	-5.7	-6.1
Expected Total Consumption	79,086	72,432	100,329	-1.7	6.7	2.4
Transformation into Electricity (1)	30,458	13,298	34,814	-15.3	21.2	1.3
Final consumption	48,628	59,135	65,515	4.0	2.1	3.0
Non-energy consumption	5,487	7,078	9,157	5.2	5.3	5.3
Energy consumption	43,141	52,057	56,357	3.8	1.6	2.7
Energy sector (2)	10,851	11,505	11,507	1.2	0.0	0.6
Homes	1,369	1,796	2,192	5.6	4.1	4.8
Transportation	5,438	6,684	7,235	4.2	1.6	2.9
Industrial	25,126	31,670	34,978	4.7	2.0	3.4
Others (3)	358	402	445	2.4	2.0	2.2

Notes: (1) Includes self-production.
(2) Does not include E&P consumption.
(3) Includes the sectors: commercial, public and agricultural.

In turn, **Table 11 - 8** presents a summary of the expansion indicated in the PDE 2031 considered in the Socio-environmental Analysis and **Table 11 - 9**, the list of hydroelectric projects made available to the PDE 2031 for the exercise of the expansion of centralized generation.

Summaries of the results of physical expansion and investments are presented in **Table 11 - 10** and in **Table 11 - 11**. Finally, **Table 11 - 12** presents the forecast of the domestic energy matrix in 2031.

Table 11 - 8: Summary of the Expansion Planned in the PDE 2031

Source or activity	Expansion of PDE 2031
Hydropower plants (UHE in Portuguese acronym)	5,201 MW Contracted: 254 MW (2 UHEs in the South and 1 in the Midwest) Indicative: 4,947 MW, upgrading of existing UHEs (4,297 MW) in all regions of Brazil and 1 new UHE (650 MW) in the North
Small hydropower plants and hydropower generation units (PCH and CGH in Portuguese acronym)	3,335 MW Contracted: 635 MW (47 PCHs and CGHs) mainly in the South, Southeast and Midwest Indicative: 2,700 MW in the Southeast/Midwest and South electric subsystems
Non-renewable Thermoelectric plants (UTE in Portuguese acronym) (natural gas, refinery gas, coal, diesel and nuclear)	31,274 MW Contracted: 6,250 MW of UTEs, 7 new Natural Gas (NG) UTEs (3,321 MW) and 4 existing NG UTEs with new contracts (1,196 MW), 1 nuclear UTE (1,405 MW), 2 diesel UTEs (288 MW) and 1 refinery gas UTE (40 MW) Indicative: 25,024 MW, 22,624 MW of NG UTEs in all regions, 1,000 MW of nuclear UTE in the Southeast and 1,400 MW of coal-fired UTE in the South
Renewable UTEs (sugarcane bagasse, black liquor, wood chips/forest residues and RSU)	2,060 MW Contracted: 1,360 MW (21 new and 7 expanded UTEs), 18 sugarcane bagasse UTEs (666 MW), 2 black liquor UTEs (363 MW), 4 wood chip/forest residues UTEs (297 MW) and 4 municipal solid waste (RSU in Portuguese acronym) UTEs (33 MW) distributed in the South, Southeast, Midwest and Northeast Indicative: 700 MW, 400 MW of bagasse UTE and 300 MW of RSU UTE in the Southeast/Midwest electric subsystem
Wind farms	10,689 MW Contracted: 6,345 MW (183 wind farms) in the Northeast Indicative: 4,344 MW in the Northeast
Photovoltaic plants	5,814 MW Contracted: 3,114 MW (92 projects) in the Northeast and Southeast Indicative: 2,700 MW in the Southeast/Midwest electric subsystem
Transmission	33,633 km (20% of the system) 17,361 km (52%) are scheduled to go into operation until 2026 Socio-environmental analysis of 269 transmission lines, 25,086 km long North (4,686 km), Northeast (3,917 km), Midwest (1,524 km), Southeast (9,951 km) and South (5,008 km)
Oil E&P and Natural Gas	277 UPs (Production Units in contracted areas) for exploration and production of oil and natural gas, in addition to 27 UPUs (Production Units in non-contracted areas that belong to the Federal Government) Onshore UPs in the North, Northeast, Midwest and Southeast Offshore UPs concentrated in the Southeast, also occurring in the North, Northeast and South Onshore UPUs in the North, Northeast and Southeast UPUs in marine areas in the Northeast, Southeast and South
Refineries, natural gas processing plants (UPGN in Portuguese acronym) and liquefied natural gas (GNL in Portuguese acronym) terminals	2 refineries, one in the Northeast (BA) and one in the Southeast (SP), 2 expansions of an existing refinery, in the Northeast (BA) and Southeast (RJ), and 3 hydrotreatment units in existing refineries, in the Southeast (RJ and SP) 2 UPGNs, 1 planned in the Southeast (RJ) and 1 indicative UPGN in the Northeast (SE) 4 GNL regasification terminals: 1 scheduled in the North (PA) and 3 indicatives in the South (SC), Southeast (SP) and Northeast (PE)
Gas pipelines	2 transport gas pipelines: 1 scheduled, in the Southeast (RJ) and 1 indicative in the Northeast (CE) 3 outflow pipelines: 1 scheduled, in the Southeast, and 2 indicative pipelines, in the Southeast and Northeast
Ethanol	13.7 billion liters 18 plants planned: 8 from corn, 4 from sugarcane, 2 flex (sugarcane and corn) and 4 from other raw materials (soybean and cereals), mostly in the Midwest region; 57 plants expanded in all regions of Brazil, most of them in the Southeast; and 24 indicative plants
Biodiesel	5.5 billion liters 13 planned plants (Midwest, North, South and Southeast) and 3 expanded plants (South, Southeast and Midwest)
Self-production and distributed generation	Self-production: 4,711 MW (Thermoelectric: 4,471 MW; Hydroelectric: 234 MW; Solar 5.2 MW; Wind: 0.6 MW) Distributed Generation: 29,205 MW (Photovoltaic: 26,172 MW; Thermoelectric: 2,607 MW; Wind: 300 MW; CGH: 126 MW)

