NOT TO BE CITED

Economic and regional impacts of investments in electricity generation in Brazil[1]

Tiago B. Diniz <tiagotbd@gmail.com>
Joaquim Bento de Souza Ferreira Filho
Mark Horridge

Abstract: To accomplish climate agreements, Brazil intends to raise the share of renewables, other than hydropower, in electricity supply. According to the Brazilian Decennial Energy Plan (PDE 2026), the country will expand its installed capacity mostly by investments in gas, wind and solar sources. However, areas suitable for those projects are regionally concentrated and, in some cases, in the poorest regions such as the Northeast. Hence, the expansion of power supply also entails economic and regional issues. We explore this topic analyzing the economic and regional impacts of the investments in electricity generation, under various policy scenarios provided by the PDE 2026. For that, we apply a regional recursive-dynamic CGE model for Brazil, TERM-BR10, specially enhanced to deal with electricity features. Our results show that a supply plan with more insertion of solar source could increase the national GDP by 0.45% and by 2.3% in specific regions. They also show that a scenario without new hydro dams does not imply in economic loss, in terms of national GDP or employment. We also came to the conclusion that policy guidelines have welfare and distributive benefits, with greater impact to poorest regions and low income households.

Keywords: renewable electricity; investments; Brazil; CGE modeling

JEL Codes: D58; Q42; Q48; R13

1. INTRODUCTION

Brazil committed in the 21st United Nations Climate Change Conference (COP21) to reduce its greenhouse gas emissions by 37% below 2005 levels in 2025, via controlling deforestation and increasing the share of sustainable biofuels in energy mix and the share of renewables, other than hydropower, in power supply (BRASIL, 2015). Although these commitments are not an obligation, it has been acting as a guideline for policymakers and the country has recently reinforced its position at international meetings, such as COP22.

In the electricity sector, specifically, Brazil proposes to accomplish the agreement mostly by raising the share of wind and solar generation in the electricity mix. According to the newest Brazilian Decennial Energy Plan (PDE 2026), during the period 2017-2026, the country should more than double its installed capacity for wind power (184.0%) and drastically increase its capacity for solar (45900.0%). Meanwhile, it also intends to reduce the share of oil and diesel sources, cutting off about 52% and 60% of its installed capacity, respectively. As a result, the country should achieve in 2026 an electricity matrix with 81% of renewables, composed by 54% of hydro, 14% of wind, 8% of biomass and 5% of solar. Non-renewables sources should represent about 19% and consist mainly of gas (EPE, 2017).

To support this expansion, the country should invest about R$ 174 billion (US$ 53 billion) directed only for new projects whose start up date is after 2020 (EPE, 2017). Geographically, the locations with potential for wind and solar energy, and therefore with

[1] This work was developed with not simultaneously financial support from CAPES/PDSE/ Process nº 88881.133314/2016-01 and from Instituto Escolhas.

more investments, are mainly located in the poorest areas of Brazil such as the Northeast region. It means that the Brazilian Decennial Energy Plan and the investments in renewable sources are not only a climate and an energy concern, but also entails important economic issues such as regional inequality and development.

Despite this relevance, there is still a scarce literature on this topic in Brazil. Previous studies were mostly focus on the implication of investments in renewable electricity on jobs, such as Pereira et al (2013) and Simas and Pacca (2013; 2014), and the economic consequences of reducing emissions (Instituto Escolhas, 2017). Internationally, the impact on jobs has been widely discussed (UK, 2014; Lehr et al, 2008; Moreno et al, 2008) and some works have extended the analysis to other variables such as GDP (Pollin et al, 2009; Dai et al, 2016). Nevertheless, to our best knowledge, regional analysis is still an absence.

This study aims to fill this gap by applying a regional recursive-dynamic CGE model, TERM-BR10, to evaluate the economic and regional implications of the investments in electricity generation in Brazil. Our purpose, specifically, is to examine economic impacts of the investments under various scenarios described by the PDE 2026, focusing on its different effects on GDP, employment, production, among others variables. This allows us, for example, to understand if an electricity mix with more renewable sources implies in economic benefits to the country and specific regions or not.

The remainder of this paper is structured as follow: section 2 contains a brief description about the Brazilian Decennial Energy Plan, PDE 2026, and its electricity supply scenarios; section 3 describes the economic model (TERM-BR10) and the methodology applied to compute our policy shocks as well as the simulation strategy; while the section 4 present our results. Section 5 reports our final remarks.

2. THE BRAZILIAN DECENNIAL ENERGY PLAN – PDE 2026

2.1 Overview

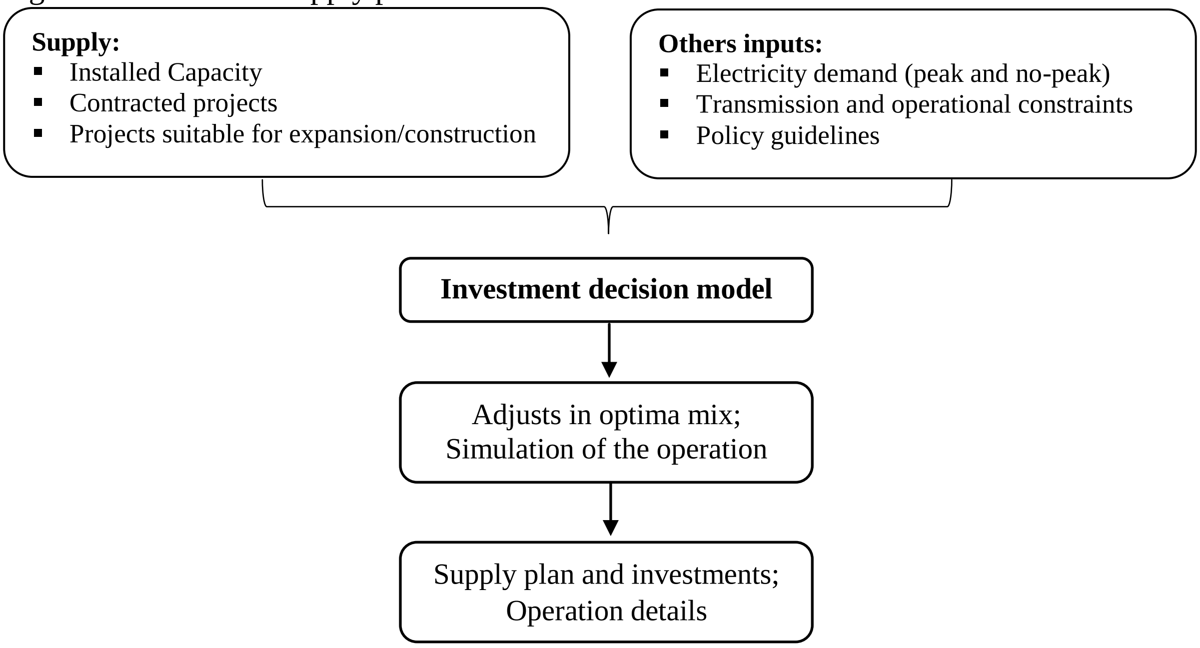
The Brazilian Decennial Energy Plan is a document elaborated by the Brazilian Ministry of Mines and Energy (MME) to provide information for society and investors regarding government standpoint for energy supply and demand 10 years ahead. Although not deterministic, the plan provides the Federal Government approach for energy efficiency, energy and electricity demand, fuels and electricity supply, investments and environmental analysis of planned energy matrix. The document is usually published annually and also contains supplementary material and technical reports describing the methodology, environmental analysis and others specific issues. The most recent Brazilian Decennial Energy Plan, PDE 2026, covers the period of 2017-2026.

The analysis of electricity sector consists of a demand forecast, developed under macroeconomics, demographics and electricity efficiency assumptions, and a supply plan specifying an electricity mix to support that demand. In order to determine the supply, the planners subject projects suitable for expansion or construction to an investment model that optimize the minimum cost mix (construction and operation)[2]. Exogenous constraints, such as policy guidelines, are inputs to the optimization process. The optimum mix is then subject to

[2] For further details about the investment model visit: http://epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-40/topico-67/NT%20DEE%20028_17.pdf

additional constraints (those not handled by the investment model) and simulations. After adjustments, the supply plan is ready for evaluation by policymakers. (Figure 1)

Figure 1 – Process of supply plan construction from PDE 2026.



Source: elaborated by authors based on EPE (2017).

In this process, PDE 2026 innovates providing not one but various optimums mix considering uncertainty and different environmental and energy restrictions. Supply alternatives for situations with no new hydro dams (not already contracted) in the electricity mix or with a reduction in cost for solar source are provided. An electricity mix developed without policy intervention is also available.

