MINISTÉRIO DE MINAS E ENERGIA
SECRETARIA DE PLANEJAMENTO E DESENVOLVIMENTO ENERGÉTICO

2031
TEN-YEAR ENERGY EXPANSION PLAN

epe
Empresa de Pesquisa Energética

Ministério de
Minas e Energia

9. Energy Efficiency and Distributed Energy Resources

9.1 Initial Remarks

Distributed Energy Resources (RED) are defined as technologies of generation, storage of electric energy and reduction of consumption located within the limits of the area of a determined distribution concessionaire, normally next to consumer units, behind the meter. In this sense, the distributed energy resources considered in the PDE 2031 cover:

- Energy efficiency;
- Distributed Micro and Mini Generation (MMGD)
- Self-production of energy (not injected);
- Thermal solar energy.

It is important to highlight that the concept of self-production adopted here (not injected) only includes the portion of self-production destined for the self-service of the final consumer. Any electrical generation surpluses are not accounted for in this RED concept. The alternative "demand response[1]", although it may be included in the concept of RED, was not addressed in this chapter. Additionally, the modality of direct contracting of Distributed Generation through public calls by the distributors, according to Decree No. 5,163, of 2004, was not included in the projections. This modality has a history of low adherence by distributors, and its insertion in the ten-year period should remain marginal.

The importance of these resources is related to the fact that their insertion as a service option will demand new planning practices for the expansion and operation of the energy generation system, as well as the electrical grids. However, while RED presents challenges, there can be several benefits associated with their integration into the system.

Among these benefits, we can mention the proximity between the sources of generation and points of consumption, which can lead to the reduction of electrical losses. Additionally, RED can provide sufficient reliability for system operators in extreme situations, if they are properly spatially allocated and operated at the most appropriate times. However, the adoption of RED adds another source of uncertainty both for planning the expansion of the energy system and for its operation, making them more complex.

According to the PDE 2031 studies, it is estimated that the electrical contribution of the RED as a source of service could account for 21% of electricity consumption by 2031, which would correspond to 175 TWh, with self-production contributing 10%, MMGD with 8% and energy efficiency with 4% in that horizon (**Table 9 - 1**). When considering the total energy consumption, it is estimated that distributed energy resources can meet about 9% of this energy demand by 2031, with emphasis on energy efficiency (5%) and self-production (2%). The details of the contribution of each of the alternatives that make up the RED will be presented in the next items of this chapter. **Chart 9 - 1** illustrates the contribution of RED to meet the potential demand for electricity in the ten-year horizon.

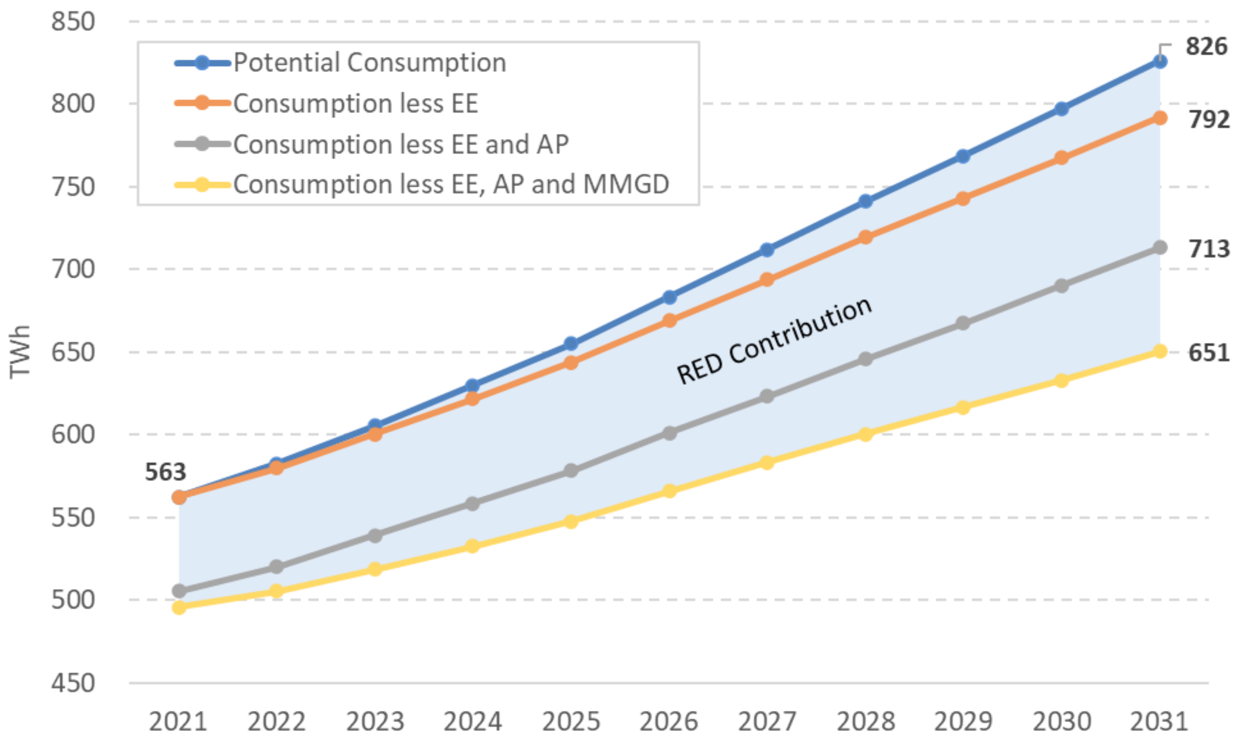
[1] The **demand response** refers to the mechanisms to manage customer consumption in **response** to supply conditions, such as, for example, reducing or shifting energy consumption at critical moments through payments or in **response** to market prices (Gellings, 2009). (No EPE-DEE-NT-022/2019-r0).

Table 9 - 1: Brazil: Energy Efficiency and Distributed Energy Resources

Total Energy [1] (thousand toe)	2021	2026	2031
Potential power consumption [2]	247367	289423	334389
Thermal solar energy [3]	13	84	169
Energy Efficiency	0	7758	17322
Consumption with conservation	247355	281580	316899
Non-injected self-production	4886	5837	6748
MMGD[4]	849	3032	5400
%			
Consumption met with EE and RED	2	6	9
Thermal solar energy [3]	0.01	0.03	0.05
Energy Efficiency	0.0	3	5
Non-injected self-production	2	2	2
MMGD[4]	0.3	1	1.6
Fuels (thousand toe)	2021	2026	2031
Potential fuel consumption	198970	230630	263340
Consumption with conservation	198970	224029	248799
Energy efficiency of fuels	0	6601	14541
Electric Energy (GWh)	2021	2026	2031
Potential electricity consumption [2]	562758	683638	826153
Thermal solar energy [3]	147	981	1960
Electrical Efficiency	0	13462	32336
Consumption with conservation	562611	669196	791858
Non-injected self-production	56813	67873	78461
MMGD[4]	9870	35253	62795
%			
Consumption met with EE and RED	12	17	21
Thermal solar energy [3]	0	0.1	0.2
Electrical Efficiency	0	2	4
Non-injected self-production	10	10	10
MMGD[4]	2	5	8
Total avoided average load [5] (MWavg)	9304	16367	24439

Notes: (1) Total energy corresponds to electricity consumption in all sectors plus fuel consumption in the industrial, energy, agricultural, commercial, public and transport sectors (Total energy = electricity consumption + fuel consumption).
(2) Includes the share of solar thermal energy.
(3) Solar thermal energy for the residential sector incremental compared to 2021.
(4) MMGD: Distributed Micro and Mini-generation.
(5) The level of total losses considered was 18%.

Chart 9 - 1: RED Contribution



Notes: (1) Potential Consumption includes the incremental portion compared to 2021 of Solar Thermal Energy from Solar Heating Systems (SHS).
(2) EE: electrical efficiency. For the purposes of representation in the graph, the portion related to SHS was added to the efficiency estimate.
(3) AP: self-production not injected into the grid.
(4) MMGD: Distributed micro and mini-generation

9.2 Energy Efficiency

The results of energy saved presented in this chapter indicate the difference between the projection of final energy consumption, incorporating energy efficiency gains, and the energy consumption that would occur if the technological standards observed in the base year of 2021 were maintained; that is, zero energy efficiency gain in 2021. Thus, in this PDE, the first efficiency gains will be noticed in the modeling in the year 2022. In this regard, the concept used in the metric of these results refers to what is known as the zero efficiency scenario, as defined in Jannuzzi, Swisher and Redlinger (2018).

Box 9 - 1: Energy Efficiency in the PDE

Energy efficiency (EE) is an effective and priority resource for meeting energy demand (EPE, 2020). The energy demand projection in the Decennial Plan already considers EE gains, reducing energy demand in the future and

Box 9 - 1: Energy Efficiency in the PDE

the need to expand energy supply in Brazil. Next, the EE calculation methodology used in the planning studies will be presented.

Energy efficiency gains are calculated by the difference between the projection of final energy consumption – which already incorporates these efficiency gains – and the projection of potential consumption (without efficiency), maintaining the base year standards. Thus, changes in the structure of the industry and the economy do not distort the indicator, as described in BOX 1-1. The efficiency presented in the Plan considers the energy conservation that occurs from the base year. In PDE 2031 the base year is 2021; therefore, only the efficiency gains obtained after 2022 are incorporated. The efficiency of the historical period is already included in the consumption realized and therefore it is not quantified in the EE gains of the ten-year period.

Energy efficiency is estimated within each sectoral model of projection of final energy consumption (industry, energy sector, residential, commercial, public, agriculture and transport) and in the model of projection of electricity demand (MDE). Therefore, the EE results presented in Chapter IX of the PDE deal with the estimated gains for the final energy consumption sectors, not incorporating the energy savings obtained in the transformation (such as gains in electricity generation and refining).

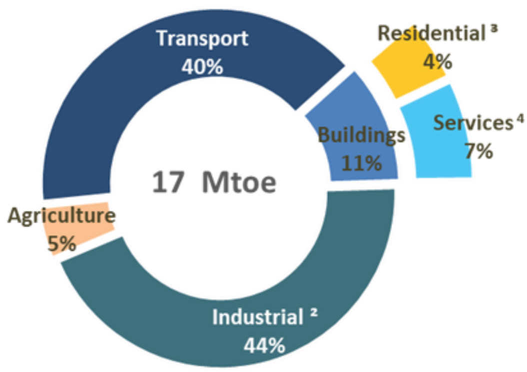
Consumption with and without efficiency is calculated based on different indicators: the most appropriate for each sector or segment, such as consumption by physical production, added value, residential, equipment, built-up area, planted area, etc. In the industrial sector, for example, efficiency gains are based on technology, on the optimization of systems and processes, on the performance of equipment and on the replacement of energy sources (based on the indicators of the Balance of Useful Energy).

The EE results presented in this chapter incorporate technological changes (changes in processes and equipment efficiency) and changes in consumption patterns (e.g., with energy management). They also qualitatively consider the existing policies, programs and actions already in place in Brazil: their advances and autonomous gains to be made by consumers, that is, the natural technological replacement due to the end of the useful life of equipment for more efficient ones.

The impacts of the COVID-19 pandemic continue to affect the global and domestic scenario, as highlighted in Chapter 1.

In the PDE 2031 studies, it is estimated that in 2031, energy efficiency gains can contribute to the service of about 17 million toe in 2031, about 7% of the final Brazilian energy consumption observed in the year 2020 in the BEN 2021. Among the final consumption sectors, the largest contribution in relation to the total saved must be observed in transport and industry, as shown in **Chart 9 - 2**.

Chart 9 - 2: Sectoral contribution to energy efficiency gains in 2031[1] (% of total gain)

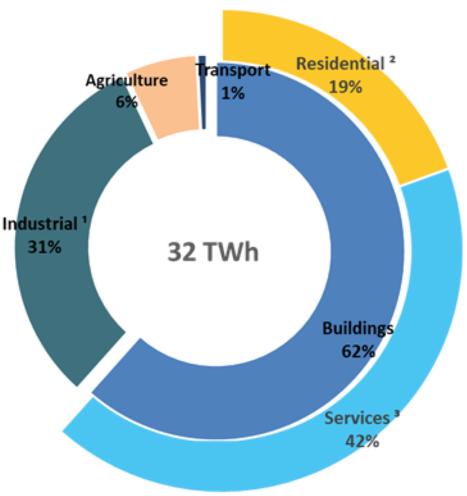


Notes: (1) Corresponds to total electricity consumption in all sectors plus fuel consumption in the industrial, energy, agricultural, commercial, public and transport sectors.

(2) Includes the energy sector.
(3) Comprises energy consumption in urban and rural residences.
(4) Includes utilities.

It is estimated that efficiency gains in electricity consumption will reach around 32 TWh in 2031 (4% of the estimated total electricity consumption in that year), corresponding to the electricity generated by a hydroelectric plant with an installed capacity of around 7 GW, equivalent to almost the power of the Itaipu Power Plant (Brazilian part). When considering buildings and utilities, it is pointed out that they represent 62% of electrical efficiency gains, showing their importance in terms of public energy efficiency policies. The industrial sector contributes 31% to electrical efficiency gains.

Chart 9 - 3: **Sectoral contribution to electrical efficiency gains in 2031 (% of total gain)**



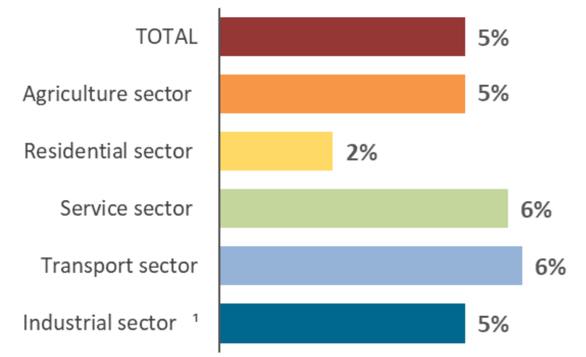
Notes: (1) Includes the energy sector.
(2) Comprises energy consumption in urban and rural residences.
(3) Includes utilities.

Additionally, with regard to the projection of energy efficiency gains in fuel consumption, it is estimated that they will reach around 14.5 million toe in the year 2031 (5.5% of fuel consumption in that year). This number, expressed in barrels of oil equivalent, corresponds to about 290,000 barrels per day, or approximately 10% of the oil produced in Brazil in 2020.

When evaluating the contribution of energy efficiency gains within the final consumption sectors, in turn, total energy efficiency gains (electricity and fuels) are totaled in the order of 5% in 2031, with the highest percentages observed in the sectors of transport and services (which encompasses commerce and the public sector) (**Chart 9 - 4**).