Icon credits: EPE and designed by Flaticon

Table 11 - 9: List of Hydropower Plant Projects Provided in PDE 2031 in the ten-year timeframe

Earliest Entry Into Operation Date	UHE[2]	Capacity (MW)	Watershed	River	STATE
2028	Apertados	139	Paraná	Piquiri	PR
2028	Castanheira (ARN-120)	140	Juruena	Arinos	MT
2028	Ercilândia	87.1	Paraná	Piquiri	PR
2028	Telêmaco Borba	118	Paraná	Tibagi	PR
2028	Tabajara	400	Wood	Ji-Paraná	RO
2029	Formoso	342	São Francisco	São Francisco	MG
2031	Bem Querer (J1A)	650	Branco	Branco	RR
2031	Santo Antônio	84.3	Uruguai	Chapecó	SC
	TOTAL	1,960.4			

[2] Hydropower plants (UHE in Portuguese acronym)

Table 11 - 10: Result Summary

		2021	2026	2031	2021-2026		2027-2031		2021-2031	
					Increm-ent	%	Increm-ent	%	Increm-ent	%
Macro-economic Parameters										
GDP (10^9 BRL)		4,190	4,811	5,577	620.3	15%	766	16%	1,387	33%
Population (1) (10^6 inhab)		214.1	220.9	226.3	6.9	3%	5.4	2%	12.2	6%
GDP per capita (10^3 BRL/inhab)		19.6	21.8	24.6	2.2	11%	2.9	13%	5.1	26%
Domestic Energy Supply per capita (toe/inhab)		1.38	1.52	1.70	0.1	10%	0.2	12%	0.3	23%
Domestic Energy Supply by GDP (toe/10^6 BRL)		160.9	167.2	169.5	6.3	4%	2.2	1%	8.6	5%
Energy Intensity of the Economy (toe/10^6 BRL)		0.070	0.070	0.069	0.0	-1%	-0.001	-1%	-0.001	-2%
Income-elasticity in energy consumption					0.93		0.76		0.83	
Final Consumption (2) (106 toe)		**261**	**297**	**333**	**35.8**	**14%**	**36.0**	**12%**	**71.8**	**27%**
Natural Gas (106 m³/day)		*55.9*	*76.0*	*88.6*	*20.0*	*36%*	*12.6*	*17%*	*32.6*	*58%*
Coal and Coke (10^6 t)		*18.8*	*20.4*	*23.8*	*1.6*	*8%*	*3.4*	*17%*	*5.0*	*26%*
Firewood and Charcoal (10^6 t)		*63.7*	*64.6*	*65.1*	*0.9*	*1%*	*0.5*	*1%*	*1.4*	*2%*
Sugarcane Bagasse (10^6 t)		*137.7*	*157.2*	*170.2*	*19.5*	*14%*	*13.0*	*8%*	*32.5*	*24%*
Electricity (TWh)		*562.6*	*669.2*	*791.9*	*106.6*	*19%*	*122.7*	*18%*	*229.2*	*41%*
Ethanol (10^6 m³)		*29.4*	*37.8*	*44.2*	*8.4*	*29%*	*6.5*	*17%*	*14.8*	*51%*
Biodiesel (10^6 m³)		*6.5*	*10.0*	*11.2*	*3.5*	*54%*	*1.2*	*12%*	*4.7*	*73%*