2.2 Economic assumptions and supply scenarios

PDE 2026 and its demand forecast were developed under demographic and economic assumptions. The plan considers that the Brazilian population will keep growing, but under decreasing rates. During the period 2017-2026 it is expected to have an average growth rate of 0.6% a year. This corresponds to an addition of 13 million habitants by the end of the period. Regionally, the North and Midwest regions should growth at higher rates. However, not enough to cause significant changes in demographic distribution (EPE, 2017).

In economy, PDE 2026 assumes a growth rate of 3.8% annually for world's GDP and of 4.0% for the international trade. Due to economic and political conditions, is expected for Brazil a smooth recovery. For 2017-2026, it is assumed an average rate of 2.5% for Brazilian GDP. Nevertheless, by the end of this period the economy should increase about 3.0% per year[3].

The electricity demand is driven by those economic and demographic assumptions. EPE estimates for the reference scenario an average increase of 3.7% in the electricity consumption during the period of 2017-2026, and of 3.5% for electricity demanded in the

[3] The plan also has an optimistic forecast. In this case, the average rate for GDP is 3.2%. However, we are not considering this scenario in our analysis.

national grid. On the supply side, the plan published one reference scenario and seven alternative supply plans, considering uncertain conditions, the called "what-if" scenarios. However, detailed information by source is only provided for six of them, restricting, a priori, our analysis to those cases[4].

Among these options, we restricted our study to four scenarios: Case 1 - reference scenario, Case 4 - solar expansion, Case 5 - no new hydro dams, and Case 8 - directed expansion. This choice was based on the fact that these scenarios share the same economic and electricity demand assumptions as well as exogenous constraints (Figure 2). Hence, they are comparable. Besides, they embody relevant policy and environmental issues, such as hydrologic scarcity, more rigorous conditions for environmental licenses and huge increase in renewable sources. These make the investigation of the economic implications of these scenarios, and the differences between them, quite interesting for Brazil, especially in regional level.

The expansion of installed capacity, in every case, consists of projects already contracted[5], which basically support the additional supply until 2020, and new projects considered for 2020-2026. For this last period, projects (and sources) could be different between scenarios due to specific policy guidelines considered in each Case (Figure 2). Therefore, differences between Cases are only related to the planned expansion.

For each one of those scenarios, PDE 2026 has a detailed expansion by source, year and location at macro regional level (Table 1). It is important to highlight that even established to support the same demand, the total expansion of installed capacity is slightly different between scenarios due to the peculiarities of the sources considered in each case. Consequently, the total amount of investment estimated for that is also different (Table 1).

Table 1 - Total expansion (MW) for 2020-2026 under selected scenarios provided by PDE 2026

	Case 1	**Case 4**	**Case 5**	**Case 8**
Hydro	2,631	2,631	-	2,631
Small Hydro (PCH/CGH)	1,500	1,500	1,500	1,500
Biomass	2,804	2,804	2,804	2,804
Forest Biomass	400	400	400	400
Wind (south)	2,365	2,006	2,187	2,790
Wind (Northeast)	9,460	8,024	8,749	11,159
Photovoltaic	7,000	10,508	7,000	6,000
Natural Gas (Southeast)	112	-	995	83
Natural Gas (South)	1,054	1,198	-	1,459
Natural Gas (Northeast)	1,500	1,500	1,500	-
Peak alternative* (South)	3,070	4,049	368	4,181
Peak alternative* (Northeast)	184	1,436	-	939
Peak alternative* (Southeast)	8,944	7,117	12,457	7,686
Coal	-	-	2,000	-
TOTAL (MW)	41,024	43,173	39,960	41,633
Estimated Investment (R$ millions)	174,480	180,853	167,468	179,227

Source: EPE (2017).

* Following NT DEA 015/17, we are assuming natural gas for peak alternative.

[4].Those without detailed forecast are: i) Case 3, built for uncertain demand; and ii) Case 6, built considering a hydrologic restriction in Northeast region.

[5] Contracted projects are mostly from hydro, wind and thermal sources. For a detailed description, see EPE (2017).

Figure 2 – General and policy assumptions for selected PDE 2026' scenarios

General assumptions and constraints

- An average rate of 2.5% for Brazilian GDP (2017-2026);
- Nuclear power plant Angra 3 operation start date: jan/2026;
- No renewal for those Diesel and Oil thermal units with contracts finishing during the PDE horizon;
- An uniform expansion for wind power (to be optimized by the investment decision model) from 2021, being 80% at Northeast and 20% at South region;
- An uniform expansion for solar photovoltaic (to be optimized by the investment decision model) from 2021 of at least 1.000 MW by year;
- An uniform expansion for biomass power from 2021, subject to sugarcane supply;
- Expansion of forest biomass thermal plants from 2023, limit to 100 MW annually;

Policy guidelines

Case 1
Reference Scenario

i) Expansion of 1000 MW of wind power in 2020, being 800 MW at Northeast region and 200 MW at the South;

ii) Expansion of 1000 MW of solar photovoltaic in 2020;

iii) Installation of a thermal plant (gas) at Northeast region in 2023

Case 4
Solar Scenario

i) Considers 40% reduction in the cost of investment for solar photovoltaic generation from 2023.

ii) Therefore, after 2023 the solar expansion is greater than the minimum determinate by general guidelines.

iii) As an implication, the wind expansion is reduced relatively to the reference scenario due to peak supply reasons.

Case 5
No new hydro dams

i) Due to licensing delays and environmental impacts, this scenario considers an expansion without new hydro dams until 2028.

ii) To support this constraint, this scenario allows expansion in thermal generation from coal source.

Case 8
Directed Expansion

i) The optimization without the general constraints results in an expansion mostly concentrated in one source, then not reasonable (Case 7 in the plan)

ii) Case 8 consist of make the free expansion implementable, inputting general constraints in the optimization.

iii) Among realistic scenarios, it is the one with less intervention.

Source: elaborated by authors based on EPE (2017).

3. METHODOLOGY

3.1 The TERM-BR10

The TERM model was originally developed for Australia in earlies 2000 by the Centre of Policy Studies. Since then, different versions of the model have been adapted for other countries, such as China, Brazil, Indonesia and USA, to analyze policies related to environment, migration, trade and other subjects[6]. Our CGE model, the TERM-BR10, belongs to this family and is the most recent version of TERM for Brazil.

The TERM-BR10 is a regional, bottom-up and multi-period (recursive dynamic) computable general equilibrium model, based and closely similar to its predecessor, the TERM-BR. The data structure and the core theory behind the model (equations, agents' behavior, trade matrix) were described by Horridge (2011) and others papers such as Horridge et. al. (2005), Horridge & Wittwer (2010) and Witter & Griffith (2011). Regarding Brazil, several applications were made as Ferreira Filho and Horridge (2006, 2010, 2014, 2016) and Diniz and Ferreira Filho (2015). Therefore, in this paper our focus is on the updates, improvements and modifications incorporated by TERM-BR10, mostly regarded to the new database and the electricity data and mechanism.

The model is calibrated based on the 2010 Brazilian Input-Output table (while the previous TERM-BR use 2005 database). The IO table covers 67 sectors and 127 commodities. The electricity (sector and commodity) comes aggregated with gas, water and other utilities. This format lacks generation details and, consequently, it is not appropriate to work with electricity sector in Brazil due to its diversified electricity mix.

To solve that we used data from the Brazilian Energy Balance (BEN 2016) to disaggregate the sector (and the commodity) into 12 different activities/products: one for gas distribution, one to represent electricity transmission and distribution, and 10 different electricity generations – wind, solar, hydro, biomass (sugar), biomass (ethanol), thermal (oil), thermal (diesel), thermal (coal), thermal (gas), and others generations. Also we split the Petroleum and Natural Gas sector (and product) into two sectors/products, respectively. Then, our initial database consist of 136 commodities and 76 sectors. Finally, we transform our Make matrix to a commodity x commodity diagonal table (136 x 136)[7].

The TERM-BR10 is representative of the 27 Brazilian regions: 26 regions and the Federal District. Regional supplies (or production) were obtained splitting the national production using official information from the 2010 Municipal Agriculture Survey (PAM/IBGE), the Brazilian Energy Balance (BEN 2016), and the Cadastro Central de Empresas (CEMPRE/IBGE), among other official sources. Local demand was estimated using the 2008 Brazilian Expenditure Survey (POF - Pesquisa de Orçamentos Familiares, published by IBGE). The 27 regions were linked through large trade matrices, estimated based on local supply and demand estimates using a gravitational-like type method, as described by Horridge (2011).