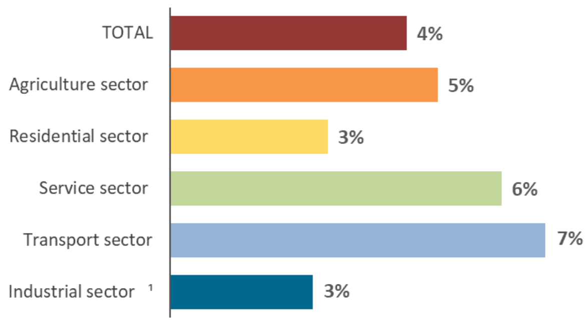
From the point of view of electrical efficiency, the service and transport sectors also stand out, the latter with amounts around 262 GWh in the year 2031 (**Chart 9 - 5**). Sector trends will be further explained in the following items.

Chart 9 - 4: Sectoral contribution for total energy efficiency gains (% in each sector)



Note: (1) Includes the energy sector.

Chart 9 - 5: Sectoral contribution for electrical efficiency gains (% in each sector)



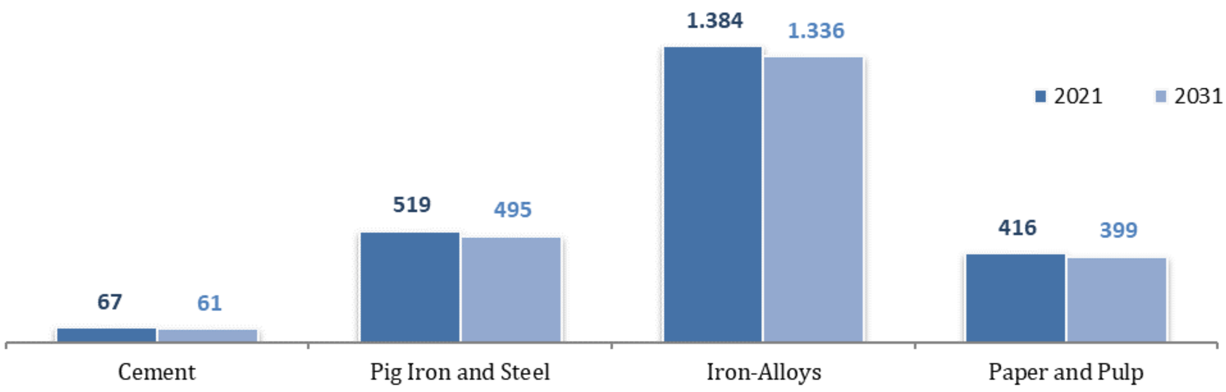
Note: (1) Includes the energy sector.

INDUSTRIAL SECTOR

On the horizon of the PDE 2031, it is estimated that energy efficiency gains in Brazilian industry[2] will allow savings of about 5% of its total energy consumption in 2031, which is equivalent to avoiding the consumption of approximately 7.6 million toe, comparable to the total consumption of petroleum products (which includes diesel, fuel oil, LPG and kerosene) for thermal use observed in the industry in 2020. In terms of electricity consumption, the estimate is that electrical efficiency gains will contribute to a reduction of 3% in 2031, or about 10 TWh, equivalent to the electrical consumption observed in the cement and ceramic industries added in 2020.

The contribution of energy efficiency includes a combination of existing policy mechanisms applicable to Brazilian industry, as well as autonomous actions by industries, linked to aspects such as retrofit of facilities, new industrial units, more modern and energy efficient (greenfield), and actions of energy use management, among others. The evolution of specific consumption in selected industrial segments is illustrated in **Chart 9 - 6**, with emphasis on the cement segment, which shows a reduction of 8% in this indicator.

Chart 9 - 6: Industrial sector: specific energy consumption (toe/10^3 t)



Source: Prepared by EPE.

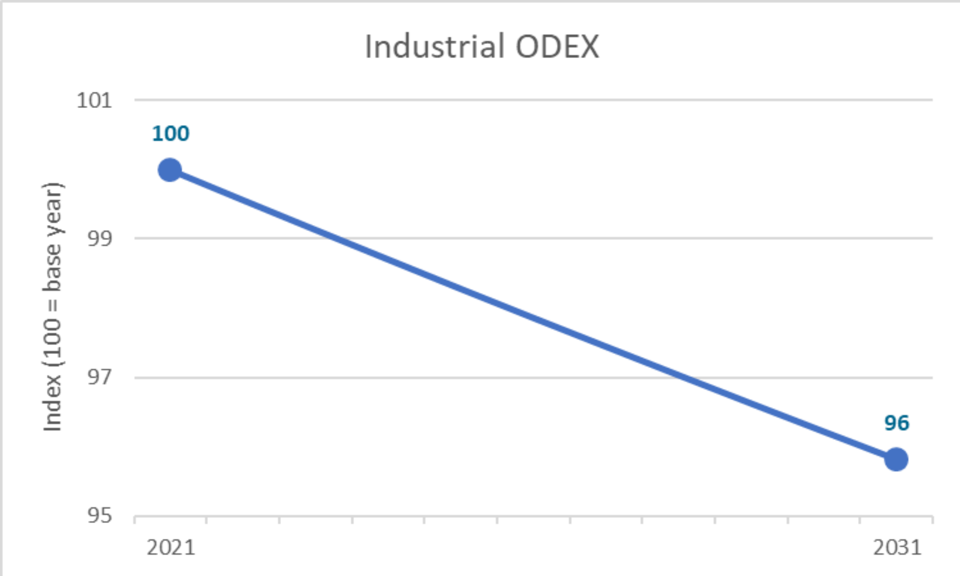
Energy efficiency can also be calculated using the ODEX methodology[3], used in the Energy Efficiency Atlas – Brazil 2020 (EPE, 2021). The calculation considers the annual variation of the

[2] Includes the energy sector.

[3] ODEX is an efficiency gains index that considers the variation of consumption indicators and weights in

specific consumption or energy intensity of each segment and weights the participation of each one in consumption. **Chart 9 - 7** presents the variation of industrial efficiency, which reaches about 4% of gains in 2031.

Chart 9 - 7: Industrial ODEX: energy efficiency indicator



Note: does not include energy sector

Box 9 - 2: Impact analysis of the PDEf proposal on the industrial sector

Within the scope of the National Electric Energy Conservation Program – PROCEL, implemented by Eletrobras, a study was contracted to prepare a proposal for a Ten-Year Energy Efficiency Plan – PDEf. The work was carried out by the consulting company iX - Estudos e Projetos, under the 2nd PROCEL Resource Application Plan (PAR PROCEL 2018).

For the industrial sector, the study evaluated existing policies and proposed new mechanisms. With the improvement of existing policies and the application of the new proposed mechanisms, it is estimated that the efficiency of the industrial sector could increase by around 1.8% p.p., equivalent to 3 million toe in 2031 (total energy) and 10 TWh (energy electric).

Efficiency in 2031 - Industry	PDE 2031	PDEf*	PDE + PDEf*
Electrical efficiency (TWh)	2.9%	2.5%	5.4%
Fuel efficiency (million toe)	5.5%	1.6%	7.1%
Total efficiency (million toe)	5.0%	1.8%	6.8%

Source: Prepared by EPE – estimated values

To calculate this estimate, the following adjustments were made to the potential calculation:

- Adequacy to the premises of PDE 2031;
- Inclusion of the energy sector;

relation to the weight in consumption, reducing the influence of the structure effect. A drop in the indicator over time indicates energy efficiency gains.

Box 9 - 2: Impact analysis of the PDEf proposal on the industrial sector

- Separation of gains from current programs into expected gains and proposed improvements – the first is already in the PDE scenario, the second enters as PDEf;
- Consideration of gains from the base year (2021), according to the PDE methodology.
- Consideration of accumulated energy savings, in line with the PDE;
- For minimum indices/PBE/Seal PROCEL, use of the EPE/Mitsidi estimate (adapted to PDE 2031), by equipment;
- For energy efficiency grids, calculation of the potential from the EPE/Mitsidi estimate, bottom-up (considers number of grids, number of companies per grid, size of companies, % savings per grid and average consumption);
- Consideration that the consumption reduction promoted by the PEE/ANEEL projects remains for 5 years;
- In the case of decentralized auctions, only electrical efficiency is considered.

The major gains in energy conservation are in the adoption of targets for energy intensive, holding centralized energy efficiency auctions and establishing obligations for non-energy intensive.

The following is a summary of the measures proposed in the work, considering the improvement of existing policies and the implementation of new policies and mechanisms to promote energy efficiency in the industrial sector:

- PROCEL Industry and Voluntary Agreements: Expansion of the Aliança Program, with expansion of the technical team and executing institutions and reduction of secrecy;
- Energy Efficiency Program for Electricity Distribution Concessionaires - PEE/ANEEL: Amendments to the Energy Efficiency Program Procedure (Propee), to encourage investments in the industrial sector and include energy management and regulatory changes;
- Labeling and minimum indices: evaluate inclusion in PBE and the definition of minimum energy efficiency indices for other representative equipment, such as industrial fans, hydraulic pumps, compressors and refrigerated counters; promote the certification of motor systems; and adopt standardization for measuring mechanical quantities;
- Energy efficiency auctions: structuring and implementation of centralized and decentralized auctions;
- Mandatory targets for energy intensive and white certificates: definition of conservation targets, establishment of the figure of the energy manager, development of an energy management system and issuance of white certificates;
- Obligations for non-energy intensive: establishment of the figure of energy managers and obligation to carry out energy diagnoses;
- Voluntary Agreements and Energy Efficiency Learning Networks: development of a new program, aimed at small and medium-sized companies;
- Information System: development of a public and updated energy efficiency information system in order to reduce information barriers.

It should be noted that the study carried out within the scope of PROCEL is of a propositional nature, and that the effective implementation of the proposed measures depends on evaluation and discussion by the competent public and private institutions.

PUBLIC BUILDINGS AND UTILITIES

Residential, commercial and public buildings in 2020 accounted for about 46% of electricity consumption and 15% of Brazil's total energy, which includes electricity and fuels. Adding the portions related to utilities (public lighting, water, sewage and sanitation), the aggregate will account for 51% of electricity and 16% of Brazil's total energy in 2020, according to data from the National Energy Balance (EPE, 2021).

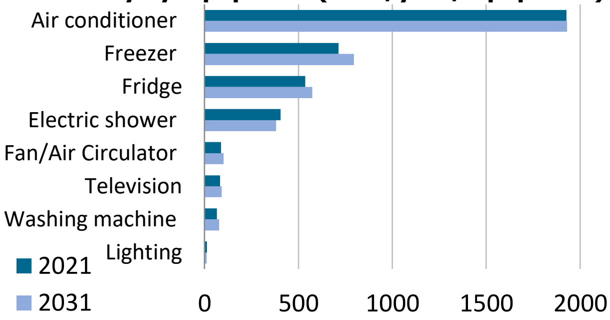
RESIDENTIAL

Electricity, LPG, natural gas, wood and charcoal are the main sources of energy used in Brazilian homes. Due to its predominance in residential sector, electricity could contribute greatly to energy efficiency gains between 2021 and 2031.

The most modern equipment purchased by the population over the period, which will integrate the national stock, will possibly exhibit greater efficiency than those already in use, due to regulation, policies to promote energy efficiency and market-induced technological development. Therefore, the introduction of new equipment, whether for the first purchase or replacement, and the scrapping of unused units or at the end of their useful life will be vectors for reducing the average residential electricity consumption.

On the other hand, upon the progress of families' income admitted as a premise in the adopted scenario, among other causes, it is expected that the equipment will be more used inside the residences over the years, that is, their habits of use are now repressed, mainly by poor families, may increase in terms of hours of use per day and the number of days in the year. For example, EPE calculations using data collected in the Survey of Possession and Habits of Use of Equipment - PPH 2019 (PROCEL/ELETROBRAS) estimate that, on average, washing machines were used on 110 days in 2019, which is approximately once every three weeks. Therefore, incorporating all these effects, the average residential electricity consumption of the main equipment used in Brazil's homes is shown in **Chart 9 - 8**.

Chart 9 - 8: Residential average consumption of electricity by equipment (KWh/year/equipment)



The penetration of more efficient devices can be the result of autonomous decisions by market players, resulting from the dynamics and competitiveness of the industry, as well as from the cost-benefit analysis carried out by consumers. Likewise, policies to induce energy efficiency in equipment implemented by the Federal Government, in partnership with all the stakeholders involved, can generate effects over time. These Federal Programs have been implemented in Brazil since 1984, with the creation of the Brazilian Labeling Program (PBE), coordinated by the National Institute of Metrology, Quality and Technology (INMETRO), which created comparative labels of the energy performance of equipment, providing education to consumers and stimulating the products' manufacture with a higher level of efficiency by the industry. According to INMETRO, PBE[4] currently has 38 programs that involve different types of products, from air conditioners and refrigerators to buildings and light vehicles. In partnership with PBE, the PROCEL (for electrical equipment) and CONPET (for products using fuels derived from oil and natural gas) seals were created in 1993 in order to value and reward the most energy-efficient devices.

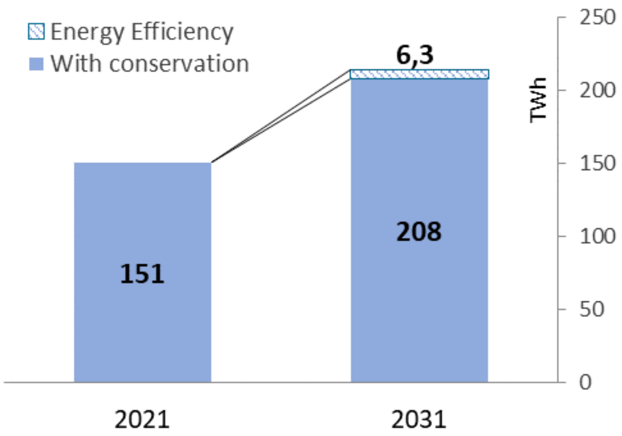
As of Law No. 10,295/2001, known as the Energy Efficiency Law, INMETRO, which voluntarily

[4] More information at: https://www2.inmetro.gov.br/pbe/pdf/folder_pbe.pdf

established labeling programs, began to compulsorily assess the energy efficiency of equipment manufactured or sold in Brazil. In 2007, for example, the Interministerial Ordinance MME/MCT/MDIC No. 364 was published, the first regulation of minimum energy efficiency rates for air conditioners, revised by the Interministerial Ordinance No. 323 in 2011 and by the Interministerial Ordinance No. 2 in 2018. With the publication of these regulations, conformity´s evaluation of the conditioners started to be done in a compulsory way by INMETRO. In 2020, through Inmetro Ordinance nº 234, the partial improvement of the conformity assessment requirements for air conditioners was carried out, with the establishment of a new performance index for this equipment and the reclassification of the energy efficiency categories. To accompany this movement, the Energy Efficiency Indicators and Levels Management Committee - CGIEE, implementer of the Energy Efficiency Law, is promoting the review of the minimum energy efficiency indexes defined by Interministerial Ordinance No. 2 in 2018 and new targets program is under public consultation. The same happened with refrigerators and freezers for residential use. With the publication of the Interministerial Ordinance MME/MCTI/MDIC No. 362, of 2007, later revised by the Interministerial Ordinances No. 326, of 2011, and No. 01, of 2018, the evaluation of the compliance of refrigerators regarding energy efficiency became compulsory. Recently, in 2021, through INMETRO Ordinance nº 332, the Institute promoted the partial improvement of the conformity assessment requirements of refrigerators, including the reclassification of energy efficiency categories. Also in this case, the CGIEE has already requested the preparation of regulatory impact assessment studies to promote the review of Interministerial Ordinance No. 1, of 2018, and establish new maximum energy consumption rates for refrigerators and freezers.