Oil Products (10^6 m³)		*101.1*	*105.5*	*117.7*	*4.3*	*4%*	*12.2*	*12%*	*16.6*	*16%*
Diesel Oil		*53.2*	*58.7*	*65.9*	*5.4*	*10%*	*7.2*	*12%*	*12.6*	*24%*
Fuel Oil		*2.4*	*2.3*	*2.5*	*-0.1*	*-5%*	*0.2*	*10%*	*0.1*	*4%*
Gasoline		*28.9*	*24.8*	*27.4*	*-4.2*	*-14%*	*2.6*	*10%*	*-1.6*	*-5%*
LPG		*14.1*	*14.9*	*15.8*	*0.8*	*6%*	*0.9*	*6%*	*1.7*	*12%*
Kerosene		*2.5*	*4.9*	*6.1*	*2.4*	*96%*	*1.3*	*26%*	*3.7*	*148%*
Domestic Energy Supply (3) (10^6 toe)		**295**	**336**	**384**	**41.1**	**14%**	**48.4**	**14%**	**89.4**	**30%**
Oil (10^3 barrels/day)	- Production	*2,917*	*4,259*	*5,169*	*1,342*	*46%*	*910*	*21%*	*2,252*	*77%*
	- Export	*-1,120*	*-2,320*	*-3,238*	*-1,200*	*107%*	*-918*	*40%*	*-2,118*	*189%*
Natural Gas (10^6 m³/day)	- Production (4)	*124.8*	*178.7*	*245.8*	*54.0*	*43%*	*67.0*	*38%*	*121.0*	*97%*
	- Import	*27.6*	*19.8*	*14.8*	*-7.8*	*-28%*	*-5.0*	*-25%*	*-12.9*	*-47%*
Diesel Fuel (10^6 m³)	- Production	*42.8*	*45.3*	*43.9*	*2.6*	*6%*	*-1.4*	*-3%*	*1.1*	*3%*
	- Import/Export	*11.8*	*15.0*	*24.4*	*3.3*	*28%*	*9.4*	*63%*	*12.7*	*107%*
Fuel Oil (10^6 m³)	- Production	*15.2*	*13.0*	*12.1*	*-2.2*	*-14%*	*-0.9*	*-7%*	*-3.0*	*-20%*
	- Export	*-12.5*	*-10.5*	*-9.3*	*2.0*	*-16%*	*1.2*	*-11%*	*3.1*	*-25%*
Gasoline (10^6 m³)	- Production	*26.3*	*26.5*	*26.8*	*0.2*	*1%*	*0.3*	*1%*	*0.5*	*2%*
	- Export	*1.2*	*-3.0*	*-0.7*	*-4.2*	*-353%*	*2.3*	*-76%*	*-1.9*	*-160%*
LPG (10^6 m³)	- Production	*9.7*	*13.2*	*17.0*	*3.5*	*36%*	*3.8*	*29%*	*7.2*	*75%*
	- Import	*4.4*	*1.7*	*-1.2*	*-2.7*	*-61%*	*-2.9*	*-167%*	*-5.5*	*-126%*
Kerosene (10^6 m³)	- Production	*4.0*	*6.2*	*6.6*	*2.2*	*55%*	*0.4*	*6%*	*2.6*	*64%*
	- Export	*-1.5*	*-1.4*	*-0.4*	*0.2*	*-12%*	*0.9*	*-67%*	*1.1*	*-71%*
Ethanol (10^6 m³)	- Production	*30.7*	*38.9*	*45.4*	*8.2*	*27%*	*6.5*	*17%*	*14.7*	*48%*
	- Export (5)	*-1.33*	*-1.17*	*-1.23*	*0.2*	*-12%*	*-0.1*	*5%*	*0.1*	*-8%*
Electricity (TWh)	- Production+Import	*674*	*805*	*945*	*130*	*19%*	*141*	*17%*	*271*	*40%*

Table 11 - 10: Result Summary (cont.)