To split the Input-Output investment vector between our 136 industries, we use information from Miguez (2016)[8]. To our best knowledge, this is the most recent and the only work which estimate an investment absorption matrix for 2010 Brazilian IO table. Even though, for the electricity sectors we use additional information such as Tourkolias et al

---

[6] See https://www.copsmodels.com/term.htm.
[7] For detailed explanation and procedures example, see https://www.copsmodels.com/archivep/tpmh0062.zip
[8] For further details about this process, contact the authors.

(2014), Cansino et al (2014), Cursino Neto (2007) and Braciani (2011). We also performed interviews with renewable energy specialists from Eletrobras CHESF, a big owned-state electricity company in Brazil. The investment vector for each electricity type is described by Table A-01 in Appendix.

Our model also distinguishes ten different types of workers, classified according to their wage incomes, as a proxy for skills. The income earned by those ten different workers types is assembled to compose the household income – the expenditure unit of the model. Then, our model distinguishes ten different household types, classified by their income. For electricity sectors, we use supplementary information from Brazilian Employment Department (RAIS/MTE) to improve our vector of workers skills distribution across each generation industry.

For the purpose of this research, we combined the Thermal Oil and Diesel electricity in only one sector/product, because Brazil will not invest in those sources anymore as well as will not renew contracts that will expiry during the PDE horizon (EPE, 2017). We also combined the Biomass from Sugar and Ethanol in one product, called "GerBagaco", and we aggregated the industries Biomass (Sugar) with Sugar and Biomass (Ethanol) with Ethanol. Hence, both Sugar and Ethanol industries produce the "GerBagaco" electricity and their own product (sugar and ethanol, respectively). This is the only case where our make matrix, after aggregation, is not diagonal. The others sectors and goods were aggregated as well, resulting in 39 industries and 40 commodities.

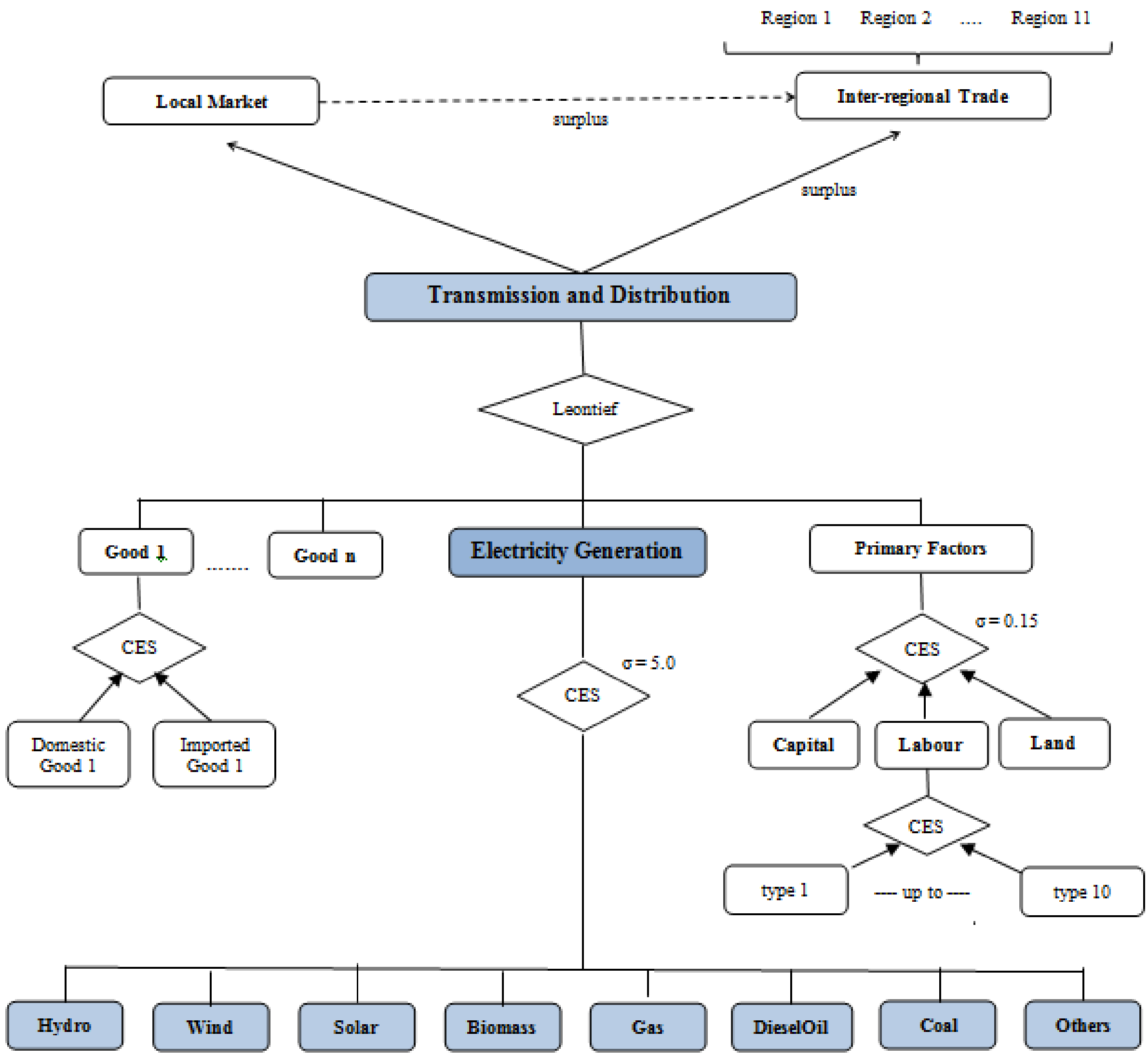
The Brazilian 27 regions were aggregated to 11 regions considering both economic and electricity (new investments) relevance. They are: RestNO (North region, except Pará state), Para (Pará state), MaranPiaui (Marahão and Piaui states), CearaRGNorte (Ceará and Rio Grande do Norte states), PEparaibAL (Pernambuco, Paraíba and Alagoas states), BahiaSE (Bahia and Sergipe states), RestSE (Southeast region, except São Paulo state), SaoPaulo (São Paulo state), RestSUL (Paraná and Santa Catarina states), RGSul (Rio Grande do Sul state) and CentroOest (Central West region). After all this process, our final database contains 11 regions, 40 commodities (8 electricity types and 1 Transmission and Distribution – T&D) and 39 industries, being 7 specifically for electricity generation and 1 for T&D. Table A-02, in Appendix, list these sectors and commodities.

3.1.1 The core model and electricity mechanism

TERM-BR10 follows TERM's equation system. As described by Horridge (2011), the producers choose a cost-minimizing combination of intermediate and primary factor inputs, subject to production functions which are structured by a series of Constant Elasticity of Substitution (CES) "nesting" assumptions. The primary factors and intermediate inputs are each demanded in proportion to industry output (Leontief assumption). The primary factor aggregate is a CES composite of capital, land and a labour aggregate – which it is itself a CES composite of labour by skill group. The aggregate intermediate input is a CES composite of different compound commodities, which are in turn CES composites of goods from different sources: imported and/or national, which could be from one or a mix of those 27 regions (11 after aggregation). The exception is for Transmission and Distribution (T&D) industry, that we assume a Leontief combination of electricity and other goods to compose the aggregate intermediate input (Figure 03).

In our model, the T&D industry collects the electricity produced by all generation activities locally and then supply it to households and others industries. The excess of each region is distributed along the national territory, via inter-regional trade. With this approach, the electricity supplied by each region is a mix of the production of the generation types. The share of each source in this electricity composite is subject to changes accordingly to relative prices under a CES system. It means, in other words, that TERM-BR10 could properly substitute one type of electricity by another in response to changes in production and prices regionally. By its turn, the consumption in each region, if it is not self-sufficient in production, could be a composite of local and other regions' electricity.

Figure 03 – Electricity production and trade mechanism in TERM-BR10.



Source: elaborated by authors.

The model's recursive dynamics[9] consists of three mechanisms: (i) a stock-flow relation between investment and capital stock, which assumes a 1-year gestation lag; (ii) a positive relation between investment and the rate of profit; and (iii) a relation between wage growth and regional labor supply. The capital in each period grows by an amount equal to the

[9] As described by Horridge (2002), a "annual recursive dynamics model" means that each solution of the model represents the changes between one year and the next. The 'initial' data base that is the starting point of each computation represents the economy as it was both at the end of the previous period and at the beginning of the current period.

rate of investment at the beginning of the period, less a deduction for depreciation. Thus, a change in investment this period (t) affects the growth rate of capital not in this period but in the next (t+1). The investment allocation in its turn is driven by two components: a) investment/capital ratios are positively related to expected rates of return; and (b) expected rates of return converge to actual rates of return via a partial adjustment mechanism (Horridge, 2002).