In this context, it is estimated that efficiency gains in the use of electricity in Brazilian homes could reach around 6.3 TWh in 2031, corresponding to 3% of total residential electricity consumption in the same year, as illustrated in **Chart 9 - 9**. It should be noted that implementation of more ambitious minimum indices over the ten-year horizon can accelerate the progress of these efficiency gains. In addition, additional stimuli associated with residences, such as recent revisions to building construction performance standards (ABNT NBR 15,220 - Thermal Performance of Buildings and ABNT NBR 15,575 - Housing Buildings - Performance) and building labeling policies, encouraged through the Brazilian Building Labeling Program (PBE Edifica) and by the PROCEL Edifica seal, can contribute to the reduction of residential energy demand.

Chart 9 - 9: Power consumption in homes (TWh)

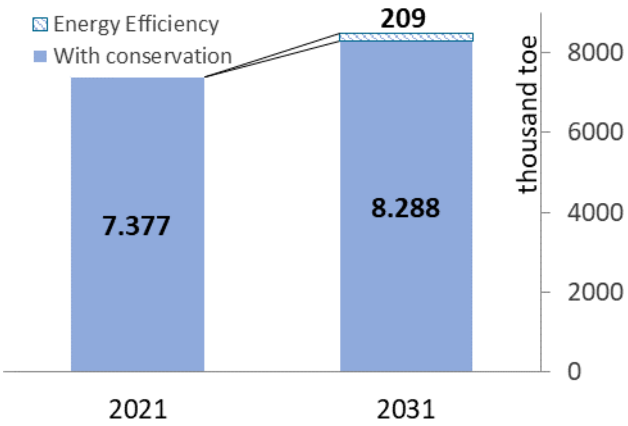


With regard to other energy sources used in residences, LPG and natural gas also have opportunities for energy efficiency gains within the PDE 2031 horizon, predominantly for cooking and heating water. In the first case, both a reduction in the specific consumption of ovens and stoves is expected due to the increase in the average efficiency of the burners (subject to compulsory labeling), as well as the replacement of inefficient sources (traditional biomass) by more modern ones (LPG and natural gas).

In the opposite direction, the progress of the economic conditions of the families in the ten-year horizon may increase the demand for foods that require a greater amount of energy in their preparation, such as meats, which will probably lead to an increase in consumption of fuels, offsetting the efficiency gains (intensity effect) of the cooking equipment.

With regard to water heating, in addition to the expansion of the use of natural gas to replace electric showers, especially in urban centers, the use of solar heating systems (SHS) is expected to advance by displacing electricity. The quality standards of collectors and reservoirs are already standardized by PBE. Therefore, it is estimated that efficiency gains in the use of LPG and natural gas in Brazilian homes could reach around 209 thousand toe in 2031, corresponding to 2.5% of residential consumption of these fuels in the same year (**Chart 9 - 10**).

Chart 9 - 10: Consumption of LPG and NG in homes (thousand toe)



Another important contribution to the systematization and planning of energy efficiency in homes in Brazil can come from the publication of the first Ten Year Energy Efficiency Plan (PDEf), whose objective is to be a strategic plan of long-term actions for the efficient use of energy in different areas of society. The initial studies for the PDEf, based on the energy savings presented in the Ten Year Energy Expansion Plan (PDE) 2029, were carried out with resources from the 2nd Resource Application Plan of the National Electric Energy Conservation Program - PROCEL (PAR PROCEL 2018), in accordance with the governance of the Program established by Law No. 13.280, of 2016, and have been available on the PROCEL/ELETROBRAS website[5] since the beginning of 2021. The results of this work resulted in eleven products that include analyzes and proposals to improve the efficiency mechanisms that already exist in Brazil today and recommendations for the creation of new programs, with transversal and sectorial actions in relevant national segments, such as Buildings, Industry, Public Power, Transport and Agribusiness. Among the next steps in the elaboration of the product, discussions with sector players, public consultation, review and consolidation of contributions received and formatting of the publication for later dissemination are planned.

[5] Available at: https://eletrobras.com/pt/Paginas/PlanoDecenalEficienciaEnergetica.aspx

COMMERCIAL AND PUBLIC

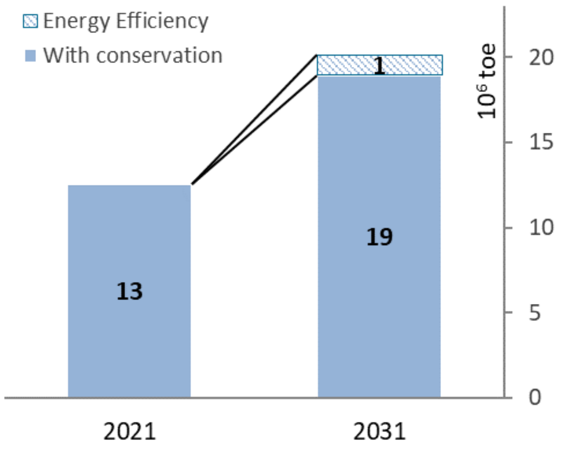
The service sector considers commercial and public buildings in addition to public lighting, water, sewage and sanitation services. The representativeness of this sector in relation to the final energy consumption of Brazil is 7%, according to data from BEN (EPE, 2021). However, restricting the analysis to electric energy alone, this representativeness passes to approximately a quarter (24%) of all electricity demanded in Brazil, configuring itself as a sector of significant relevance in the electricity consumption matrix.

This is because electricity is mostly used for the provision of energy services in the sector, such as lighting, motive power and refrigeration. Electricity concentrates more than 92% of the total energy consumed in this sector, followed by LPG with 5%, and a 1% share for each of the following fuels: natural gas, firewood and charcoal.

The projection of efficiency gains in the service sector, considering, in addition to electricity, other sources, was calculated at 6% of projected consumption in 2031, reducing final consumption by approximately 1.2 million toe that year, which is equivalent to approximately consumption to the ferroalloys segment in the year 2020 (EPE, 2021).

For the projections made, it was possible to estimate the electrical efficiency gains in the service sector based on the energy gains calculated in the last two editions of the Useful Energy Balance - BEU (base years: 1994 and 2004) and with the energy efficiency policies in force. In this PDE, a methodology was used that starts from the data collected by the survey of the service sector for the year 2015[6].

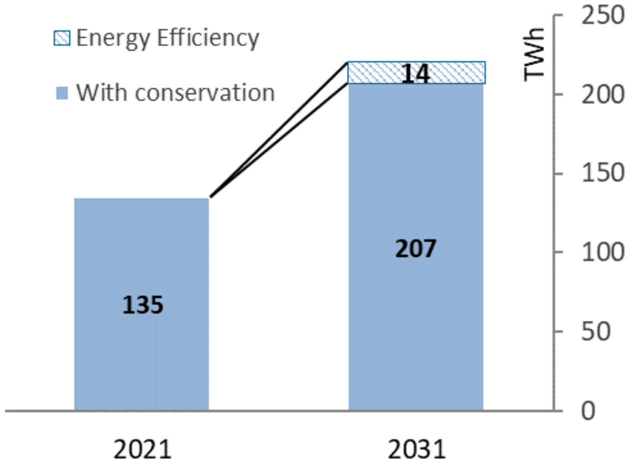
Chart 9 - 11: Service sector: energy consumption and efficiency gains



The electrical energy saved was calculated at 6% of the projected consumption in 2031, reducing final consumption by approximately 13.6 TWh in that year, which is equivalent to 11% of the electricity consumption of the service sector or the mining and pelletizing segment in the year of 2020 (EPE, 2021).

Chart 9 - 12: Service sector: electricity consumption and electrical efficiency

[6] These results refer to the Project Characterization of Energy Use in the Services Sector, at national level, according to Contract No. CT-EPE-012-2014, signed between EPE - Energy Research Company and Foco Opinião e Mercado, the resources come from of Loan Agreement No. 8,095-BR, formalized between the Federative Republic of Brazil and the International Bank for Reconstruction and Development – BIRD, on March 1, 2012. Products related to this project are available at: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/projeto-de-assistencia-tecnica-dos-setores-de-energia-e-mineral-projeto-meta



Box 9 - 3: Impact analysis of additional electrical efficiency measures in buildings

This Box evaluates the gains of the additional policies proposed in the study for the preparation of a proposal for a Ten-Year Energy Efficiency Plan – PDEf, carried out by the consulting firm iX - Estudos e Projetos, under the PROCEL/Eletrobras Program (2021). Product 3 of this work presents proposals for new transversal actions and the projections of electric energy savings for these policies. This Box analyzes the policies and measures proposed for the residential and service sectors. The following is a summary of the proposals of the Eletrobras study and the EPE's projection for adaptation to the period until 2031:

Table 9 - 2: Electricity Savings for the Residential and Service Sectors

Additional Transversal Policies and Mechanisms (TWh)								
Year	Residential Sector			Service Sector				
	Economics	LEE	EED	**Economics**	LEE	AV	MCB	EED
2029	**3.3**	2.0	1.3	**5.5**	3.4	0.8	0.8	0.5
2030	**3.7**	2.2	1.5	**6.1**	3.8	0.9	0.9	0.5
2031	**4.1**	2.5	1.6	**6.8**	4.2	1.0	1.0	0.6

Note: Estimated projections for the years 2030 and 2031, based on the projected 2019-2029 in the studies for the PDEf. For more information, go to: https://eletrobras.com/pt/Paginas/PlanoDecenalEficienciaEnergetica.aspx
LEE – Energy Efficiency Auction; EED - Digital Energy Efficiency; AV- Voluntary Agreement; MCB - White Certificate Market.

The proposals in the PROCEL/Eletrobras (2021) study for additional transversal policies for residential buildings and the service sector could add 10.8 TWh in 2031 in relation to the efficiency gains pointed out in the PDE 2031, in which they are considering gains from current policies, in addition to autonomous gains, totaling 30.8 TWh, as shown in the table below.

Table 9 - 3: Additional Electricity Gains in Buildings

Residential and Service Sector [1] in 2031	PDE 2031	PDEf Additional Policies	PDE 2031 + PDEf
Electrical efficiency (TWh)	19.9	10.8	30.8

Source: Prepared by EPE – preliminary values
Note: [1] The Services Sector includes public lighting and sanitation, according to the opening of BEN.

Box 9 - 3: Impact analysis of additional electrical efficiency measures in buildings

The policy of efficiency auctions, centralized and decentralized, pointed out by the PROCEL/Eletrobras study, presents initial gains in 2023. In 2031 this policy achieves an additional savings of 6.6 TWh, which represents 61% of the additional gains.

It should be noted that the proposals will still be evaluated and discussed before the preparation of the PDEf.

TRANSPORT SECTOR

Demand for transport services is expected to grow over the next decade, especially given the projected growth in the economy. The improvement in the economic scenario should promote an increase in per capita income and income distribution, which in turn increases consumption and personal mobility, which increase both the demand for freight and passenger transport. It is estimated an increase in cargo transport activity, between 2021 and 2031, of 3.4% per year, and in passenger transport activity of 5.4% per year. Although the demand for transport is growing considerably, energy demand for transport is projected to grow by only 2.5% per year.

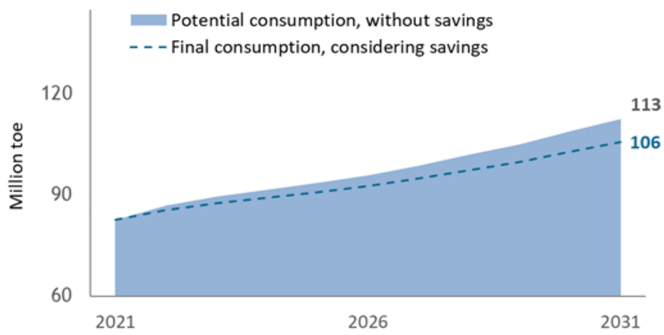
In this context, the importance of efficiency in the transport sector for Brazil's energy security is highlighted. Thus, with regard to energy efficiency, technological improvements in engines, the introduction of new technologies and cultural changes in the use of individual transport are considered, which affect the intensity of use and the level of occupation of vehicles. As an example of technological improvements, we can mention the implementation of micro airfoil in trucks, which reduce drag and energy consumption, in addition to aerodynamic improvements in aircraft. Individual efficiency gains are closely related to the investments in research and development made by the industry.

Furthermore, the transport sector has potential gains in systemic efficiency, such as the migration from the use of individual transport to collective transport, or the substitution of cargo handling by road for rail and waterway modes. While hybridizing an individual vehicle has the potential to increase the energy efficiency of this transport activity by 30% (IEA, 2021[7]), the migration from individual transport to metro-rail transport can reduce the energy intensity of this individual journey by 80%.

[7] Available at: https://www.iea.org/reports/fuel-economy-in-major-car-markets#country-database

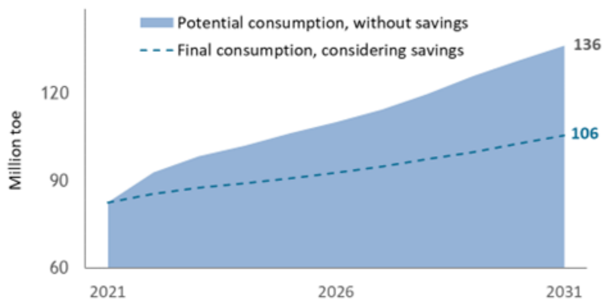
To estimate the impact of new technologies, such as improvements in new equipment and vehicles, a methodology is applied that considers the previously projected efficiency gain of each transport mode to be null for the analysis horizon. Keeping the efficiency of new equipment over the ten-year period at the same value as expected in 2021, it is projected that the energy demand of transport should rise from 83 million toe in 2021 to 113 million toe in 2031, a value 7% higher than the energy demand previously projected with conservation (106 million toe), according to **Chart 9 - 13**.