	2021	2026	2031	2021-2026		2027-2031		2021-2031	
				Increm-ent	%	Increm-ent	%	Increm-ent	%
Electricity Generation Installed Capacity (6) (GW)	**200**	**233**	**275**	**33**	**16%**	**42**	**18%**	**75**	**37%**
Centralized	179	195	220	15	9%	25	13%	41	23%
Hydraulic (7)	116	118	124	2	2%	7	6%	9	7%
Thermal (8)	37	41	51	4	10%	9	23%	13	36%
- Renewable	14	16	16	1	10%	0	3%	2	13%
- Non-renewable	23	25	35	2	11%	9	36%	12	50%
Wind	20	26	30	6	33%	4	17%	11	55%
Solar	4	8	10	3	74%	3	35%	6	135%
Nuclear	2	2	4	0	0%	2	121%	2	121%
Self-production and GD	21	38	55	17	83%	17	44%	34	162%
Renewables (9)	16	32	48	16	103%	16	49%	32	202%
Non-renewables	5	6	7	1	21%	1	17%	2	42%
Power Transmission (10)									
Transmission Lines (km)	175,273	192,634	208,907	17,361	10%	16,273	8%	33,633	19%
Substations (MVA)	421,879	503,081	539,004	81,202	19%	35,924	7%	117,126	28%
Transport of Natural Gas (km of gas pipelines) (11)	9,409	9,503	9,630	94	1%	127	1%	221	2%

Notes: (1) IBGE estimate for the resident population on July 1 of each year.

(2) Final consumption in the industrial, agricultural, transport, residential, commercial, public sectors. It also includes consumption in the energy sector (E&P, refineries and system movement) and consumption as raw materials. Does not include consumption for electricity generation and consumption for bunker.

(3) Import and export values have a positive and negative sign, respectively.

(4) Expected production, estimated based on forecast availability of natural gas for UPGNs.

(5) Average annual variation calculated from 2022 to 2031, which is equivalent to the estimated period with ethanol exports.

(6) Includes plants already in commercial operation in isolated systems, with interconnection forecast within the timeframe of the study and considering the motorization of the plants.

(7) Does not include the import of generation from UHE Itaipu.

(8) Includes generation using natural gas, mineral coal, fuel and diesel oils and industrial gas. Does not include nuclear power.

(9) The portion corresponding to the SIN is not included.

(10) The values refer to installations of the SIN Basic Network, including substations bordering the distribution grid.

(11) Does not include transport pipelines in the planning phase that have not yet been proposed by the MME.

Table 11 - 11: Summary of investment estimations

	BRL billion Period 2021-2031	%
Electricity Supply	528	16.2%
Centralized Generation (1)	292	9.0%
Distributed Generation (Micro and Mini Generation)	135	4.1%
Transmission (2)	101	3.1%
Oil and Natural Gas	2,664	81.9%
Oil and Natural Gas Exploration and Production	2,496	76.8%
Oil Product Supply	31	0.9%
Natural Gas Supply	138	4.2%
Liquid Biofuel Supply	60	1.8%
Ethanol (4) – Production units and gas pipeline infrastructure	58	1.8%
Biodiesel/BioQAV – Production plants	2	0.1%
TOTAL	**3,252**	**100.0%**

Notes:

(1) Includes estimates of investments in plants already granted and authorized, including plants with contracts signed in energy auctions.

(2) Includes facilities already tendered that will come into operation in the ten-year period; and 2021 investments are considered to be realized.

(3) Reference exchange rate: BRL 5.20 / USD (Dec/2020).

(4) Includes investments for 1G, 2G and corn sugar and ethanol units.