3.2 Computing policy shocks

PDE 2026 provides an expansion plan for several scenarios, but it lacks details about the location of the projects, specifying only macro regions. Thus, we regionalized the investments to our 27 regions (11 after aggregation).

To find out the location for projects already contracted we use the WEBMAP tool[10]. This system details contracted expansion with information as capacity (MW), state (region) and the start-year of operation. Using this data, we regionalized the expansion already contracted year by year. For planned projects, we used as guideline the technical report NT DEA 015/17, jointly published with PDE 2026 by EPE. This document is dedicated to the environmental analysis of the plan and contains information about the location of hydro dams and gas, nuclear and coal plants, as well as geographic considerations for the expansion of biomass, wind and solar sources. Additionally, we also considered the results of the last auctions for wind, biomass and solar technologies. The Table A-03, in Appendix, shows the distribution criteria we applied to split the PDE 2026 regional level to the 27 regions of TERM-BR10. Then, we aggregated the MW expansion matrix to the 11 regions considered for simulation.

This process results in a PDE 2026 expansion matrix (contracted + planned) year by year, disaggregated by source, for each scenario in our regional level for the period 2017-2026. Adopting 2016 installed capacity as base year, we are able to compute for any region and/or any source growth rates (geometric, year by year, etc). For simulation purpose, we assumed a linear expansion, adding the same amount of MW every PDE year.

To compute our policy shocks, we subject the capital stock of the model's electricity industries to its correspondent annual variation from the PDE expansion[11]. Then, we calculate the investment necessary to support this new capital stock expansion, driven by PDE rates. The percent variations of investment against the previous year are our shocks. As we assumed a one period gestation lag, it is straightforward that to simulate an expansion of installed capacity for the period 2017-2026 the investment has to be placed in 2016-2025. Finally, in our case, for each one of our four scenarios we have a three-dimension matrix for shocks: electricity industries X regions X years. For this reason, these tables are not available in this paper, but are available upon request.

[10] See https://gisepe.epe.gov.br/WebMapEPE/

[11] We don't have the Biomass industry in our model. The "GerBagaco" commodity is produced by Sugar and Ethanol sectors. From the PDE expansion for Biomass, we are assuming 75% for Sugar industry and 25% for Ethanol.

3.3 Simulation strategy

Our simulation is an evaluation of the economic consequences of policy guidelines embodied by PDE 2026 scenarios. For that, we have to establish a baseline path, describing the “natural” expansion of the economy and electricity supply, and the policy or “perturbed” scenarios, incorporating the government directions for the electricity matrix. The deviations from the perturbed to the baseline path are interpreted as the effects of policy interventions.

The simulation contains three parts: i) update of database from 2010 to 2015, using macroeconomic aggregates; ii) PDE investment period (2016-2025); and an extended period (2026-2035), in order to capture the spread out effects of the investments. The differences between baseline and policy scenarios are restricted to the shocks for the PDE period.

As a long-run dynamic simulation, the economic system is mainly characterized by the evolution of primary factors and technological progress. The TERM-BR10 has three primary factors (labour, capital and land), for which we are assuming that:

i) Labour supply is driven by regional work force projections. Besides, labour could flows between regions accordingly to relative real wages.

ii) Capital is endogenous and its evolutions it is associated to investment. The investment in each sector, by its turn, follows rates of return. The exception is electricity generation industries, where we are controlling the investment for simulation purposes.

iii) Land is mainly used by agriculture and livestock, but mining, oil, gas and hydro generation sectors also use a slight amount of this resource. For the period 2016-2035, we are expanding the agricultural land in each region by a uniform rate equivalent to 1/4 of the increase rate observed in the last 5 years.

For technological progress we consider an annual increase of 2.0% for land productivity and of 0.5% for productivity of Transmission and Distribution industry[12]. On the demand side, we adopt a growth rate of 2.5% for exports (quantity) and the PDE’s rates for GDP during the period 2017-2026 and an average rate of 3.0% after that.

In electricity industry, we assume the Case 8 (directed expansion) as our baseline. This is the scenario with less policy interventions and hence, closer to a natural expansion of installed capacity. Our policy alternatives are the Case 1 (reference), Case 4(solar) and Case 5(no new hydro dams). These scenarios have specific guidelines that affect the electricity mix (Figure 2).

We consider that PDE investments are mainly support by foreign savings. This assumption in our closure relies on the fact that Brazil is under fiscal austerity and is mostly funding its infrastructure projects via concessions. In electricity, foreign investment have been leading this process, achieving more than 75% of total investment in the sector[13]. On the other hand, this assumption could affect the exchange rate during the investment period, but it should smoothly return to its equilibrium level after that.

[12] In Brazilian context, it represents a reduction in losses and differences (“Perdas e Diferenças”) of the national grid.

[13] According to data from Brazilian Central Bank, in 2017, foreign investment in capital in electricity corresponds to approximately 75% of the total (BNDES disbursements + foreign investment in capital).

4. RESULTS

4.1 Macroeconomic aggregates and production

Our results show that all policies have a positive deviation from the baseline in macroeconomic aggregates. This gives us a first insight that government guidelines embodied by those scenarios are resulting in economic benefits. The exception is Exports. However, we could interpret this as an outcome of our long-run closure, where the investment is supported by foreign savings and, consequently, implies appreciation of the exchange rate (Table 2). The strict relations between Capital Stock and Investment as well as Household consumption and GDP were also verified.

Table 2 – Macro variables: % cumulative deviation (2016-2035) from baseline

	GDP	Real Household consumption	Real Investment	Capstock	Exports Volume	Exchange Rate
Case 1 (Reference)	0.12	0.14	0.40	0.27	-0.82	-0.24
Case 4 (Solar)	0.45	0.52	1.43	1.11	-2.58	-0.90
Case 5 (no-hydro)	0.07	0.09	0.24	0.18	-0.47	-0.12

Source: model results.

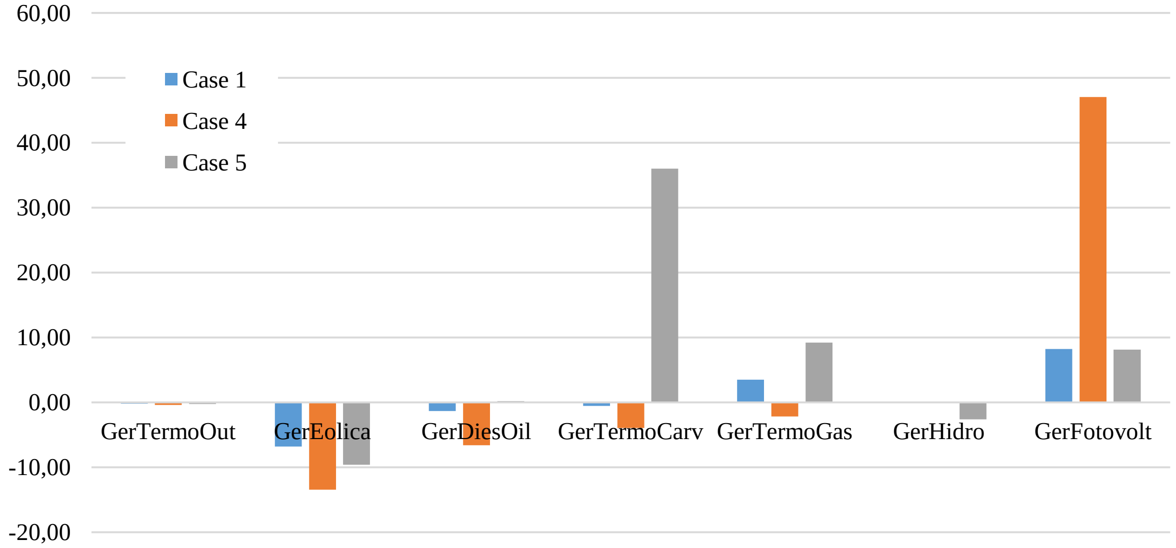
The Reference scenario, the closest to our baseline, results in a slight increase of GDP (0.12%), due to more investments in solar and gas sources. The Case 4, intensive in solar source and which has the greater amount of investment estimated by PDE 2026, is responsible for the large impacts: 0.45% in GDP and 1.43% in aggregated investment. By its turn, the no new hydro dam scenario (case 5) also has a positive effect in economic terms, even with less investment in monetary units, estimated by PDE 2026, than the baseline.