Chart 9 - 13: Consumption in the transport sector with and without individual efficiency gains



In order to estimate the systemic efficiency gains, the energy intensity of the cargo and passenger segments was set at a value equal to the value obtained in the year 2021, without changing the activity of the segments. This calculation seeks to approximate energy costs in a scenario in which the transport matrix maintains the shares of each of its modes. The energy demand in this scenario reaches 136 million toe in 2031, a value 29% higher than previously obtained, according to **Chart 9 - 14**.

Chart 9 - 14: Consumption in the transport sector with and without systemic efficiency gains



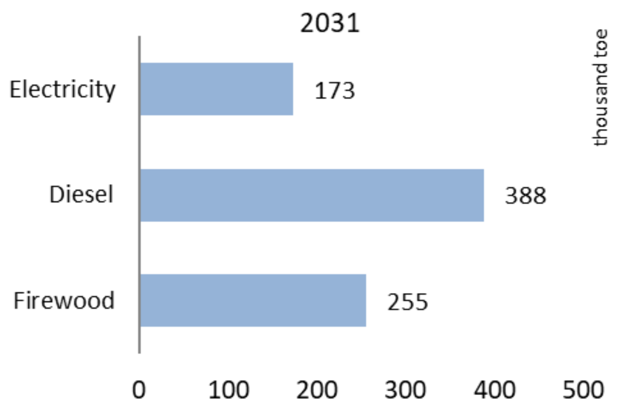
It is worth considering that there are other ways to make the transport sector even more efficient. Increased investments in roads and paving reduce tire wear and the energy intensity of trucks. A better organization of ports and investments in port infrastructure tend to reduce the time of loading and unloading of vessels, reducing the interval in which fuel is consumed without production of transport activity. Investments in intermodal terminals also reduce the intensity of the system as a whole, allowing an acceleration of the transfer to less energy-intensive modes, such as rail and waterway, more suitable for long distances, to the detriment of road, suitable for short distances.

The aspects mentioned above were considered in the reference scenario of the PDE 2031. It is noteworthy, however, that greater investments in infrastructure, combined with government programs that promote the scrapping of old fleets, can be added to policies to stimulate the efficiency of new equipment. Together, these Federal Programs have the potential to further reduce the energy demand of the transport sector, avoiding part of the increase in energy demand arising from the increase in demand for transport activity. This allows the mitigation of emissions of atmospheric pollutants and the reduction of costs, which can bring other benefits, since the various sectors of the national economy depend on transport to some extent.

FARMING SECTOR

While efficiency gains are concentrated in the most relevant energy sources (diesel, firewood and electricity) and result in 5.1% or 819 thousand toe of energy savings in 2031, the evolution of demand in the agricultural sector varies little over the horizon of PDE 2031, with an average growth of 1.4%.

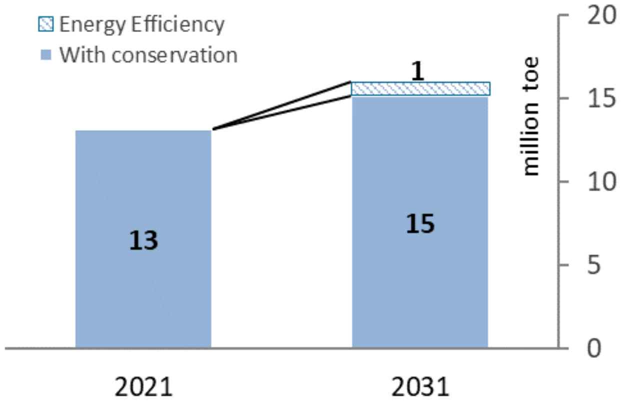
Chart 9 - 15: **Farming sector: Efficiency gains per source in 2031 (thousand toe)**



Note: LPG and Charcoal with 1 ktoe each.

Among them, the greatest potential is associated with firewood; however, the largest share of the contribution of energy efficiency in absolute terms is associated with diesel and the efficiency of internal combustion engines. In sequence, come the gains related to the use of electric motors in machines and equipment and of pumping systems for more efficient irrigation, increasing the conservation of electricity (**Chart 9 - 16**).

Chart 9 - 16: Farming sector: Total energy consumption and energy efficiency



9.3 Distributed Micro and Mini-generation

The Distributed Micro and Mini Generation (MMGD) modality surprises with its numbers every year. In 2020, for the first time, distributed photovoltaic technology led the addition of installed capacity for the year, with 2.5 GW installed, surpassing the numbers of all other technologies, including centralized generation. In 2021, the MMGD modality continues to develop at a strong pace, having surpassed the 6 GW mark in the first half of the year.

The quality of national energy resources, high final electricity tariffs and an extremely favorable net metering scheme have made investing in own generation very profitable in Brazil. This has led not only residential consumers, but also rural producers, retail chains, banks and industries to invest in MMGD systems either locally or remotely.

The large volume of recent installations triggered an alert regarding the sustainability of maintaining the current rules defined in Normative Resolution ANEEL REN nº 482, of 2012, which regulates MMGD in Brazil. Distributors have fixed and variable costs built into their tariff, and the distributed generator, by reducing its bill, stops contributing both installments, although it does not reduce both costs, as it continues to use the grid. Therefore, fixed costs are passed on to other consumers of the National Interconnected System, through tariff increases. Therefore, the full compensation model, together with the use of monomial tariffs, as envisaged in its creation, would stimulate development and, therefore, should undergo a review process.

An international analysis shows that this review of MMGD regulations is taking place in several countries, not just Brazil. Several countries have reduced or eliminated the premium rates paid to generators for energy fed into the grid (e.g. Germany, Australia, Japan and the United Kingdom). Other countries have increased the fixed rate part (Nevada – USA), implemented an annual fee for generators (Belgium) or started charging a dynamic rate to consumers with DG (California – USA). Additionally, it should be noted that such regulatory changes are being practiced internationally not only with a focus on distributed generation, but within a broader context of modernization of the electricity sector, which seeks to allow the insertion of other distributed energy resources (batteries, demand response and electric vehicles, for example) efficiently (Castro and Dantas, 2018).

The energy compensation mechanism in Brazil was being reviewed by ANEEL in 2019. However, with the heated debate on the topic, the main agenda was interrupted and the definition of the rules for MMGD in Brazil was transferred to the Legislative Power.

In view of this scenario, at the end of 2020, the National Energy Policy Council (CNPE) presented the following guidelines for the formulation and implementation of public policies aimed at Distributed Micro and Mini Generation in Brazil:

I. Non-discriminatory access to distribution networks;
II. Legal and regulatory security, with deadlines for maintaining the incentives of current consumers who have MMGD;
III. Allocation of network usage costs and charges, considering the benefits of MMGD;
IV. Transparency and predictability in the processes of elaboration, implementation and monitoring of public policy;
V. Gradual transition of rules.

Based on the CNPE guidelines, in August 2021, the House of Representatives almost unanimously approved the replacement of the Bill (PL) 5829/2019 that creates the Legal Framework for Distributed Micro and Mini-generation. After passing through the Senate and presidency sanction, the PL became Law n. 14,300, of January 6, 2022, and practically maintained the wording of the PL previously approved in the Chamber. This PDE considers the changes brought by Law n. 14,300 from 2022 in their MMGD projections.

Changes brought by Law no. 14,300 of 2022

In addition to providing more legal certainty to investors, the Law brought a series of changes to the Electric Energy Compensation Model established by REN 482/2012. Among the changes, the following stand out:

- The photovoltaic (PV) mini DG limit is reduced from 5 MW to 3 MW. For dispatchable sources, the limit of 5 MW remains;
- The concept of dispatchable sources is established, including hydroelectric sources, biomass, cogeneration and PV + batteries (the latter configuration still limited to 3 MW);
- Microgrids and the possibility of contracting ancillary services from MMGD are defined, although there is a need for future regulation;
- New rules for charging the availability cost are established. In practice, there will be a reduction in this charge for old and new generators;
- Defined new forms of civil association allowed in community generation models, which will facilitate the implementation of this type of generation;
- Creates the Social Renewable Energy Program, which provides for contracting MMGD with resources from the Energy Efficiency Program (PEE) to serve low-income consumers, although there are no goals and the implementation plan should be established by the distributors;
- Establishes that mini DG projects above 500 kW (with the exception of shared or multiple consumer DG projects) must pay a guarantee of faithful compliance (from 2.5 to 5.0% of CAPEX) for implementation;
- GD is now considered an involuntary contractual exposure by the distributors;
- Finally, it establishes new rules for the compensation of energy injected into the grid, which will be detailed below.

New compensation rules

It is important to emphasize that for existing generators and those that file a request for access within 12 months after publication of the Law, the compensation rules for all tariff components (current rule) continue to apply until 2045. Additionally, it should be noted that the change affects only the portion of energy injected into the grid. The portion generated and consumed instantly has the same effect as a reduction in consumption and, therefore, continues to save all tariff components.

For new generators that file the request after the 12th month, the rules presented in **Table 9 - 4**. Considering the publication of the Law in early 2022, the new rules come into force, therefore, from 2023.

Table 9 - 4: Compensation rules for generation injected into the grid by MMGD - Law n. 14,300 of 2022

	2023 to 2028[1]		From 2029	
	General Rule	**Mini GD > 500 kW[2]**	**General Rule**	**Mini GD > 500 kW[2]**
Dist. TUSD	Gradual charging from 15% to 90%	100%	Charging of 100% of these costs, discounting GD benefits. The benefits will be calculated by ANEEL within 18 months from the publication of the Law, following CNPE guidelines and contributions from society.	
Transmission TUSD	-	40%		
R&D, PEE and TFSEE charges	-	100%		
Other Duties	-	-		
Losses TUSD	-	-		
Other TE	-	-		
Energy TE	-	-	-	-
Type Collection Demand Group A[3]	TUSDg	TUSDg	TUSDg	TUSDg

Notes: (1) For units that file a request for access at the distributor between the 13th and 18th month from the date of publication of the Law, the transition period runs until 2031. As it is a rule valid for only six months, this condition was not detailed. (2) Generators above 500 kW from non-dispatchable sources and remote self-consumption or shared with a holder with more than 25% of the injection share. (3) Indicates what type of demand tariff is applied to group A consumers. TUSDd (demand) is currently charged.

Law no. 14,300 of 2022 sheds light on the likely regulatory scenario for MMGD. However, there are still uncertainties related to the remuneration of energy injected into the grid from 2029 onwards, resulting from the calculation of MMGD benefits for the electricity sector. This definition must occur within 18 months from the publication of the Law.

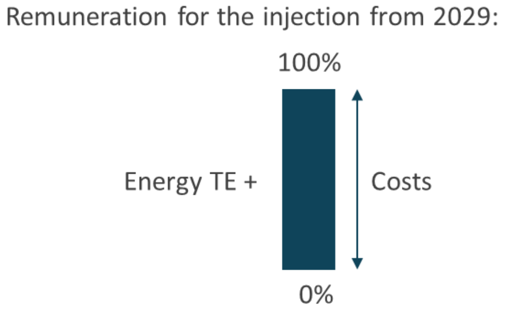
Even affecting remuneration only from 2029 onwards, its definition should influence investments over the decade as it affects the cash flow of these ventures.

Given the uncertainty related to the amount of benefits that will be calculated for the MMGD, some scenarios were modeled by varying this factor.

The Reference Scenario for the expansion of MMGD in the PDE 2031 only considers the charge of 100% TUSD Distribution as of 2029. This implies that about 50% of the costs (Charges, Transmission, Losses and Others) will be deducted through the benefits.

In the alternative scenarios, different remunerations for the energy injected into the grid are simulated. From TE Energy + 0% of costs, which would be the lowest remuneration, to TE Energy + 100% of costs, which would mean the original compensation of 1 to 1.

Figure 9 - 1: Illustration of the sensitivities evaluated in the PDE 2031 for the compensation of MMGD from 2029



The 4MD model was used to make the MMGD projections in the PDE 2031. It is a Bass model developed by EPE in 2015 and which has been improved and expanded to include more consumer sectors, sources and regulatory scenarios. More details on 4MD can be found in the methodological note published with the Plan[8].

Despite the variety of simulated scenarios, it should be noted that other factors may affect the projections. The review of the low voltage tariff model, for example, can define a multipart tariff for this group of consumers (involving not only the energy component), affecting the competitiveness of MMGD. Currently, this topic is on ANEEL's regulatory agenda and is also part of Bill 414/21 (formerly PLS 232), but its application is uncertain. The Social Renewable Energy Program, on the other hand, can bring new investments in MMGD to serve low-income consumers. However, the interest of the distributors in the Program and the scale to be developed is not clear. In this sense, in this PDE, the effects of these two factors on the diffusion of MMGD were not simulated. Additionally, other trajectories of tariff readjustments, evolution of per capita income, equipment costs, for example, were not explored in the scenario analysis.

Results

Table 9 - 5 summarizes the main results for the modeled scenarios. **Chart 9 - 17** illustrates the evolution of installed capacity for each scenario and then a detail of the Reference scenario is presented.