Table 11 - 12: Domestic Energy Matrix Forecast – Year 2031

Forecast of the Domestic Energy Matrix - Year 2031										SECONDARY ENERGY SOURCES																	
CONSOLIDATED - 2031 (10 toe)	OIL	NATURAL GAS	STEAM COAL	STEEL MILL COAL	URANIUM U3O8	HYDRO POWER	FIREWOOD	SUGARCANE PRODUCTS	OTHER PRIMARY SOURCES	ENERGY TOTAL PRIMARY ENERGY	DIESEL OIL	FUEL OIL	GASOLINE	LPG	NAPHTHA	KEROSENE	COKE GAS	COALCOKE	URANIUM CONTAINED IN UO2	ELECTRICITY	CHARCOAL	ETHANOL ANHYDROUS AND HYDROUS	OTHER OIL PRODUCTS	OIL NON-ENERGY PRODUCTS	COAL TAR	TOTAL SECONDARY ENERGY	TOTAL
PRODUCTION	267,296	89,060	2,122	0	8,807	42,574	27,811	66,249	48,407	552,327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	552,327
IMPORT	8,809	4,744	4,961	10,829	0	0	0	0	0	29,343	21,944	73	0	0	3,040	2,413	0	1,151	0	1,013	0	534	2,585	1,055	0	33,808	63,151
INVENTORY VARIATION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL SUPPLY	276,105	93,804	7,083	10,829	8,807	42,574	27,811	66,249	48,407	581,670	21,944	73	0	0	3,040	2,413	0	1,151	0	1,013	0	534	2,585	1,055	0	33,808	615,478
EXPORTS	-176,264	0	0	0	0	0	0	0	-56	-176,320	-1,237	-8,996	-550	-708	0	-2,776	0	0	0	0	0	-1,175	-271	-77	0	-15,790	-192,110
NOT USED	0	-2,826	0	0	0	0	0	0	0	-2,826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2,826
REINJECTION	0	-36,117	0	0	0	0	0	0	0	-36,117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-36,117
GROSS DOMESTIC SUPPLY	99,841	54,862	7,083	10,829	8,807	42,574	27,811	66,249	48,351	366,408	20,707	-8,923	-550	-708	3,040	-363	0	1,151	0	1,013	0	-641	2,314	978	0	18,018	384,425
TOTAL TRANSFORMATION	-99,841	-25,460	-2,514	-10,829	-8,807	-42,574	-10,072	-30,006	-36,797	-266,901	44,041	11,325	21,613	10,361	2,310	5,416	1,687	9,268	0	80,270	5,072	23,434	7,523	6,131	326	228,776	-38,125
OIL REFINERIES	-99,841	0	0	0	0	0	0	0	-1,908	-101,749	37,235	11,616	20,644	4,289	5,680	5,416	0	0	0	0	0	0	7,772	5,220	0	97,872	-3,878
NATURAL GAS PLANTS	0	-9,730	0	0	0	0	0	0	1,350	-8,380	0	0	0	5,971	0	0	0	0	0	0	0	0	0	911	0	6,882	-1,498
GASIFICATION PLANTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COKING PLANTS	0	0	0	-10,829	0	0	0	0	0	-10,829	0	0	0	0	0	0	2,422	9,268	0	0	0	0	-1,469	0	338	10,558	-271
NUCLEAR FUEL CYCLE	0	0	0	0	-8,807	0	0	0	0	-8,807	0	0	0	0	0	0	0	0	8,675	0	0	0	0	0	0	8,675	-132
PUBLIC UTILITY POWER PLANTS	0	-10,460	-2,209	0	0	-42,136	0	-7,672	-11,810	-74,286	-1,874	0	0	0	0	0	0	0	-8,675	68,122	0	0	0	0	0	57,572	-16,714
SELF-PRODUCER POWER PLANT	0	-4,712	-306	0	0	-439	-556	-3,166	-11,648	-20,826	-426	-292	0	0	0	0	-735	0	0	12,148	0	0	-628	0	-12	10,056	-10,771
CHARCOAL PLANTS	0	0	0	0	0	0	-9,516	0	0	-9,516	0	0	0	0	0	0	0	0	0	0	5,072	0	0	0	0	5,072	-4,444
DISTILLERIES	0	0	0	0	0	0	0	-19,168	0	-19,168	0	0	0	0	0	0	0	0	0	0	0	19,036	0	0	0	19,036	-132
OTHER TRANSFORMATIONS	0	-558	0	0	0	0	0	0	-12,781	-13,339	9,107	0	970	100	-3,370	0	0	0	0	0	0	4,398	1,848	0	0	13,053	-286
LOSSES IN DISTRIBUTION AND STORAGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-13,183	0	0	0	0	0	-13,183	-13,183
FINAL CONSUMPTION	0	29,401	4,569	0	0	0	17,739	36,243	11,554	99,506	64,749	2,402	21,063	9,654	5,350	5,053	1,687	10,419	0	68,100	5,072	22,793	9,836	7,109	326	233,611	333,118
NON-ENERGY FINAL CONSUMPTION	0	2,941	0	0	0	0	0	0	0	2,941	0	0	0	0	5,350	2	0	0	0	0	0	611	0	7,109	206	13,277	16,219
ENERGY FINAL CONSUMPTION	0	26,460	4,569	0	0	0	17,739	36,243	11,554	96,565	64,749	2,402	21,063	9,654	0	5,051	1,687	10,419	0	68,100	5,072	22,182	9,836	0	120	220,334	316,899
ENERGY SECTOR	0	12,054	0	0	0	0	0	17,429	0	29,483	1,445	194	0	0	0	0	119	0	0	3,842	0	0	3,214	0	0	8,813	38,296
RESIDENTIAL	0	704	0	0	0	0	5,376	0	0	6,080	0	0	0	7,584	0	0	0	0	0	17,889	271	0	0	0	0	25,743	31,823
COMMERCIAL	0	117	0	0	0	0	100	0	0	217	41	13	0	435	0	0	0	0	0	12,326	94	0	0	0	0	12,910	13,128
PUBLIC	0	26	0	0	0	0	0	0	0	26	6	8	0	330	0	0	0	0	0	5,458	0	0	0	0	0	5,801	5,827
FARMING	0	0	0	0	0	0	3,497	0	0	3,497	8,332	11	0	24	0	0	0	0	0	3,301	10	9	0	0	0	11,687	15,184
TRANSPORTATION	0	2,324	0	0	0	0	0	0	49	2,373	53,582	1,082	21,063	0	0	5,050	0	0	0	297	0	22,173	0	0	0	103,247	105,620
INDUSTRIAL	0	11,235	4,569	0	0	0	8,767	18,814	11,505	54,889	1,343	1,094	0	1,280	0	1	1,567	10,419	0	24,987	4,697	0	6,623	0	120	52,132	107,021