These specific results, which occur in both Case 1 and Case 8, evidence that there is no a straight link between the total amount of investment, estimated outside the model, and its impact on the economy in terms of GDP, aggregated investment and other variables. These impacts are also driven by the spread out effects of the electricity industry which receive the investment. In this case, the no-hydro scenario has more investment in Coal and Solar sources than the baseline. These technologies, by its turn, have an investment vector more concentrated in equipment and machinery while the hydro dams are infra-construction intensive (Table A-02, in Appendix). Our results, hence, reflect the net impact of all those effects.

The specifics about investment in electricity industries also affect the production of others sectors. In the Reference scenario, for example, the Natural Gas industry expanded 0,82% (in relation to the baseline), reflecting the Natural Gas plant that Case 1 has in addition to the Case 8. This also happens to Case 5 (1.21%), in which the investment in thermal electricity from gas increases to substitute the absence of new hydro dams. In Solar scenario, on the other hand, we observe the Electronic sector increasing by 1.15% in response to large investments in photovoltaic generation, meanwhile the Natural Gas industry reduces production in -1.45%. Sectors associated with other generations sources as Oil, Sugar and Machinery for Construction declined their production as well.

The electricity industries, particularly, increase or reduce their production in response to changes in prices and/or the expansion of their capital stock. Our results show that Solar generation industry ("GerFotovolt"), for example, increases its production in every scenario, but followed by a reduction of wind electricity (Graph 01). This is consisting with PDE 2026 expansion plans, where an addition of solar is followed by reduction in wind electricity due to peak and seasonality reasons. However, as the net effect in GDP is positive, it suggests that, *a* *priori* and subject to the supply plan estimated by PDE 2026, to support a specific demand using photovoltaic generation has a greater spread out effect than wind technology[14]. Besides, our results also show that the policy of restrict new hydro dams (Case 5) is compensated by an increase in electricity generation form Coal ("GerTermoCarv"), as planned by PDE 2026.

Graph 01 – Electricity industries production: % cumulative deviation (2016-2035) from baseline



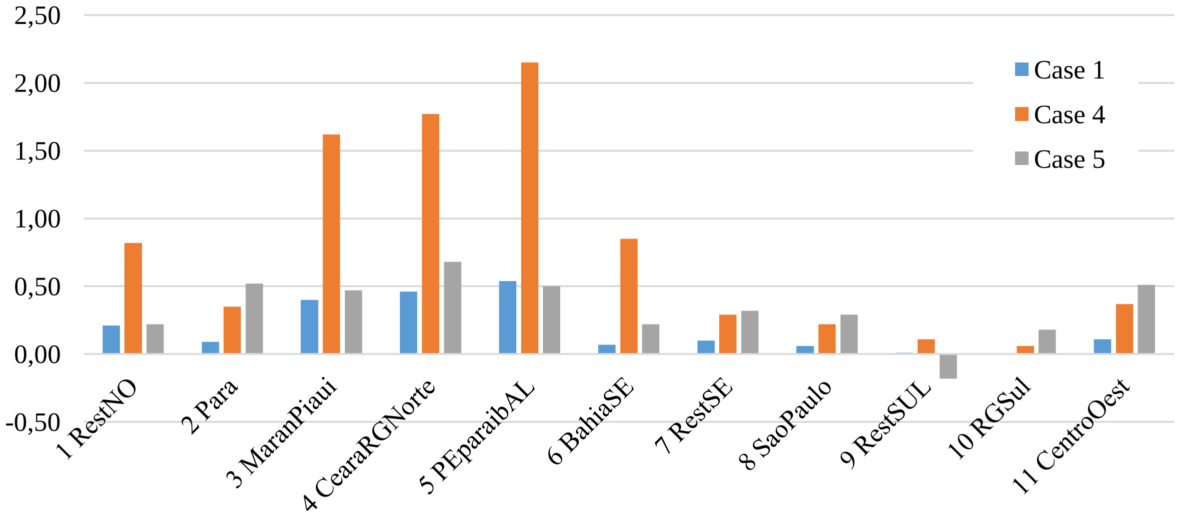
Source: model results.

Regionally, differences between the policy scenarios are clearly visible. In the case 5 (no-hydro), for example, those regions with large share of hydro generation in its electricity mix, such as North and South regions[15], face a GDP loss. On the other hand, locations with geographic conditions to host solar investments had an increase in GDP in scenario 4. This is the case of Northeast regions, such as PEparaibAL, CearaRGNorte and MaranPiaui. These areas also have positive deviation under Reference scenario due to greater solar and gas investments than our baseline (Graph 2). As expected, the household consumption follows regional GDP, while the capital stock is linked to the investment. Regarding to the exports, all regions face negative deviation because of the same reasons as the national exports (Table A-04).

[14] This does not mean that one dollar invested in solar source have more impact than in Wind.

[15] Pará state is located in North region and site the Belo Monte dam. However, this project is already contracted and, consequently exists in all scenarios. Thus, this state is not too affected by the constraints of Case 5.

Graph 2 – Regional GDP: % cumulative deviation (2016-2035) from baseline by policies alternatives.



Source: model results.

The electricity generation at regional level also respond to prices and capital stock. Hence, wind and hydro electricity has negative deviation in all regions and in all scenarios, as a consequence of government interventions. On the other hand, solar electricity had large increase in almost all regions (Table A-05). Summarily, under PDE 2026 guidelines the Northeast region is the most benefitted in terms of electricity production, as expressed by the results of Transmission and Distribution industry. However, it is important to highlight that under hydro restriction (Case 5) the Southeast region ("RestSE" and "SaoPaulo") have the largest deviation for T&D due to its increase in gas electricity supply (Table A-05).

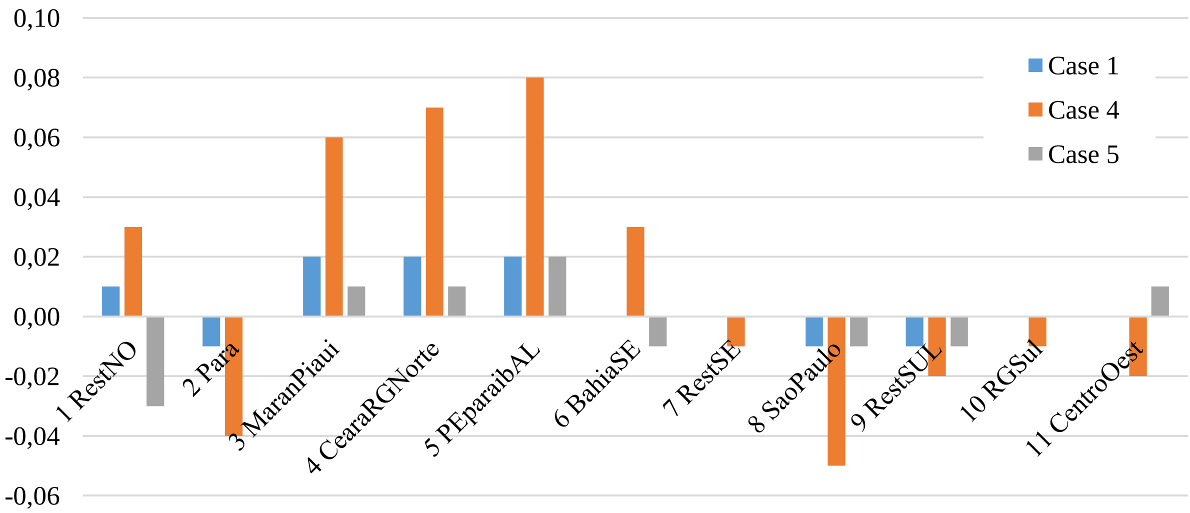
The impact among other sectors was also affected by regional characteristics. The agriculture and cattle industry, for example, had large expansion in Northeast region, where it represents, in relative terms, a significant part of GDP. São Paulo state, which has about 35% of national industry, had positive deviation in sectors such as Construction, Services and Manufacturing due its local activity as well as demands from other regions.

4.2 Employment and distributive effects

Despite the economic growth, we do not observe for aggregated employment significant deviation between scenarios and the baseline, once they are subject to the same population and work force expansion as well as a long-run closure. However, at regional level we observe, in general, an increase in the employment in North and Northeast regions combined to a reduction other regions, specially South ("RestSul" and "RGsul") and Southeast ("RestSE" and "SaoPaulo"). This movement is quite noticeable in Case 4 (solar), in which the Northeast regions have a large GDP growth, and it is slightly different for Case 5, when the employment in "RestNO" region is affected by the restrictions applied to new hydro dams[16] (Graph 3).