Table 9 - 5: Summary of projection results for the MMGD

Scenarios	Adopters (2031) Million	Installed Capacity (2031) GW	Generation (2031) GWavg	Investments (2022 to 2031) BRL billion
TE + 100% C	5.0	47.0	10.6	168
TE + 60% C	4.3	39.0	8.2	129
Reference	4.2	37.2	7.2	122
TE + 40% C	4.0	34.7	6.9	109
TE + 20% C	3.6	30.5	5.6	88
TE + 10% C	3.4	28.7	5.2	80
TE + 0% C	3.2	27	4.8	73

[8] https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-607/topico-593/NT_Metodologia_4MD_PDE_2031.pdf

Chart 9 - 17: Installed Capacity per Scenarios

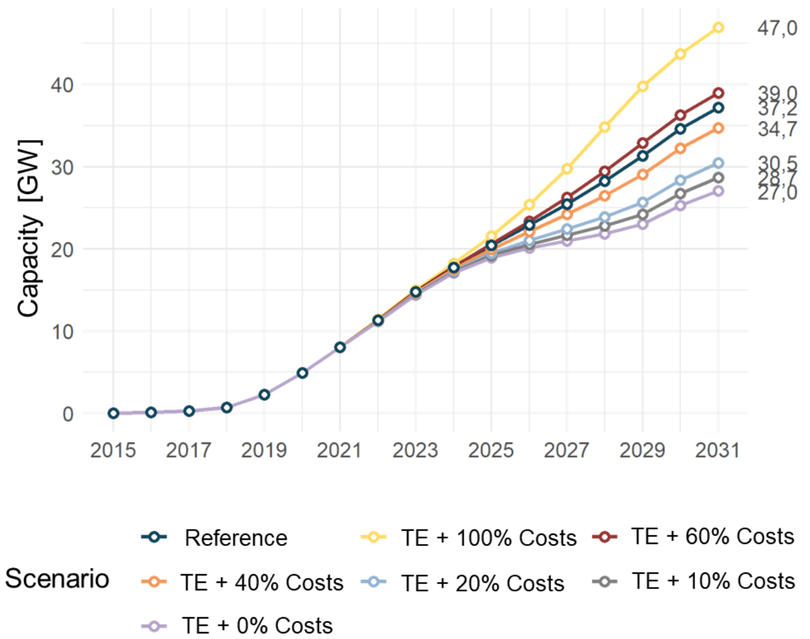


Chart 9 - 18: **Distribution of installed capacity in the Reference Scenario per source in 2031**

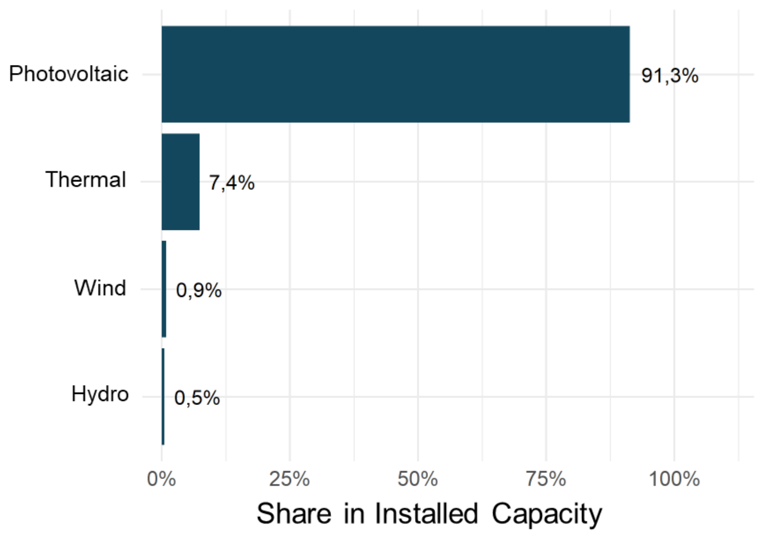
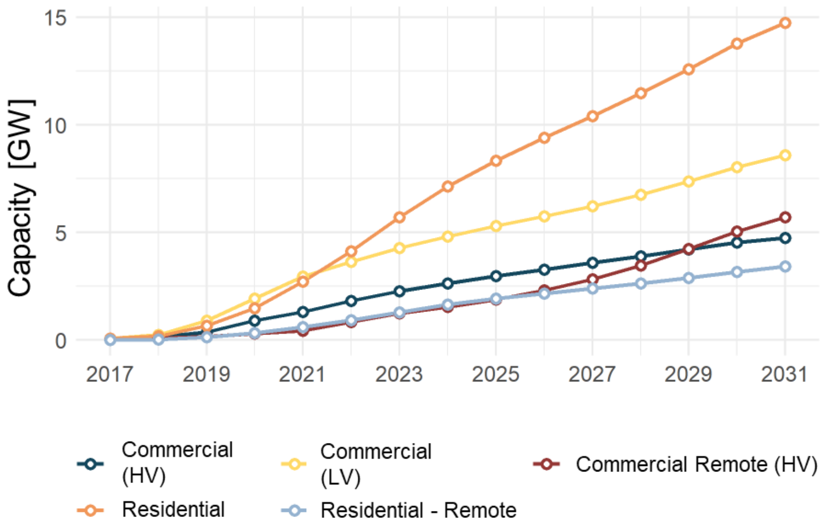


Chart 9 - 19: Distribution of installed capacity in the Reference Scenario per segment in 2031

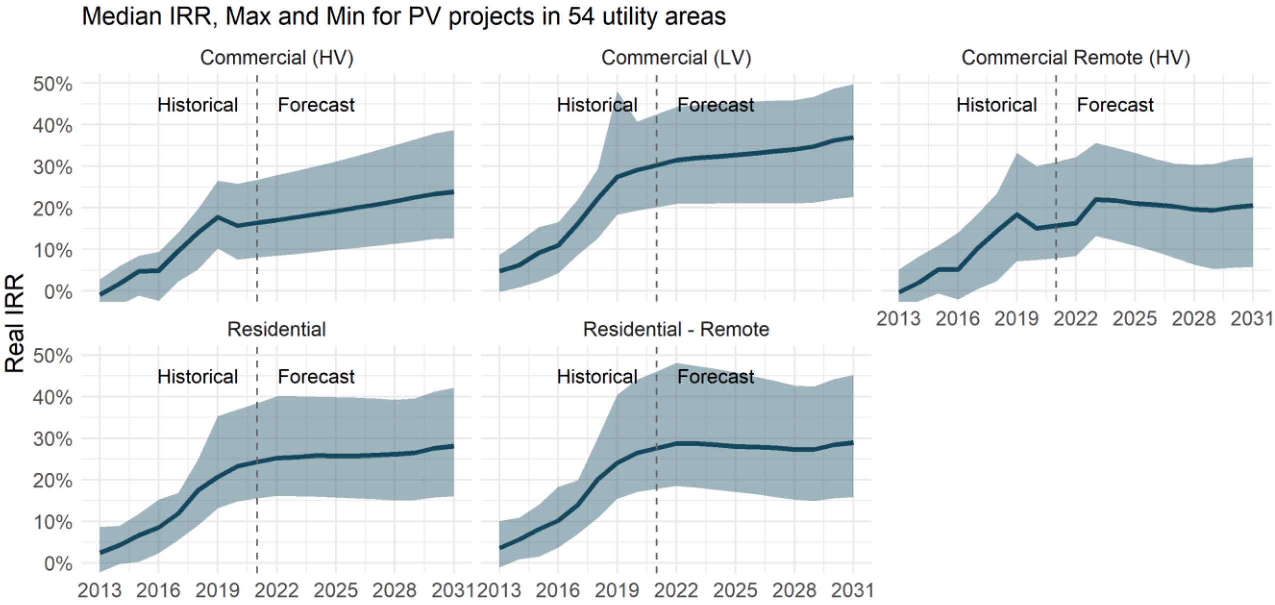


As shown by **Chart 9 - 19**, the scenarios constructed present a wide range for the result of installed capacity in 2031, which can vary from 27 GW (lower scenario) to 47 GW (upper scenario). This shows how the calculation of benefits can influence the development of the MMGD market in Brazil. In any case, it is worth mentioning that even in the lower scenario, which only provides for the compensation of TE Energy, the MMGD modality continues to grow vigorously in Brazil. In this scenario, the installed capacity would multiply by 5 between 2020 and 2031.

The Reference scenario, adopted in this edition of the PDE as a reference, is a moderate scenario, among the simulated alternatives. In this scenario, due to the payment for the use of the distribution network (TUSD Dist.), there is an initial reduction in the internal rates of return on investments. However, as shown in **Chart 9 - 20**, due to the reduction in technology costs over the decade, it is estimated that IRRs will return and exceed the levels of 2021.

In the case of the Commercial Remote High Voltage/Low Voltage (HV/LV) segment, additionally, there is the potential to explore other sources, in addition to photovoltaic. As shown in Box 9.3, other technologies may have lower costs than photovoltaic, gaining space in this market segment.

Chart 9 - 20: IRR history and projection for different PV MMGD typologies in the Reference scenario



Notes: (i) Analysis considers direct sales model with 100% equity; (ii) amounts for new investments made each year.

Box 9 - 4: Remote Mini GD: Opportunities in other technologies

Looking at the history of remote distributed mini generation projects, there is a predominance of photovoltaic technology. The year 2020 ended with about 80% of the accumulated installed power coming from this technology. The remainder is mainly divided between hydroelectric and biomass projects.

However, in order to reduce information asymmetry, EPE carried out a study that demonstrates that there are attractive investment opportunities through other technologies, in addition to photovoltaic. In addition to biogas, CGH and wind, which already have a history of development in DG, projects were also simulated to use process heat in cement plants (estimated potential of 366 MW (Pinto, 2018)) and pyrolysis gases emitted in the process of charcoal production (estimated potential at 644 MW (Leme et al., 2018).

The analysis considered projects installed in a new A4 consumer unit, paying for the contracted demand, and offsetting the credits in B3 commercial units. Conservatively, it was considered the investment with 100% equity. For all technologies, a construction time of 12 months was considered. Wind projects, coal gas and cement plant heat projects were simulated only in some FUs, depending on whether or not there is technical potential for the application. The rules of REN 482 in force in 2020 were considered. The other simulation parameters can be found in **Table 9 - 6**.

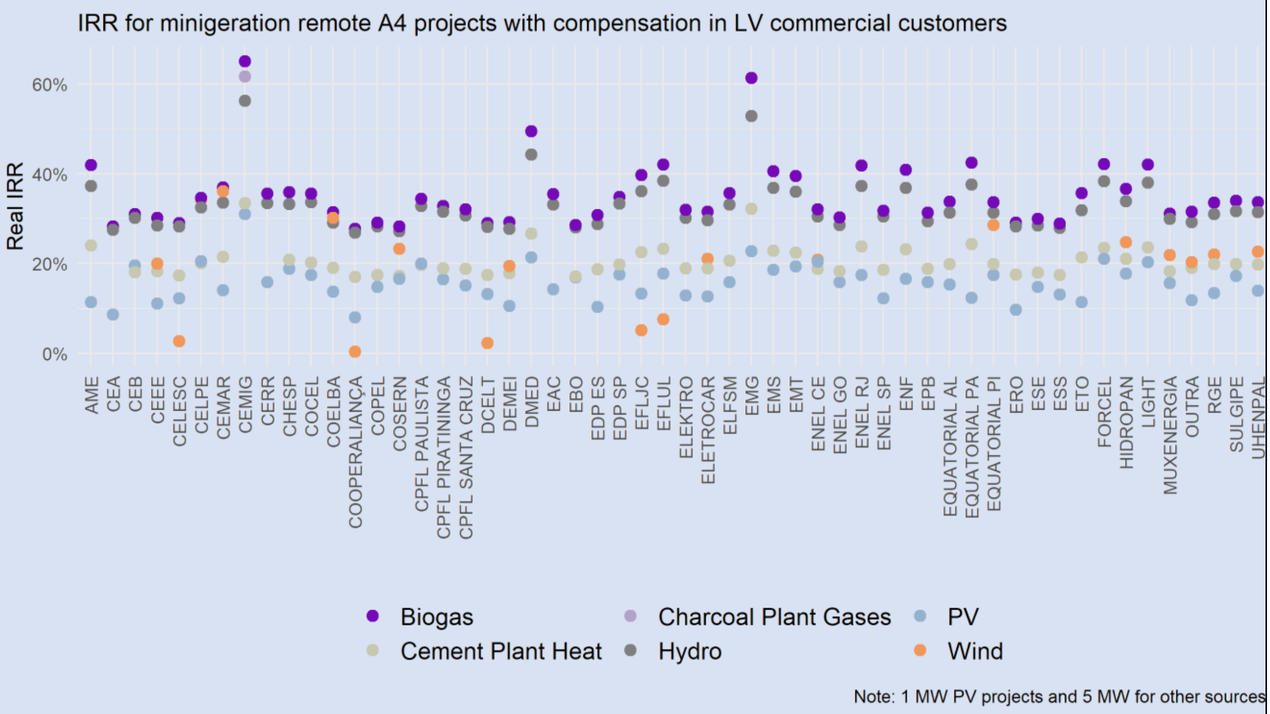
Table 9 - 6: Summary of calculation parameters for the TEQ of the remote mini GD

Main parameters	Unit	Photovoltaic	Biogas	CGH	Wind	Charcoal plant gases	Cement plant heat
Capacity factor (FC)	%	18-24% (ca)	65%	49%	17-49%	90%	87.5%
Initial investment	BRL/kW	4610	8000	7500	6900	12500	21500

Box 9 - 4: Remote Mini GD: Opportunities in other technologies

Grid boosting cost	BRL/kW	200	200	200	200	200	200
Fixed O&M	BRL/kW/year	94	700	90	110	625	364
Service life	years	25	15	30	20	20	30

Chart 9 - 21: TIR for Remote Mini GD projects



As shown in **Chart 9 - 21**, the photovoltaic source has, in general, the lowest IRR among the simulated technologies. On the other hand, it is understood that other factors, in addition to economic viability, direct the interest of entrepreneurs towards solar energy, such as: (a) a more geographically uniform solar resource, which allows the development of projects in different locations, which can be adapted to the existing distribution infrastructure; (b) greater modularity of the technology, which facilitates scaling for each client; (c) greater capillarity of integration companies and equipment suppliers; (d) low need for operation and maintenance compared to other sources, which facilitates remote operation. In any case, the analysis shows that there are opportunities in exploring other technologies via remote compensation.

9.4 Storage Behind the Meter

Electricity storage can be applied to different links in the electricity sector. In Brazil, for use in consumer units, behind the meter, the use of batteries is still little used due to their high cost and the few possibilities of application with financial return. As a reference, a residential or commercial lithium-ion battery system cost in 2021, on average, approximately BRL4,000/kWh. However, given the expectations of technology cost reduction, the EPE sought to assess the prospects for its entry into the horizon in this PDE.

Given the current regulatory framework and its perspectives, three main use possibilities for batteries in consumer units can be seen in the ten-year horizon, which will be discussed in more detail below:

i. Increased self-consumption of distributed microgeneration;
ii. Displacement of consumption with White Rate;
iii. Displacement of consumption with Tariff A4.

Additionally, two forms of supplementary revenue for the use of batteries were evaluated in this PDE to assess the impact on the financial viability of the investment:

iv. Valuation of the cost of the deficit (when providing backup in times of blackout);
v. Sale of carbon credits with the replacement of diesel generation at peak hours.

Table 9 - 7: Possibilities of using batteries behind the meter (in blue) and models simulated by EPE

	BT tariff Conventional	BT tariff White	A4 tariff (Green or Blue)
Backup and quality	✓	✓ Assessed in PDE	✓
Reduction in demand peak			✓
Consumption displacement		✓ Assessed in PDE	✓ Assessed in PDE
MMGD self-consumption increase	✓ Assessed in PDE	✓	✓

SIMULATIONS

EPE simulated the attractiveness of the investment using real consumption data from 15 consumers. The hourly data referring to 2019 consumption were provided by the company Sun Mobi through an agreement with the EPE[9]. The data were processed and normalized so that all consumers had an annual consumption of 10,000 kWh. Thus, the object of interest is the difference in the consumption profile between consumers and not its absolute value. The simulation of the hourly operation of the systems and the financial analysis of each project were performed using the System Advisor Model (SAM) software. In all simulations, an annual real discount rate of 6% was used. More simulation details can be found in **Table 9 - 8**.