11.1 The Energy Transition in the Ten-Year Timeframe

The concept of energy transition is associated with significant changes in the structure of the world's primary energy matrix in a process of transformation towards a low carbon economy and smaller environmental footprint. Due to the complexity and diversity of processes at play, variations in the stage and rhythm of transformations in different countries, regions or locations are characteristics present in this process of long coexistence between energy sources during their trajectories of progressive replacement. The transition of infrastructure for production, transport and use of energy resources are some of the factors that explain the slow transition of energy systems worldwide.

Cross-cutting issues such as sustainable development, climate change and technological innovations associated with electronics and the entry into the digital age are constraints that have stimulated a more efficient use of energy resources, electrification in energy conversion processes and a reduction in the participation of more carbon-intensive fuels in the world's primary energy mix in favor of low-carbon sources. In short, energy transitions involve several dimensions and bring about broad transformations in socioeconomic systems and in their relationships with the environment. This process is complex, usually long and will be based on electrification (mainly renewable), biofuels, energy efficiency (catalyzed by digitalization) and the use of natural gas.

The ten-year outline of the energy transition in the case of Brazil presents social, economic, energy, environmental and specific aspects of each source that will be part of the beginning of the transition trajectory and of the energy planning envisioned for the long term. These aspects are discussed below in the main highlights of the PDE 2031.

Increase in the number of consumers on the grid. In PDE 2031, the number of residential electricity consumers on the grid is expected to increase by 16%, equivalent to 12 million additional connections between 2021 and 2031.

Electrification in Brazil's final energy consumption matrix will increase, jumping from 18% in 2021 to 20% in 2031. Contributing to this is the increase in the participation of electricity-intensive sectors, such as primary aluminum production and pelletizing, as well as consumption by the commercial sector. It is worth mentioning the discrepancy in the electricity consumption of each individual, when comparing the different income classes, indicating that there is still room for increased consumption in the less favored classes due to the strong repressed consumption.

The advancement of technological innovations, the decrease in costs and the increase in the average income of families over time, can provide a tendency to increase the use of electrical and electronic equipment in Brazilian homes, especially in activities that still require a lot of human action, such as cleaning environments or preparing food. Currently, cell phone charging already consumes a relative amount of electricity in households, around 1.7% of the total electricity demanded by households, due to the high ownership of the devices (almost one per person) and their time of daily load. It is estimated that this can also happen for other rechargeable electrical and electronic devices.

Migratory movements associated with the urbanization process of society should influence residential energy consumption by modifying the use of the main energy sources related to the existing infrastructure, the climate and the way of organizing and living. In general, while rural areas are associated with houses and farms located in places with a milder climate whose sources are based on the use of biomass (firewood and charcoal) for energy consumption, in cities, typically warmer, smaller buildings and apartments using electricity, LPG or natural gas predominate. Residential energy consumption also varies positively depending on the economic conditions and natural characteristics of each region of Brazil. EPE estimates, based on data from the Survey of Possessions and Habits of Use of Electrical Equipment in the Residential Class - PPH 2019 (PROCEL/ELETROBRAS, 2019) indicate that about 35% of Brazilian households do not heat water in Brazil, the largest part of them in the North and Northeast regions. In the PDE 2031, there is the prospect of the displacement of residential firewood, in favor of more modern fuels, such as LPG and natural gas, especially for cooking. These fuels allow greater efficiency and control of burning, in addition to not generating particulate materials, which are harmful to human health. It is important to emphasize that, in order to expand consumption of these sources in potential consumer markets, distribution and resale logistics are necessary, in the case of LPG, and a distribution network, for natural gas.