[16] At a first view, these deviations could be interpreted as small, but they are relevant in terms of jobs. For example, in 2035 the work force at "CearaRGNorte" is estimated in 9.34 million workers. If we consider Case 4, the deviation of 0.07% represents about 6,580 employers, i.e. additional jobs derivate from investments that this scenario has in addition to the baseline. For "PEparaibAL" region, this number is 9,941 jobs.

Graph 3 – Regional Employment: % cumulative deviation (2016-2035) from baseline by policies alternatives.



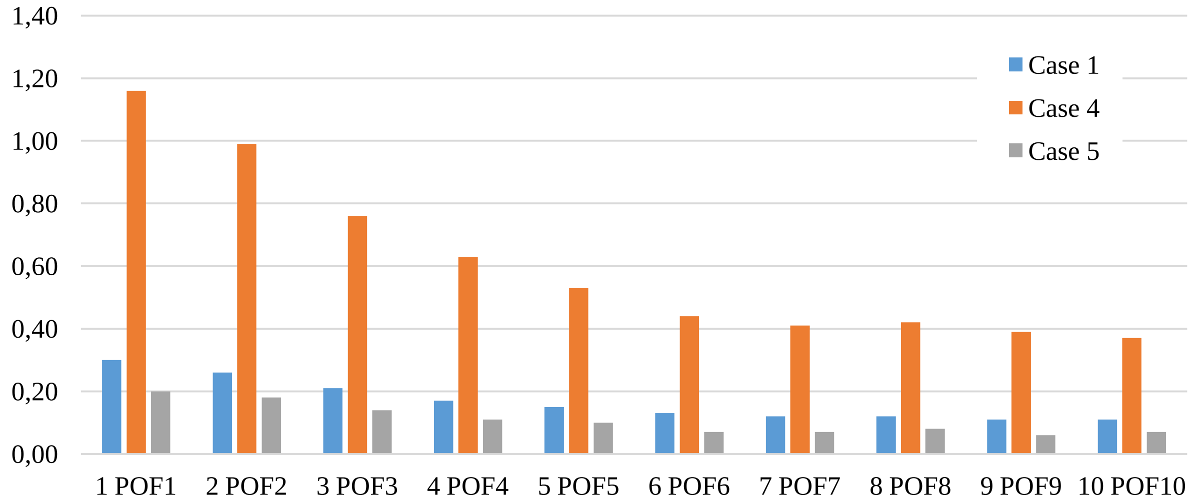
Source: models results.

Our results also show that regions with greater variations in employment also had the largest increases in wages. In opposite way, regions with a reduction in jobs are those with small increase or negative variations in salaries (Table A-06). This clearly shows that regional employment follows the relative wage and that the net effect is a movement of employment from regions with large share of national GDP, such as “SaoPaulo”, to those with small share, such as the Northeast regions “MaranPiaui”, “CearaRGNorte” and “PEparaibAL”.

We are also able to see that the increase in wages was relatively bigger in low skilled jobs than in other classes (Table A-7). This supports our regional results, once Northeast regions have large share of their labour force composed by low skilled workers. However, it is important to highlight that high skilled jobs also had a positive effect in both quantity and wages due to economy activity in specialized industries associated to electricity generation, such as manufacturing and electronics. This effect, by the way, is more intensive in Case 4.

Supported by regional macroeconomic and employment results, the impact to household consumption was relatively bigger in those families with low income (Graph 4). Unmistakable, this shows that policy interventions in the energy planning have welfare implications as well as that sources considered in the energy mix substantially matters to these impacts.

Graph 4 – Household consumption: % cumulative deviation (2016-2035) from baseline by policies alternatives and income categories.



Source: models results.

5. FINAL REMARKS

The scenarios provided by The Brazilian Decennial Energy Plan (PDE 2026) shows that Brazil has a privileged position regarding its electricity supply: the country could face different geographic and market restrictions and still provide a diverse and renewable mix compatible with climate agreements and economic growth.

Our work shows that this flexibility in electricity supply also entails important economic and regional issues. A supply plan with more insertion of solar source, for example, could increase the national GDP by 0.45% and by 2.15% in specific regions. As well, we show that a no new hydro dam scenario does not imply economic losses, in terms of national GDP or employment. Both results are quite interesting, taking in account that cost for solar panels has been drastically reduced in the last years and the hydrologic and environmental restrictions could impose important limits to the expansion of hydro dams.

We also show that the economic impacts are greater in the poorest regions and to the low income households, portraying welfare and distributive benefits of policy guidelines. This result offers useful insights for policy makers, once Brazil still faces a strong regional inequality and the combination of energy and regional policy could be effective.

Finally, we highlight that our results are restricted to the economic analysis of the electricity plans. The extension of the analysis to incorporate environmental issues, mainly emissions, is of obvious importance, and will be the next step in this research effort.

6. REFERENCES

BRASIL. **Intended Nationally Determined Contribution Towards Achieving the Objective of The United Nations Framework Convention on Climate Change**. 2015.

BYE, B. Macroeconomic modeling for energy and environmental analyses: Integrated economy-energy-environment models as efficient tools. **Statistics Norway, Research Department**, 2008/14, 2008.

CANSINO, J. M. et al. The economic influence of photovoltaic technology on electricity generation: A CGE (computable general equilibrium) approach for the Andalusian case. **Energy**, v. 73, p. 70–79, 2014.

CAPROS, P.; KARADELOGLOU, P.; MENTZAS, G. Employment impacts of energy: A survey and framework for analysis. **Socio-Economic Planning Sciences**, v. 26, n. 4, p. 257–274, 1992.

CHEN, Y. H. H.; TIMILSINA, G. R.; LANDIS, F. Economic implications of reducing carbon emissions from energy use and industrial processes in Brazil. **Journal of Environmental Management**, v. 130, p. 436–446, 2013.

DAI, H. et al. Green growth: The economic impacts of large-scale renewable energy development in China. **Applied Energy**, v. 162, p. 435–449, 2016.

DINIZ, T. B. 2013. **Impactos socioeconômicos do Código Florestal Brasileiro: uma discussão à luz de um modelo computável de equilíbrio geral**. Dissertação de Mestrado, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba. Recuperado em 2014-08-30, de

DINIZ, Tiago; FERREIRA FILHO, Joaquim Bento. Impactos Econômicos do Código Florestal Brasileiro: uma discussão à luz de um modelo computável de equilíbrio geral. **Rev. Econ. Sociol. Rural**, Brasília , v. 53, n. 2, p. 229-250, June 2015. Available from <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-20032015000200229&lng=en&nrm=iso>. access n 08 Nov. 2015. http://dx.doi.org/10.1590/1234-56781806-9479005302003

DIXON, P.B.; RIMMER, M.T. **Johansen's Contribution to CGE Modelling**: Originator and Guiding Light for 50 Years. General Paper No. G-203. Centre of Policy Studies and the Impact Project. Clayton: Monash University Press, 2010. 52 p.

EPE - Empresa de Pesquisa Energética. **Balanço Energético Nacional 2016**. EPE, 2016.

________________. **Anuário Estatístico de Energia Elétrica 2016**. EPE, 2016.

________________. **Plano Decenal de Energia – PDE 2026**. EPE, 2017.

FERREIRA FILHO, J.B.S. **Introdução aos modelos de equilíbrio geral: conceitos, teoria e aplicações**. 2010. 31 p. Piracicaba: Escola Superior de Agricultura "Luiz de Queiroz", 2010. Disponível em: <http://www.economia.esalq.usp.br/~jbsferre>. Acesso em: 15 dez. 2010.

FERREIRA FILHO, J. B. S.; HORRIDGE, M. J. **Ethanol expansion and indirect land use change in Brazil.** Land Use Policy, v. 36, p. 595-604, 2014.

FERREIRA FILHO, J. B. S.; RIBEIRA, L; HORRIDGE, M. J. **Deforestation Control and Agricultural Supply in Brazil.** American Journal of Agricultural Economics, v. 97, p. 589-601, 2015.

HORRIDGE, M. 2011. **The TERM model and its data base**. General Paper No. G-219. Centre of Policy Studies, Monash University.

Horridge, J.M., Madden, J.R. and G. Wittwer (2005), "The impact of the 2002-03 drought on Australia", Journal of Policy Modeling, Vol 27/3, pp. 285-308.

Horridge, J.M. and G. Wittwer (2010), "Bringing regional detail to a CGE model using census data", Spatial Economic Analysis, Volume 5 Issue 2, pp 229-255, Routledge [Jun 3, 2010]

HUDSON, E.A., JORGENSON, D.W. **U.S. Energy Policy and Economic Growth**, Bell Journal of Economics and Management Science 5(2):46 l-5 14, 1975.

IBGE. **Matriz de insumo-produto : Brasil : 2010**. 59p. Rio de Janeiro, 2016.