[9] See more at: https://www.portalsolar.com.br/blog-solar/energia-solar/epe-faz-acordo-com-startup-sun-mobi-para-acesso-a-dados-de-consumo-de-energia.html

Table 9 - 8: Battery simulation assumptions

Assumptions	Value
Technology	Lithium Ion (LFP)
Cycle efficiency	89%
Service life	10 years
Degradation	Linear (60% with 4,000 cycles)
Depth of Discharge (DoD)	90%
OPEX	0.5% of CAPEX per year
CAPEX	500 to 4,000 BRL/kWh

Application I: Increased self-consumption of distributed microgeneration

Currently, the model of full compensation of energy injected into the grid (REN 482/2012) offers practically no incentives for investing in batteries to increase own consumption. However, as discussed in the micro and mini distributed generation (MMGD) chapter, there are prospects of changing the energy compensation model that would create a difference between the consumption tariff and the energy injection tariff. That is, there would be greater attractiveness for those who immediately consume the generated energy, instead of injecting it into the grid. Therefore, the batteries would have the role of storing part of the generated energy that would be injected for later consumption.

In practice, variations in generation and consumption make it difficult to optimize battery usage. At times, there is a lot of generation and little consumption, charging the battery completely and having to export part of the generation to the grid. If the battery capacity is increased, the cost of the system increases, and in many cases the capacity is underutilized. For this reason, sizing is not trivial. The EPE simulated different configurations of battery power and energy capacity and presents the results for the configuration with the best average attractiveness: 4 kW/ 8 kWh.

Additionally, it should be noted that Law no. 14,300 of 2022 provides for a gradual transition from alternative 0 to 1 by 2029. After 2029 the compensation format is not defined. In any case, this indicates that a more severe compensation alternative (which would benefit the use of batteries) is still a long way off.

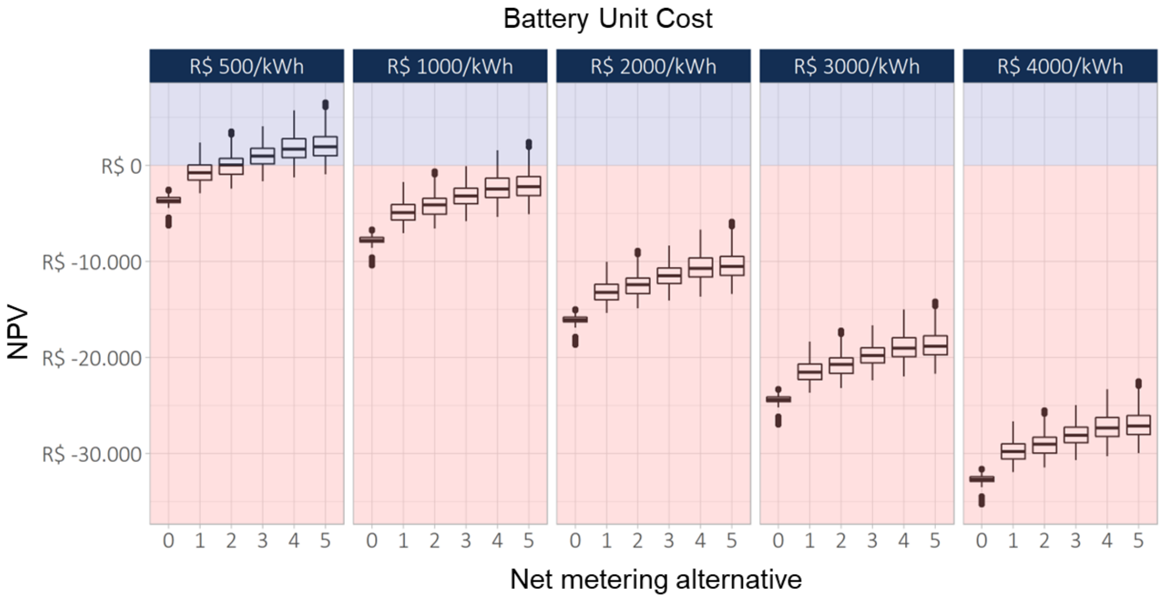
Regarding irradiation and temperature data, information from the MERRA-2 database was used for 35 representative cities around Brazil, one for each evaluated distributor. The results are presented below.

Table 9 - 9: Tariff components offset in each alternative and the corresponding value, in relation to the full tariff (Tariff B1)

	TUSD Distrib.	TUSD. Transm.	TUSD Duties	TUSD Losses	TE Duties	TE Energy	% of Full Tariff
Alternative 0							85%
Alternative 1							62%
Alternative 2							56%
Alternative 3							48%
Alternative 4							42%
Alternative 5							41%

Note: despite the compensation of all components in Alternative 0, the amount is not 100% due to the payment of ICMS on the TUSD installments.

Chart 9 - 22: **NPV of investment in batteries to increase self-consumption of micro DG for different distributors and customers**



As expected, with lower compensation rates, the greater the attractiveness of investing in batteries. However, only at prices in the range of BRL 500/kWh that the investment would have a positive return. Currently, the price is in the range of BRL 4,000/kWh and, based on the literature (Schmidt et al., 2019), a price reduction of 8.3% p.a. is expected, which would bring the price to close to R $1,700/kWh in 2031. Therefore, it would still be above what is necessary for viability. If the multipart tariff is applied, this feasibility would be more distant.

Application II: Displacement of consumption with White Rate

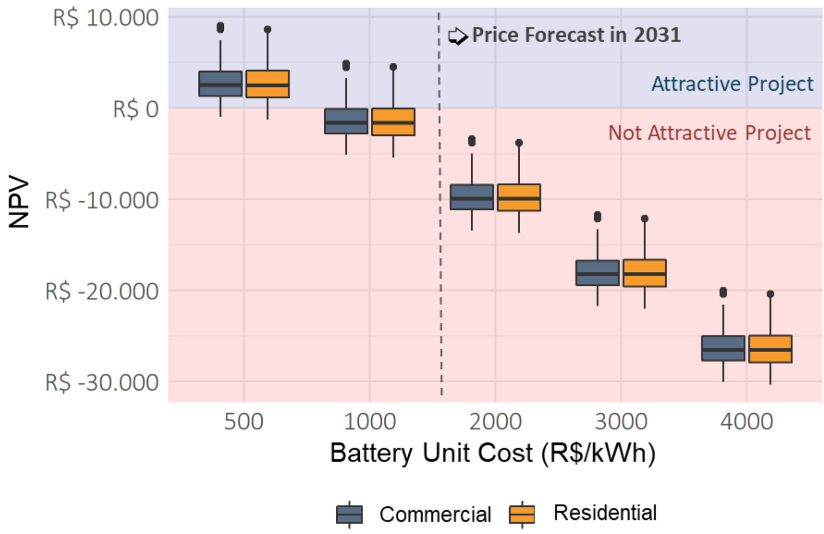
Currently, the White Tariff (TB) modality is a Time-of-Use tariff optional for low-voltage consumers in Brazil.. The peak tariff station consists of three consecutive hours defined by each distributor, with the exception of Saturdays, Sundays and holidays; the intermediate tariff post consists of the hours adjacent to the peak period; and the off-peak tariff station are the other hours.

For this application, the battery could be charged during the Off Peak (FP) period and provide energy to the consumer during the higher tariff periods – Intermediate Tariff (TI) and Peak Tariff (TP). It is necessary to assess whether the savings obtained are sufficient to pay for the investment in the battery system.

For the consumers evaluated, it was concluded that the 2 kW/8 kWh storage configuration results in the best average financial return. This configuration was used in the simulation of the 15 consumers, in all distributors in Brazil. The NPV results for each simulation are presented in **Chart 9 - 23**.

It can be seen that the Net Present Value - NPV for prices close to the current ones (BRL 4,000/kWh) is quite negative in all cases. Considering a projected price reduction of 8.3% p.y. (Schmidt et al., 2019), the battery price would drop to around BRL1,700/kWh in 2031. Therefore, it would still not be enough to make the investment attractive. Only with a price in the range of BRL 500-1,000/kWh would the investment bring a positive return.

Chart 9 - 23: Distribution of the NPV of the investment in batteries with white tariff for different distributors and customers



Application II with valuation of the deficit cost.

An additional benefit of investing in behind the meter batteries is the possibility of using them in times of blackout. The number of supply interruptions and the duration of blackouts have been falling, on average, in recent years in Brazil. However, incidents of this nature still harm the way of life of consumers and the activities of firms.

To quantify the backup benefit, the average indices of Equivalent Interruption Duration per Consumer Unit (DEC) per distributor were collected. This duration, in hours, was multiplied by the average load of consumers, thus obtaining an amount of unattended load in the year (in MWh). The value that each consumer attributes to the energy deficit varies from consumer to consumer. Thus, a sensitivity analysis was carried out with a range of values, based on the study by FGV CERI (2018).

The results presented in **Chart 9 - 25** show that, when considering the benefit of reducing blackouts, there is an improvement in attractiveness. However, even considering a deficit cost of BRL 20,000/MWh, viability is not reached for batteries priced above BRL 2,000/kWh. It is concluded that this additional benefit of batteries does not prove to be a decisive factor for the financial viability of the projects.

Chart 9 - 24: **Equivalent Interruption Duration per Consumer Unit (DEC) average per distributor**

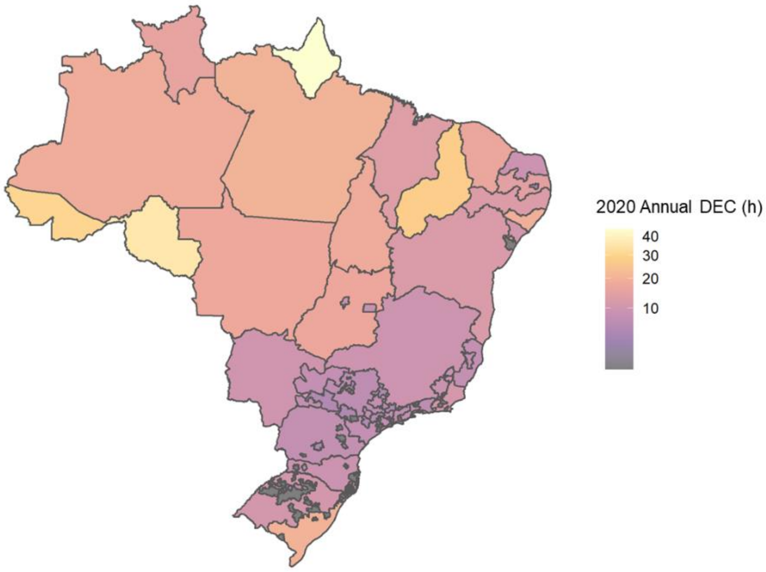
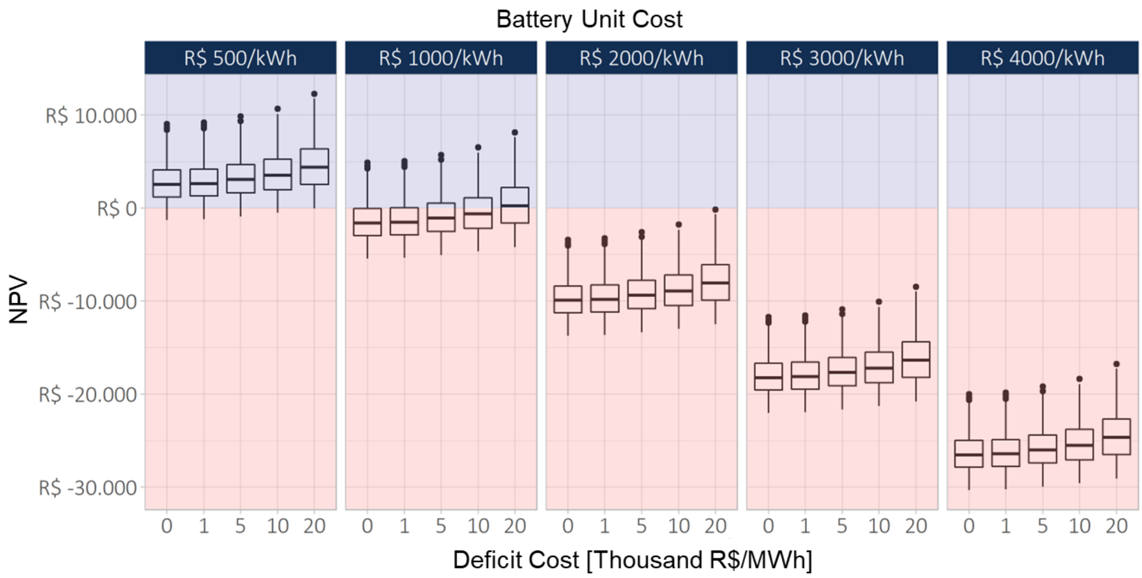


Chart 9 - 25: NPV of investment in batteries for consumption management with White Tariff according to the final price of the battery and cost of the consumers' deficit. Analysis for different distributors



Application III: Displacement of consumption in High Voltage

Since 1988, there has been a mandatory Time-of-Use tariff in Brazil for consumers served at high voltage (AT). To avoid high tariffs during peak hours (for 3 hours on weekdays), several commercial and industrial consumers make use of diesel motor generators during this period. According to an analysis by EPE (2015), there may be around 9 GW of generators of this nature in operation daily in Brazil at peak hours.

Therefore, the use of batteries can be used to “buy” energy in the off-peak period and use it in the peak period, avoiding the higher tariff, and possibly replacing diesel generation. Additionally, it is possible to mention that in addition to the economic gains, there are positive externalities with the substitution of fuel. From the consumer's point of view, the operation of diesel generators often brings the noise generated and the logistics of constant supply and maintenance. From the perspective of society, diesel generation contributes to the emission of pollutants in urban centers at times when the atmosphere is already loaded by vehicle emissions (rush hour), aggravating the public health problem.