Based on international experiences, the relevance of actions and programs is noted, as well as the creation of specific legislation and institutions to address energy efficiency as one of the most important challenges in the energy transition. The energy efficiency policies instituted include guidelines for the various sectors of the economy and equipment labeling. Another widely used measure is the ban on the use of outdated equipment. Energy efficiency makes it possible to provide the same service with less energy expenditure, which tends to generate less environmental impacts and provide greater productivity in the economy. Additionally, in general, the dissemination of efficiency measures leads to less need for electricity generation to meet demand. Consequently, at times when the system is most stressed, it is also less necessary to expand generation to meet the peak demand.

In recent years, there has been an acceleration in the insertion of RED, especially distributed micro and mini-generation (MMGD), justified mainly by the reduction in investment and transaction costs, the greater dissemination of telecommunication and control technologies, as well as the role most active of consumers. The diffusion of these technologies has a high disruptive potential, capable of profoundly transforming electrical systems that today are predominantly operated with larger resources and centrally managed. The most evident contribution of RED, in addition to energy, refers to the reduction of electrical losses, resulting from the proximity between generation and consumption. The other contributions require specific conditions, such as ideal locations and operations at the right times to provide reliability to system operators in extreme situations. This fact can reduce the systemic cost of meeting demand, if more expensive plants do not need to be activated and replace or postpone conventional investments in infrastructure. In addition, “smart” mechanisms for integrating and managing these resources are under intense development and this should contribute to expanding the potential efficiency gains obtained from the insertion of more RED. As an example, we can mention the figure of “aggregators” of distributed energy resources, which form virtual plants and dispatch them in the electricity market.

From a socio-environmental perspective, the energy transition process mainly includes decarbonization initiatives and the production of bioenergy and renewable energies. In the transition scenario, there are still socio-environmental opportunities for the energy sector with the implementation of carbon pricing mechanisms and payment for environmental services programs; the expansion of energy from waste; and the promotion of innovative low-carbon technologies such as hydrogen and renewable diesel. All these initiatives and possibilities consolidate Brazil's vocation to follow a low carbon trajectory, starting from the implementation of renewable energy projects, associated with the reduction and removal of carbon. Given this context, companies, governments and sectoral organizations have made progress in reducing their emissions with Net Zero commitments, actions to diversify their portfolio with renewables, adoption of technologies and measures for carbon removal (forest carbon offset and carbon capture, use and storage - CCUS) and energy efficiency. These measures are in line with the principles of environmental, social and governance (ESG) best practices and the goals of the UN Sustainable Development Agenda.

In a broader perspective, energy planning studies serve as a basis for the socio-environmental dimension to be incorporated into the energy transition process and, through the foreseen communication channels, also allow society to participate in the process. In this line, the PDE itself is a fundamental instrument for a just and sustainable transition, already recognized as the Sectorial Plan for Mitigation and Adaptation to Climate Change. In this way, the desired transition is supported by actions to avoid and reduce socio-environmental impacts, respecting the multiple uses of resources; and by measures that seek to increase social well-being, such as guaranteeing access to modern energy and boosting the generation of employment and income in Brazil.

In line with the long-term perspectives, the forecasts for the ten-year period for biofuels consider the maintenance of the renewability of the energy matrix, with a significant participation of this source in the transport matrix and an increase in the systemic efficiency of this sector. It is worth noting the introduction of new biofuels, as well as the electrification of transport from niches, such as captive fleets, with greater positive externalities. The PDE 2031 proposes to identify the impacts on energy chains (fossil fuels and biofuels), in order to provide information for decision-making on public policies and energy planning. Additionally, it also evaluates the role of the expansion of biomass generation, considering its attributes to meet the main needs of the electricity sector.

In this timeframe, it is essential to preserve and strengthen the role of bioenergy and the prominence of Brazil in biotechnology applied to the energy sector, working to avoid technological locks that prevent the development and use of this potential in Brazil, with benefits in the decarbonization of the matrix. In this context, greater use is expected of batteries and other forms of storage, solutions based on hydrogen and synthesized fuels, advanced biofuels, with carbon capture and use, biorefineries, among others.

The Brazilian energy strategy considers the use of its oil and gas reserves until 2050 in order to ensure the sustainable development of the nation, since the resources from collection and commercialization will be fundamental for energy security, economic development and the Brazilian energy transition itself.