IPCC, 2014: **Climate Change 2014: Synthesis Report**. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IRENA. **Renewable Energy Jobs: Status, Prospects & Policies**. IRENA Working Paper, 2011.

LEHR, U. et al. Renewable energy and employment in Germany. **Energy Policy**, v. 36, n. 1, p. 108–117, 2008.

MANNE, A. **ETA-Macro: A Model of Energy Economy Interactions**. EA-592 Research Report 1014. Palo Alto: Electric Power Research Institute, 1977.

MIGUEZ, T.H.L. Evolução da Formação Bruta de Capital Fixo na Economia Brasileira 2000-2013: Uma Análise Multissetorial a partir das Matrizes de Absorção de Investimento (MAIS)

MORENO, B.; LÓPEZ, A. J. The effect of renewable energy on employment. The case of Asturias (Spain). **Renewable and Sustainable Energy Reviews**, v. 12, n. 3, p. 732–751, 2008.

PEREIRA, A. O. et al. Perspectives for the expansion of new renewable energy sources in Brazil. **Renewable and Sustainable Energy Reviews**, v. 23, p. 49–59, 2013.

PEREIRA, M. G. et al. The renewable energy market in Brazil: Current status and potential. **Renewable and Sustainable Energy Reviews**, v. 16, n. 6, p. 3786–3802, 2012.

POLLIN, R.; HEINTZ, J.; GARRETT-PELTIER, H. The Economic Benefits of Investing in Clean Energy: How the economic stimulus program and new legislation can boost U.S. economic growth and employment. **Department of Economics and Political Economy Research Institute (PERI), University of Massachusetts.**, n. June, 2009.

SANTOS, G. F.; HADDAD, E.A.; HEWINGS, G.J.D. 2013. **Energy policy and regional inequalities in the Brazilian economy**. Energy Economics 36, 241-255.

SIMAS, M.; PACCA, S. Socio-economic Benefits of Wind Power in Brazil. **Journal of Sustainable Development of Energy, Water and Environment Systems**, v. 1, n. 1, p. 27–40, 2013.

SIMAS, M.; PACCA, S. Assessing employment in renewable energy technologies: A case study for wind power in Brazil. **Renewable and Sustainable Energy Reviews**, v. 31, p. 83–90, 2014.

SUE WING, I. The synthesis of bottom-up and top-down approaches to climate policy modeling: Electric power technology detail in a social accounting framework. **Energy Economics**, v. 30, n. 2, p. 547–573, 2008.

TOURKOLIAS, C.; MIRASGEDIS, S. Quantification and monetization of employment benefits associated with renewable energy technologies in Greece. **Renewable and Sustainable Energy Reviews**, v. 15, n. 6, p. 2876–2886, 2011.

UK Energy Research Centre**. Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy**. REF UKERC/RR/TPA/2014/002. November, 2014.

Wittwer, G. and Griffith, M. (2011), "Modelling drought and recovery in the southern Murray-Darling basin", Australian Journal of Agricultural and Resource Economics. 55(3): 342-359.

APPENDIX

Table A-01 – TERM-BR10 Electricity industries: distribution of spending in investment commodities

	GerTermoOut	GerEolica	GerTermoOleo	GerTermoDies	GerTermoCarv	BagAcucar	BagEthanol	GerTermoGas	GerHidro	GerFotovolt
1 Laranja	0	0	0	0	0	0	0	0	0	0
2 CafeGrao	0	0	0	0	0	0	0	0	0	0
3 OutPrLavPerm	0	0	0	0	0	0	0	0	0	0
4 BovOutrAnim	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
5 Suinos	0	0	0	0	0	0	0	0	0	0
6 AvesOvos	0	0	0	0	0	0	0	0	0	0
7 ExplFlorSilv	0	0	0	0	0	0	0	0	0	0
8 Petro	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
9 ProdMadeira	0	0	0	0	0	0	0	0	0	0
10 ProduMetal	0.044	0.115	0.044	0.044	0.044	0.043	0.043	0.044	0.018	0.003
11 MaqEscEquInf	0.017	0.019	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.022
12 MatEletrCom	0.009	0.061	0.009	0.009	0.009	0.009	0.009	0.009	0.017	0.186
13 EqMedContOpt	0.041	0.003	0.041	0.041	0.041	0.04	0.04	0.041	0.04	0.003
14 MaqApaEquEle	0.023	0.141	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.183
15 Eletrodome	0	0	0	0	0	0	0	0	0	0
16 TratMaqAgric	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.003	0.005
17 MaqExtConst	0.043	0.011	0.043	0.043	0.043	0.042	0.042	0.043	0.021	0.013
18 OutMaqEquip	0.345	0.16	0.345	0.345	0.345	0.211	0.211	0.345	0.088	0.191
19 Automoveis	0.012	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.015
20 CaminhOnib	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
21 OutrEquTran	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
22 Moveis	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004
23 OutAtivIndst	0.072	0.081	0.072	0.072	0.072	0.036	0.036	0.072	0.022	0.047
24 ManRepMaqEqp	0.002	0.002	0.002	0.002	0.002	0.042	0.042	0.002	0.018	0.002
25 ConstEdif	0.096	0.108	0.096	0.096	0.096	0.095	0.095	0.096	0.094	0.123
26 ConstInfra	0.136	0.111	0.136	0.136	0.136	0.318	0.318	0.136	0.514	0.079
27 SevEspConst	0.085	0.096	0.085	0.085	0.085	0.06	0.06	0.085	0.059	0.031
28 DesenSistOut	0.009	0.01	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.012
29 SevPesqDesn	0.009	0.029	0.009	0.009	0.009	0.008	0.008	0.009	0.008	0.045
30 SevArquiEng	0.037	0.017	0.037	0.037	0.037	0.015	0.015	0.037	0.022	0.019
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Source: elaborated by authors.

Table A-02 – Aggregated commodities and industries in TERM-BR10 model.

1 Agricultura	11 AlimentBebid	21 Eletronicos	**31 GerHidro**
2 CanaDeAcucar	12 TextilCouro	22 Automoveis	**32 GerFotovolt**
3 Pecuaria	13 MadCelulose	23 MaqExtConst	**33 TeDEletric**
4 PescaAcq	14 OutCombust	24 Gas	34 AguaEsgRes
5 Mineracao	15 OleoComb	**25 GerTermoOut**	35 Construcao
6 GasNat	16 DieselBiodis	**26 GerEolica**	36 Comercio
7 Petro	17 EtanolCombus	**27 GerDiesOil**	37 Transporte
8 CarnesPeixes	18 Quimicos	**28 GerTermoCarv**	38 Servicos
9 Laticinios	19 OutManuf	**29 GerBagaco***	39 SevPesqDesn
10 Acucar	20 Metalurgia	**30 GerTermoGas**	40 SevArquiEng

Source: authors. * GerBagaco is only a commodity.

Table A-03 – Regional distribution for PDE expansion by source

	HIDRO	PCH	BIOMASS	BIOMF	EOL SUL	EOL NE	FOTOVOLT	GNSE	GNSUL	GNNE	PONT SUL	PONT NE	PONT SE	CARVAO
1 Rondonia	**14.0**	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
2 Acre	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	0.0
3 Amazonas	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	0.0
4 Roraima	**28.4**	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
5 Para	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	0.0
6 Amapa	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	0.0
7 Tocantins	0.0	**2.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 Maranhao	0.0	0.0	0.0	0.0	0.0	**5.0**	**5.0**	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
9 Piaui	0.0	0.0	0.0	0.0	0.0	**10.0**	**10.0**	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
10 Ceara	0.0	0.0	0.0	0.0	0.0	**20.0**	**10.0**	0.0	0.0	**20.0**	0.0	**20.0**	0.0	0.0
11 RGNorte	0.0	0.0	0.0	0.0	0.0	**20.0**	**5.0**	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
12 Paraiba	0.0	0.0	0.0	0.0	0.0	**5.0**	**5.0**	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
13 Pernambuco	0.0	**3.0**	0.0	0.0	0.0	**10.0**	**15.0**	0.0	0.0	**20.0**	0.0	**20.0**	0.0	0.0
14 Alagoas	0.0	0.0	0.0	0.0	0.0	0.0	**5.0**	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
15 Sergipe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**5.0**	0.0	**5.0**	0.0	0.0
16 Bahia	0.0	0.0	0.0	0.0	0.0	**30.0**	**25.0**	0.0	0.0	**30.0**	0.0	**30.0**	0.0	0.0
17 MinasG	0.0	**13.0**	**15.0**	**10.0**	0.0	0.0	**15.0**	**20.0**	0.0	0.0	0.0	0.0	**20.0**	0.0
18 EspSanto	0.0	**5.0**	0.0	**10.0**	0.0	0.0	0.0	**5.0**	0.0	0.0	0.0	0.0	**5.0**	0.0
19 RioJaneiro	0.0	**8.0**	0.0	**10.0**	0.0	0.0	0.0	**15.0**	0.0	0.0	0.0	0.0	**15.0**	0.0
20 SaoPaulo	0.0	**7.0**	**25.0**	**10.0**	0.0	0.0	**5.0**	**25.0**	0.0	0.0	0.0	0.0	**25.0**	0.0