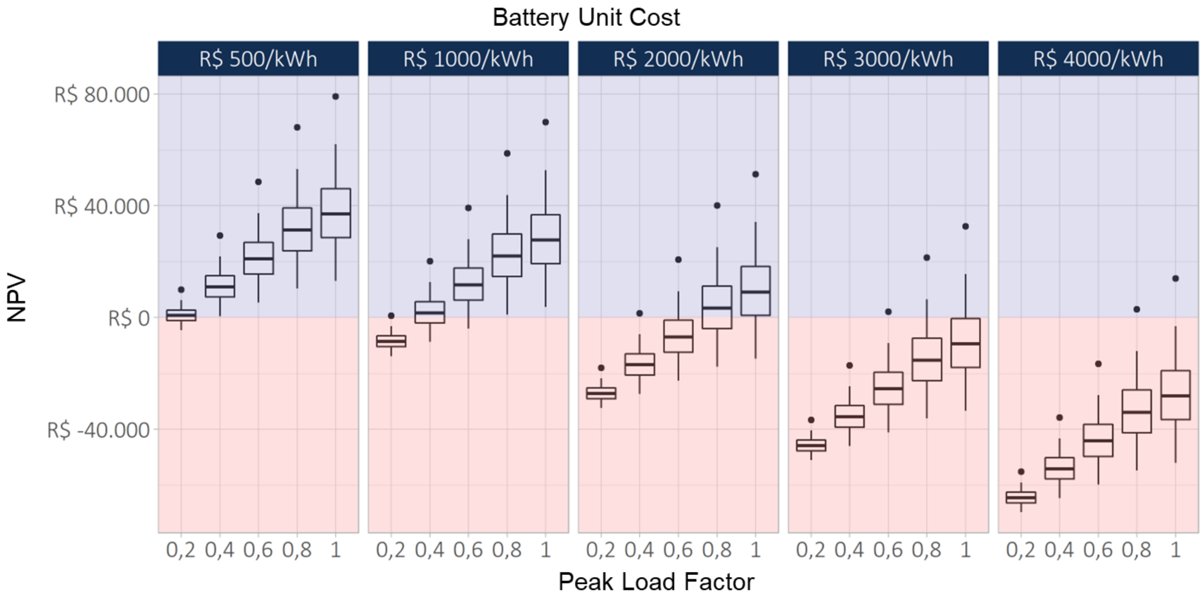
In this PDE, EPE carried out three analyzes of the use of batteries in consumers served in AT. In the first, it was evaluated whether this solution is viable to shift consumption from peak hours. Subsequently, the attractiveness was compared with the conventional solution (diesel). Finally, based on the previous analysis, a financial bonus was simulated for the investment in batteries from carbon credits, since there would be a replacement of diesel generation.

Regarding consumer data, it is known that the battery return will vary according to the peak load factor (FCp) of each consumer. That is, the ratio between average consumption and maximum demand at peak hours throughout the year. In general, the higher the FCp, the more useful the investment in batteries will be, as more consumption will be displaced. In view of this, EPE prepared synthetic energy load series, based on data provided by Sun Mobi for commercial consumers, in order to represent different FCp.

Attractiveness of batteries

NPV distribution for each simulation is presented in **Chart 9 - 26**. With a cost of BRL 4,000/kWh, the investment is practically not viable in any situation. If there is a reduction over the decade to the level of BRL 1,700/kWh, as explained in the previous section, one can expect the feasibility of investing in consumers with high FCp (>0.6).

Chart 9 - 26: Distribution of the NPV of the investment in batteries with A4 Green hourly rate for different distributors and load factors at the end



Attractiveness of batteries versus diesel generation

As seen in the previous item, with the expected drop in battery costs over the next decade, it is expected that there will be the feasibility of investing in batteries for peak load management for Group A consumers. However, it should be understood that for this application, consumers still have diesel generation as a substitute solution. Thus, the next analysis sought to compare the attractiveness of the two investments.

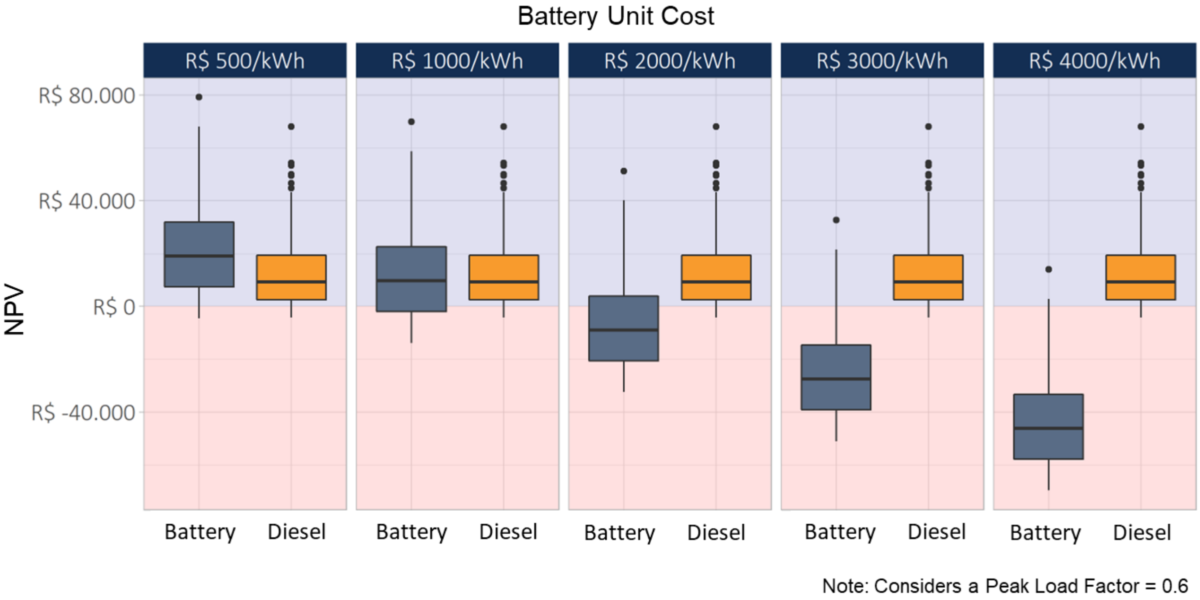
The diesel system was simulated with the assumptions presented in **Table 9 - 10**. Diesel prices were obtained by FU from the website of the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP) and represent the minimum value of the price to the final consumer, as an approximation to the price of the TRR (Retailer Retailer) - player that usually caters to this type of consumer.

The results presented in **Chart 9 - 27** represent the NPV of the batteries and the NPV of the diesel generation for consumers with FCp equal to 0.6. The results indicate that the diesel generation remains more attractive than the storage solution over the ten-year horizon. The reversal would only occur for storage close to 1000/kWh.

Table 9 - 10: Diesel generation calculation assumptions

Assumptions	Values	Reference
CAPEX (BRL/kW)	1000.00	MORIMOTO; CARMO; CHIHAYA (2017) and RIBEIRO e CRUZ (2017)
OPEX (BRL/MWh)	25.00	
Specific Consumption (l/MWh)	329	ANEEL REN 801/2017
Fuel Price	April 2021	ANP (2021)

Chart 9 - 27: Difference between NPV of battery investment and NPV of investment in diesel generation for peak use A4 Green



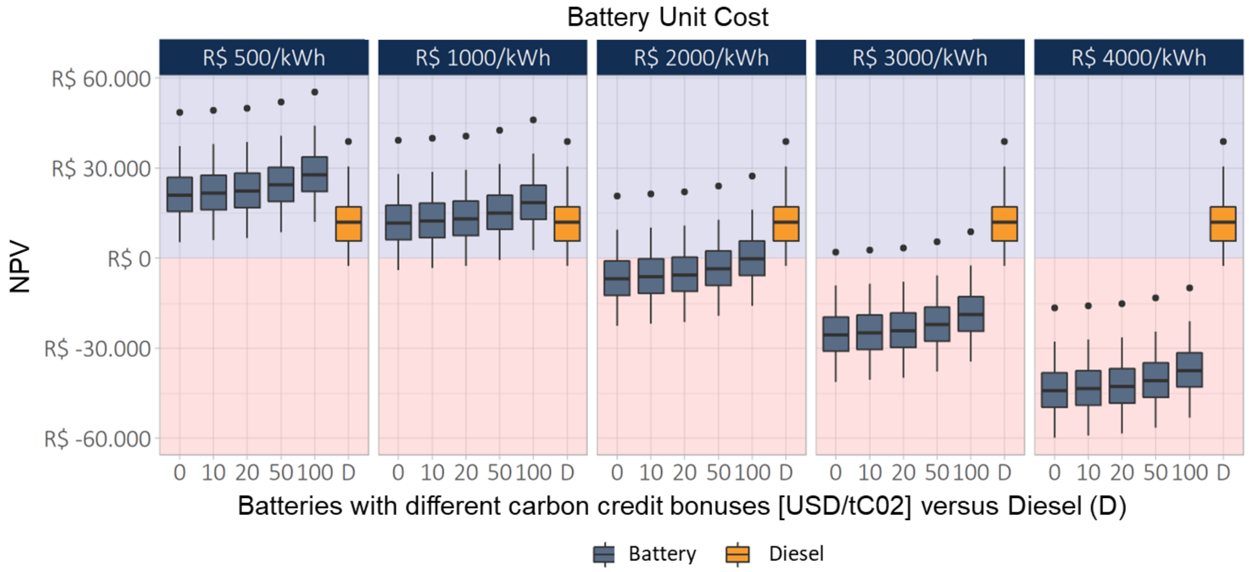
Sensitivity with carbon credit sales bonus

Carbon pricing has gained prominence recently, after carbon credit quotes surpassed 50 EUR/tCO2eq in the European market. Currently, Brazil does not have a carbon market involving the electricity sector, but there are ongoing discussions on the implementation of carbon pricing mechanisms both nationally and internationally. Law 14,120, of 03/01/2021, established that the Executive Branch defines guidelines for the consideration of environmental benefits in the electricity sector within 12 months from the publication of the Law. In this sense, throughout 2021, the MME and EPE promoted meetings, technical dialogues and workshops with the objective of debating and collecting information and perceptions to support the elaboration of the guidelines of Law 14.120.

Because batteries have the potential to replace diesel generation at peak hours, a simulation of receiving a financial bonus from reduced emissions was performed. Due to the uncertainty related to the price of carbon credits, a sensitivity with values from 0 to 100 USD/tCO2 was performed. The diesel generation emission factor was calculated at 0.77 tCO2eq/MWh, based on fuel emissions and a 10% blend of biodiesel (assumed to be zero emissions).

Chart 9 - 28 illustrates the simulation results. It can be seen that the carbon credit has a small effect on the attractiveness of investing in batteries. Its viability remains primarily dependent on a reduction in its CAPEX.

Chart 9 - 28: Difference between NPV of battery investment and NPV of investment in diesel generation for peak use A4 Green considering carbon credits



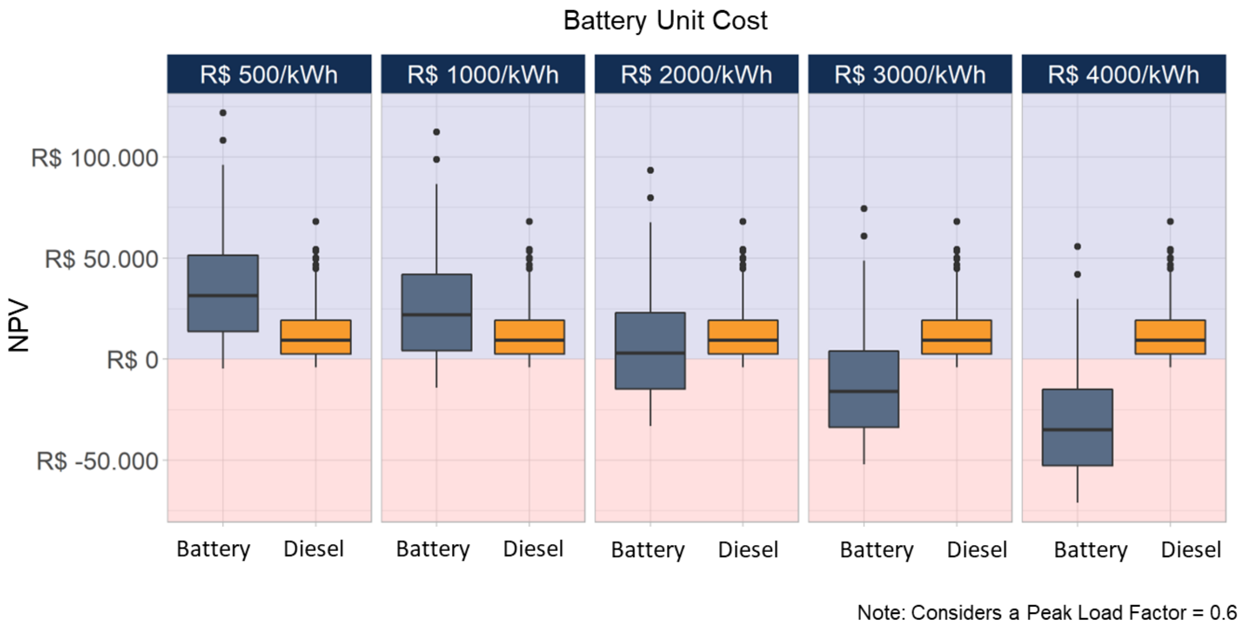
Note: Considers a Peak Load Factor = 0.6

Sensitivity to increased lifespan

The simulations presented so far have considered a battery life of 10 years. Some studies have simulated an extension of the useful life, reaching a total of 30 years, through intermediate investments to maintain the capacity of the equipment. In order to test the impact of a longer lifespan, EPE simulated the AT business case, with a lifespan of 20 years, with a replacement of 20% of the battery capacity, at a price of USD1,500/kWh, at the beginning of the 11th year of the project's life. This hypothesis was based on the NREL study (Feldman et al., 2021).

As shown in **Chart 9 - 29**, increasing the lifespan improves the viability of projects compared to **Chart 9 - 27**. With a CAPEX just below BRL 2000/kWh, the median NPV in batteries can already be observed to be higher than the median NPV of diesel generation. In any case, it is estimated that CAPEX in the range of BRL 2000/kWh will only be reached in Brazil in the second half of the current decade. Therefore, diesel generation should still remain a competitive solution for the next few years to meet the demand.

Chart 9 - 29: Difference between NPV of battery investment (20-year service life) and NPV of investment in diesel generation for peak use A4 Green



LIMITATIONS AND OUTLOOK

The simulation results showed that the economic viability of investments in batteries in Brazil is far from happening. However, there are some caveats: (i) calculations were made for 15 consumers only. Each consumer has a consumption profile, and this can change the simulation results. (ii) simulations were made based on current electricity rates, with adjustment according to inflation. A future trajectory different from this one can change the outlooks. The same is true for the price of diesel; (iii) the lithium-ion battery market in Brazil is still quite restricted, with few options for suppliers and equipment available. A higher supply can lower prices further than expected; (iv) there is a high tax burden on imports of batteries, which increase their cost by around 80%, according to market data. Therefore, a change in this scenario can also bring battery prices closer to feasibility.

In any case, the results are a good indication that batteries are still far from being economically attractive. Therefore, at the present time, the perspective for the ten-year horizon is that its entry is still marginal, present in some specific projects, which are considering other aspects (social, environmental, etc.), in addition to the economic in the investment decision. For example, the replacement of diesel generation can be done by noise reduction, just as the option for residential batteries can be driven by a desire for a backup source against blackouts, regardless of the cost of service.

EPE will continue to deepen its analysis and monitor this market to identify new opportunities and trends in the sector.