Despite the increase in the consumption of renewables, the demand for oil products in Brazil will continue to grow. Meeting domestic demand for oil products is essential, at a time of growing concern about global and local climate issues. The adoption of new specifications, such as a reduction in the sulfur content of marine fuels and an increase in the octane rating of C gasoline, are assumptions that guide the forecasts for the supply of products in the ten-year period. Furthermore, more restrictive specifications require investments in conversion and treatment units. Some of these investments are planned over the ten-year period, such as revamps or construction of a new unit in domestic refineries.

The expansion of the infrastructure for moving liquid fuels, replacing road transport, will ensure domestic supply and a more energy efficient transport matrix. In the ten-year timeframe, the expansion of rail and water transport is indicated, contemplating, in particular, investments planned in waterway terminals and ports.

Oil and natural gas present a series of challenges to be faced, especially by the gas sector, in view of the potential of this fuel for the energy transition, and the historical context for the future. Among the public policy tools indicated for solving these long-term challenges, the Novo Mercado de Gás (New Gas Market) program, launched in 2019 with the participation of EPE, and which continues to this day with the work of the Natural Gas Market Opening Monitoring Committee (CMGN), of which EPE is also a part, standing out.

The New Gas Market, as well as Law nº 14.134/2021 and Decree nº 10.712/2021 that regulates it, have been the main instruments of the public authorities in order to equate the parameters necessary for the opening of the market, also solving the challenges that had been raised in the PNE 2050 and in the diagnostic report of the Novo Mercado de Gás.

Even so, it is always important to emphasize that public policies at the federal level establish a framework on which the transactions will take place, but the regulation of natural gas distribution is an attribution of the states, and the investment in infrastructure must be carried out by the players to that these facilities can actually operate and leverage the sector.

The projects analyzed in EPE Indicative Plans[3] must be detailed by the players, and then built, only if all relevant market conditions are addressed. Only with the integration of socio-environmental conditions, public policies, and private investments, will the natural gas sector really have the advancement we so desire, effectively contributing to the energy transition scenario.

The planning of the expansion of centralized electricity supply is highlighted by three lines of action of great contribution to the energy transition: (i) advances in the identification of system requirements; (ii) adequacy of the market design and; (iii) consideration of new sources in the supply basket and improvement of their representations.

The PDE 2030 presented, for the first time, a methodological proposal that identifies the future needs of the system requirements, in a transparent and reproducible way. This methodology was improved for PDE 2031, incorporating important advances. In addition, PDE 2031 also brings a new way of representing the operating restrictions of the system, seeking to make the results of long-term studies more adherent to the operating reality. In this way, by improving the predictability of the sector, it is expected that the conditions foreseen in the planning can be effectively achieved, mitigating operational and financial risks, as well as higher-than-expected GHG emissions.

Discussions on the Modernization of the Brazilian Electric System include changes in the characteristics of the generating complex, which lead to the need to review the entire market design. By allowing the system requirements to be contracted through clear products for all players, it is possible that barriers to entry of new technologies are broken down, always contributing to the innovation of solutions, in addition to providing greater efficiency in the use of resources.

Finally, in each PDE, new generation technologies are being incorporated into the supply basket, such as floating photovoltaics, offshore wind, biogas and reversible hydroelectric plants, in addition to other renewables already consolidated in the market. The representation of these sources has also evolved with the spatial and temporal detailing of the generation profiles, and updated costs. In this way, the planning has more options for renewable sources for the expansion of supply.

The transmission expansion planning has a prominent role in the energy transition process by enabling the integration of renewable generation potentials in the most diverse regions of Brazil. One of the main planning actions in this context is the carrying out of prospective expansion studies, which aim to provide flow margin in the electrical system for new generation projects, increasing competitiveness and attractiveness in energy auctions and also in projects in the free marketing environment, in addition to minimizing possible effects of mismatch between the generation and transmission projects. In addition, with the changes in the characteristics of the generating complex leading to a significant growth in non-controllable variable sources, the uncertainties for carrying out expansion planning studies increase and it becomes necessary to evaluate different scenarios for the growth of generation and transmission. As a way of mitigating uncertainties and acting as a facilitator of the expansion of these sources in the system, the recommendations of the transmission planning

[3] (PIG - Indicative Plan for Gas Pipelines, PIPE - Indicative Plan for Processing and Flow, PITER - Indicative Plan for LNG Terminals).

studies have contemplated the use of different technologies in direct and alternating current, in extra or ultra high voltages, which allows expanding the capacity to flow large blocks of power while maintaining reliability in the operation of the system.