9.5 Self-production not injected into the grid

In large-scale distributed generation, only the self-production of electricity is considered, that is, the generation of electricity by the consumer with its own electricity generation facilities. These facilities are located next to the consumption units and do not use, or partially use, the electric grid of the transmission/distribution concessionaires, for the self-supply of electricity. The main form of self-production considered is cogeneration, a form of rational use of energy, since the efficiency of the energy production process is significantly increased from the combined production of thermal and electrical energy, with better use of the energy content of the fuel, often from waste streams from a specific industry's production process.

In this PDE cycle, for the energy generation projections in large systems, self-production of electricity, the following premises were considered:

• All new pulp production expansion will be self-sufficient in electricity, taking advantage of the lye from the process;

• In the case of steel, the expansion of installed capacity considered was classified into different types of technological route, each of which has different characteristics of electricity consumption and cogeneration potential. For each of the three types of technological route considered (integrated route with its own coke oven, integrated route without its own coke oven and semi-integrated route), the respective cogeneration potential was evaluated, based on the existing cogeneration in the current Brazilian steel plant complex;

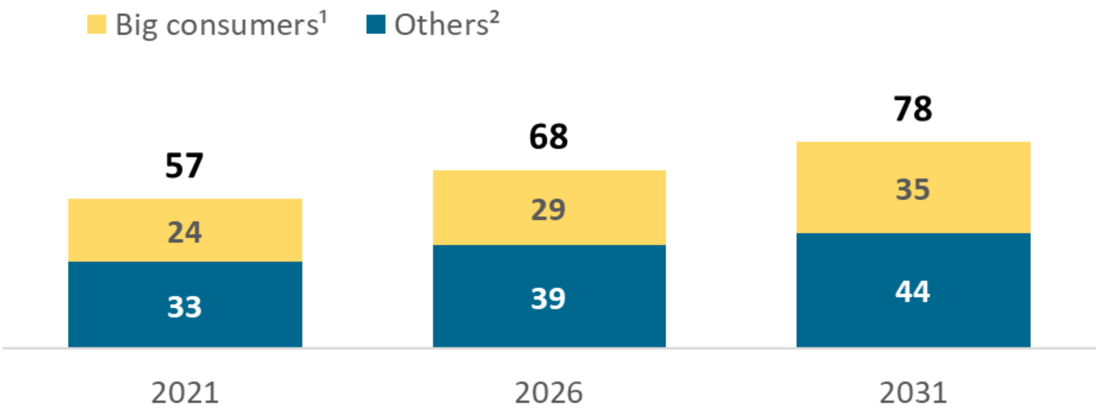
• For the petrochemical industry, it was assumed that practically the entire increase in the expansion of the physical production of ethylene from petrochemical commodities is met by self-production;

• In the segments of sugar and alcohol, exploration and production of oil and natural gas, in addition to the refining segment, self-production was calculated based on the perspectives of evolution of the respective levels of sectorial activity. Thus, self-production in the sugar and alcohol segment is correlated with the production of cane for the production of sugar and for the production of ethanol;

• Self-production in refineries is correlated with the amount of processed cargo. And self-production in oil and natural gas (E&P) exploration and production correlates with oil production.

In the ten-year horizon, it is estimated that large-scale distributed generation will reduce grid consumption by a total of 78 TWh in 2031 (**Chart 9 - 30**), or around 10% of electricity consumption, installed in industries such as steel production, cellulose and paper, petrochemicals, refining, sugar and alcohol production, among others. It should be noted that this value includes the estimate made in the commercial sector.

Chart 9 - 30: Self Production Not Injected in Electricity Network (TWh)



Note: (1) Concentrated in the steel, petrochemical and pulp and paper segments.
(2) Does not include MMDG and consumption abatement for incremental use of solar thermal energy

9.6 Thermal Solar Energy

The conversion of energy from the Sun into thermal energy is based on the absorption of solar radiation and its transfer, in the form of heat, to an element that will provide a certain energy service. In general, solar thermal energy can be used to heat water in homes and buildings and in industrial production processes. Solar water heating systems (SHS) consist of solar collectors and a thermal reservoir, where the heated water is stored. In addition, the SHS have complementary heating equipment, which can use electricity or gas, and which is activated in periods of low solar intensity, such as nights and cloudy days. The quality standards of collectors and reservoirs are standardized by the Brazilian Labeling Program (PBE), coordinated by INMETRO.

Despite being a substitution between energy sources, the greater penetration of solar thermal energy has similar effects to the dissemination of energy efficiency, which can generate externalities in several aspects. While, for consumers, the use of SHS can reduce total energy expenditure, for the electricity sector, its use can reduce grid electricity consumption, peak demand in critical periods and technical losses in the system, helping to postpone new investments in generation, transmission and distribution. Finally, from an environmental point of view, the use of SHS can help to reduce GHG emissions, as it is a clean energy source.

The diffusion of the use of thermal solar energy is evaluated by the total area of collectors installed in Brazil. The total accumulated area of collectors reached around 19.2 million m² in 2020, equivalent to 13.4 GWth[10]. In annual terms, the area of new collectors increased from about 400 thousand m² in 2005 to close to 1.417 thousand m² in 2020, representing a growth slightly greater than three and a half times in the period. It is noteworthy that the residential sector is the main destination for collectors, with almost seventy percent of the total new area installed in 2020 (ABRASOL).

[10] Considering that one square meter of solar collector is equivalent to 0.7 kW_{th}, according to ELETROBRAS (2012).

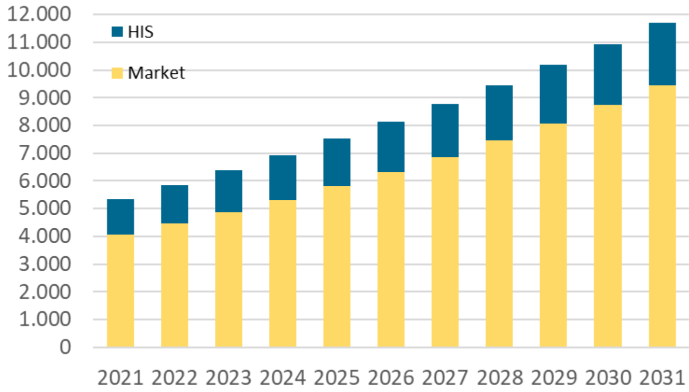
Residential Sector

Residential solar thermal energy is mainly intended for heating water. It is assumed in the PDE 2031 that the diffusion of SHS technologies displaces the use of electricity in electric showers. In this way, the avoided consumption of electricity for heating water in the interval between 2021 and 2031 due to the use of solar energy is estimated as a function of the number of residences that replace electric showers with SHS.

It is estimated that the total area of residential solar collectors installed in Brazil could reach around 14.8 million m² in 2021, equivalent to 10.4 GW_{th}. In the last decades, the diffusion of SHS was propitiated by the development of its autonomous market and of inductions resulting from public policies, including those that made mandatory or encouraged the use of technology for certain types of housing, target audiences or regions of Brazil in Social Interest Homes (HIS). As an example, there are Law No. 12,424, of July 16, 2011, and Ordinance No. 325, of July 7, 2011, both of the Ministry of Regional Development. Based on the total installed area, it is estimated that the number of residences with SHS could reach 5.3 million in 2021, being around 1.3 million HIS[11].

In the ten-year horizon, it is expected that the adoption of SHS will still be the result of market factors and induction policies. According to **Chart 9 - 31**, it is estimated that the number of residences with this technology could total close to 11.7 million units, or almost 14% of the total number of residences estimated in Brazil for 2031, with about 2.3 million units of HIS.

Chart 9 - 31: Number of residences with SHS (thousand units)



The factor that seems to have the most influence on the installation of SHS technology is its cost-effectiveness in relation to the electricity consumed by Brazilian residences, which interferes in the payback time of investment in projects. While approximately 55% of sales of SHS solutions in 2020 were in the Southeast region, 19% were in the South, 13% in the Midwest, 8% in the Northeast and 5% in the North (ABRASOL). Despite the advance in the dispersion of these sales in Brazil compared to 2019, these numbers still suggest a concentration of installations in regions with greater purchasing power and with greater reach of information regarding the benefits of technology. In another sense, there are regions of Brazil that are very hot, such as the North and Northeast, which can contribute to the low percentages of residences that heat water, as illustrated by PPH 2019 (PROCEL/ELETROBRAS). EPE calculations using the data collected in this research estimate that, on average, about 35% of Brazilian residences did not heat water in Brazil in 2019, and in the North (94%) and Northeast (88%) these statistics are much bigger.

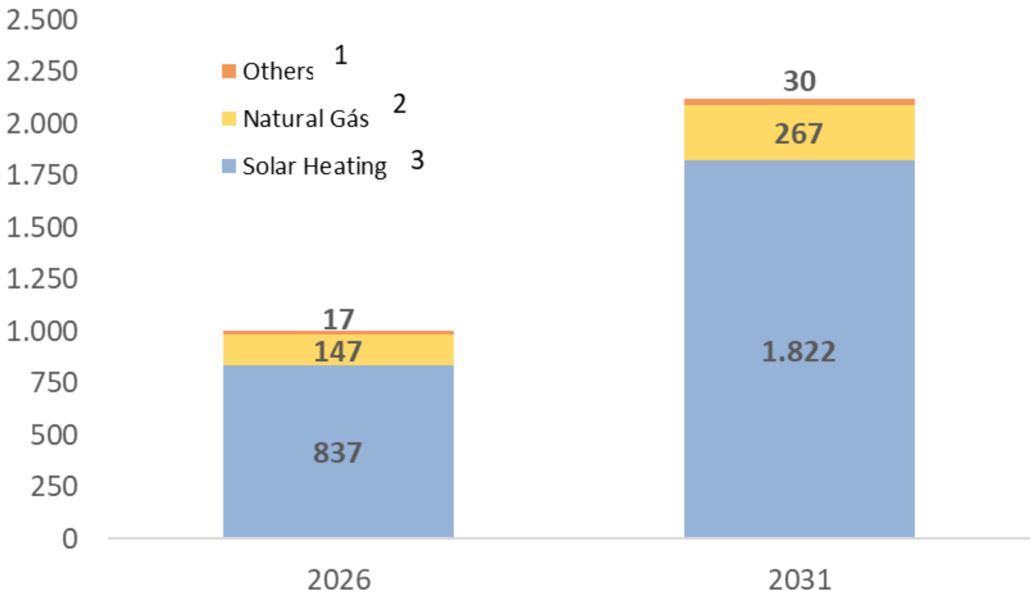
Additionally, in terms of induction policies, HIS programs may be reformulated over the analysis horizon in order to involve alternative energy generation systems, such as, for example, those involving biomass energy, wind energy or photovoltaic solar energy, which can compete for

[11] The average area of household solar collectors is assumed to be 3m² and 2m² in the autonomous and HIS market, respectively.

residential financial resources with SHS technology projects. This is the case, for example, of Ordinance No. 643 of November 13, 2017 of the Ministry of Regional Development, which provides for the use of alternative energy generation systems within the scope of the Casa Verde Amarela program of the Federal Government. It is important to note that while the diffusion of SHS is initially associated only with heating water, the other sources of generation allow the self-consumption of electricity in all its other end uses (lighting, air conditioning, conservation and cooking) inside homes.

Therefore, it is expected that the avoided consumption of electricity in homes due to the replacement of electric showers by SHS incorporates both demographic changes and technological transitions of equipment. According to **Chart 9 - 32**, the increase compared to 2021 in the avoided consumption of electricity for heating water using SHS could reach close to 1.8 TWh in 2031, the approximate equivalent of the generation of the SINOP hydroelectric plant in Mato Grosso, which has about 400 MW.

Chart 9 - 32: Avoided consumption of residential electricity for heating water using other energy sources (GWh)



Notes: (1) Increase in consumption of other energy sources that displace electricity demand in water heating with electric showers in relation to 2020.
(2) Increase in natural gas consumption that shifts electricity demand for water heating with electric showers compared to 2020.
(3) Avoided consumption of electricity for water heating with electric showers from the incremental installation of SHS in relation to 2020.

MAJOR POINTS OF THE CHAPTER
ENERGY EFFICIENCY AND DISTRIBUTED ENERGY RESOURCES

- *Energy efficiency in 2031 (20 million toe) will represent 8% of the final energy consumption in Brazil or the consumption of the pig iron and steel and cement segments in 2020.*
- *Electric efficiency gains in 2031 (32 TWh) will correspond to the generation of a hydroelectric plant with an installed capacity of around 7 GW, equivalent to an Itaipu HPP (Brazilian portion).*
- *In 2031, the volume of fuel saved (345 thousand barrels per day) will be 11% of the oil produced in Brazil in 2020.*
- *In 2031, buildings can reduce electricity consumption by 18 TWh, this amount corresponds to 56% of Brazil's saved electricity, equivalent to the consumption of the pig iron and steel sector in 2020 (17 TWh).*
- *It is estimated that the electricity saved in Brazil's residences could reach around 6.3 GWh in 2031, corresponding to 3% of residential electricity consumption in the same year.*
- *In industry, efficient energy use will account for approximately 5% of projected final energy demand in 2031. The electrical efficiency gains will represent 3%, equivalent to the current consumption of the textile and ceramic industries (10 TWh).*
- *In the transport sector, only with the efficiency of each transport mode (for example, technological improvements and intensity of use) the sector achieves gains of around 8% (10 million toe) in 2031.*
- *For distributed micro or mini-generation systems, seven scenarios were developed. In the Reference scenario, there will be around 4 million adopters in 2031, totaling 37.2 GW of installed capacity, which will contribute 7.2 GW average of generation in 2031.*
- *The analysis of the competitiveness of batteries behind the meter was carried out, and showed that the cost of this equipment is still high in Brazil, making it difficult for them to enter the ten-year period. The final price would have to fall from the current BRL 4,000/kWh to the range of BRL 500-1,000/kWh for competitiveness in the main simulated applications. However, there may be insertion of this technology due to other non-economic factors, mainly for the replacement of diesel generation in stores.*
- *An analysis of the attractiveness of remote minigeneration projects indicated that there are opportunities in exploring technologies other than photovoltaic. Biogas and CGH projects, for example, can achieve real internal rates of return of almost 40% p.a., higher than the rates found for solar sources.*
- *For the Self Production Not Injected in Electricity Network, it is estimated that this generation will reduce grid consumption by a total of 78 TWh in 2031, or around 10% of electricity consumption, installed in industries such as steel production , pulp and paper, petrochemicals, refining, sugar and alcohol production, among others. It should be noted that this value includes the estimate made in the commercial sector.*
- *The avoided consumption of electricity for heating water due to SHS could reach close to 1.8 TWh in 2031, the approximate equivalent of the generation of the SINOP hydroelectric plant in Mato Grosso which has around 400 MW.*