21 Parana	**17.5**	**15.0**	**10.0**	**10.0**	0.0	0.0	0.0	0.0	**35.0**	0.0	**35.0**	0.0	0.0	0.0
22 StaCatari	0.0	**10.0**	0.0	**10.0**	**15.0**	0.0	0.0	0.0	**30.0**	0.0	**30.0**	0.0	0.0	**15.0**
23 RGSul	**29.0**	**6.0**	0.0	**10.0**	**85.0**	0.0	0.0	0.0	**35.0**	0.0	**35.0**	0.0	0.0	**85.0**
24 MtGrSul	**3.2**	**11.0**	**15.0**	**10.0**	0.0	0.0	0.0	**10.0**	0.0	0.0	0.0	0.0	**10.0**	0.0
25 MtGrosso	**7.9**	**8.0**	**10.0**	**10.0**	0.0	0.0	0.0	**15.0**	0.0	0.0	0.0	0.0	**15.0**	0.0
26 Goias	0.0	**10.0**	**25.0**	**10.0**	0.0	0.0	0.0	**10.0**	0.0	0.0	0.0	0.0	**10.0**	0.0
27 DF	0.0	**2.0**	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	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: elaborated by authors.

Table A-04 – Macro variables: % cumulative deviation (2016-2035) from baseline, by region and policy scenarios

	North		**Northeast**				**Southeast**		**South**		**Central West**
	RestNO	**Para**	**MaranPiaui**	**CearaRGNorte**	**PEparaibAL**	**BahiaSE**	**RestSE**	**SaoPaulo**	**RestSUL**	**RGSul**	**CentroOest**
GDP											
Case 1	0.23	0.10	0.41	0.49	0.56	0.10	0.11	0.07	0.01	0.00	0.14
Case 4	0.91	0.39	1.74	1.99	2.32	0.96	0.31	0.23	0.11	0.07	0.43
Case 5	-0.17	0.07	0.31	0.39	0.48	0.04	0.17	0.06	-0.19	-0.17	0.12
Household consumption											
Case 1	0.31	0.14	0.49	0.59	0.58	0.18	0.13	0.06	-0.02	-0.05	0.20
Case 4	1.13	0.50	1.90	2.70	2.24	1.21	0.25	0.11	-0.01	-0.12	0.49
Case 5	-0.10	0.09	0.32	0.46	0.49	0.09	0.22	0.05	-0.26	-0.24	0.21
Investment											
Case 1	0.86	0.44	1.12	1.99	0.87	0.40	0.34	0.14	-0.17	-0.02	0.71
Case 4	3.34	1.86	4.92	9.35	4.34	3.11	0.94	0.27	0.04	0.47	1.23
Case 5	0.21	0.32	0.66	1.52	0.59	0.08	0.48	0.14	-1.12	-0.75	0.94
Exports (volume)											
Case 1	-1.34	-1.23	-0.80	-1.78	-1.51	-0.93	-0.86	-0.81	-0.82	-0.70	-1.08
Case 4	-4.68	-4.47	-2.98	-7.24	-5.35	-3.30	-2.83	-2.58	-2.95	-2.50	-3.31
Case 5	-0.53	-0.69	-0.64	-1.16	-0.96	-0.60	-0.71	-0.51	-0.09	-0.22	-0.81
AggEmploy											
Case 1	0.01	-0.01	0.02	0.02	0.02	0.00	0.00	-0.01	-0.01	0.00	0.00
Case 4	0.04	-0.04	0.06	0.08	0.08	0.04	-0.02	-0.05	-0.02	-0.02	-0.02
Case 5	-0.02	0.00	0.01	0.01	0.02	0.00	0.00	-0.01	-0.02	-0.01	0.01
Realwage_io											
Case 1	0.37	0.21	0.54	0.64	0.63	0.24	0.20	0.13	0.05	0.02	0.27
Case 4	1.33	0.78	2.07	2.85	2.39	1.40	0.50	0.39	0.25	0.12	0.75
Case 5	-0.03	0.13	0.36	0.50	0.52	0.14	0.27	0.10	-0.19	-0.18	0.25

AggCapStock											
Case 1	0.53	0.20	1.04	1.28	1.50	0.24	0.25	0.18	0.05	0.02	0.28
Case 4	2.14	0.87	4.52	5.04	6.34	2.48	0.76	0.67	0.34	0.22	1.00
Case 5	-0.50	0.13	0.79	1.01	1.30	0.08	0.41	0.14	-0.43	-0.41	0.20

Source: model results.

Table A-05 – Production of electricity sectors: % cumulative deviation (2016-2035) from baseline, by region and policy scenarios

	RestNO	Para	MaranPiaui	CearaRGNorte	PEparaibAL	BahiaSE	RestSE	SaoPaulo	RestSUL	RGSul	CentroOest
Wind											
Case 1	-0,1	-0,1	-7,0	-6,1	-8,7	-6,8	-0,1	-0,1	-9,6	-8,5	-0,1
Case 4	-0,1	-0,2	-13,0	-12,1	-16,5	-12,9	-0,2	-0,2	-17,7	-15,7	-0,2
Case 5	0,0	-0,1	-9,7	-8,6	-12,2	-9,5	-0,2	-0,1	-13,6	-12,0	-0,1
DieselOil											
Case 1	0,0	0,0	0,0	0,0	-0,1	-0,5	0,0	0,0	-0,1	0,0	-0,1
Case 4	0,0	0,0	0,3	-1,9	-0,5	-0,6	0,2	0,0	-0,1	-0,1	-0,1
Case 5	-0,1	-0,1	-0,1	0,0	-0,1	-0,6	-0,1	0,0	-0,1	0,0	-0,1
Coal											
Case 1	0,0	-0,1	-0,2	-0,4	-2,7	-0,5	-0,2	-0,1	-0,1	-0,1	-0,1
Case 4	0,0	-0,2	-0,1	-7,9	-2,6	-1,4	-0,1	-0,1	-0,1	-0,3	-0,2
Case 5	0,0	-0,1	-0,1	-0,4	-2,6	-0,4	-0,2	0,0	56,2	96,0	-0,1
Gas											
Case 1	0,0	0,0	3,3	16,5	14,3	-2,0	5,8	9,2	-9,4	-7,4	4,4
Case 4	0,0	-0,1	9,5	14,1	38,2	-28,1	-3,5	-5,3	-16,7	-13,3	-9,8
Case 5	0,0	-0,1	2,5	12,4	10,7	-1,9	26,3	41,1	-68,6	-60,3	9,9
Hydro											
Case 1	-0,1	-0,1	-0,1	-0,2	-0,3	-0,1	-0,1	-0,1	-0,1	0,0	-0,1
Case 4	-0,2	-0,2	-0,4	-1,0	-0,8	-0,5	-0,2	-0,2	-0,1	-0,1	-0,2
Case 5	-7,6	-0,1	-0,1	-0,1	-0,2	-0,1	-0,2	-0,1	-1,7	-11,2	-1,6
Solar											
Case 1	0,0	0,0	12,6	11,9	14,1	-4,8	10,5	8,6	0,0	0,0	0,0
Case 4	-0,1	0,0	57,0	52,9	63,3	26,4	47,6	39,0	0,0	0,0	-0,1
Case 5	0,0	0,0	12,7	11,9	14,1	-4,8	10,5	8,6	0,0	0,0	-0,1
Others											
Case 1	-0,2	-0,1	-0,3	-0,3	-0,5	-0,2	-0,3	-0,1	-0,1	-0,1	-0,3
Case 4	-0,4	-0,3	-0,7	-1,9	-1,4	-1,0	-0,5	-0,3	-0,2	-0,2	-0,3
Case 5	0,0	-0,1	-0,2	-0,3	-0,4	-0,2	-0,3	-0,2	0,0	0,1	-0,3

T&D											
Case 1	-0,1	-0,1	3,3	5,4	5,5	-2,1	2,1	1,2	-0,7	-0,8	0,5
Case 4	-0,1	-0,2	14,1	15,3	23,5	3,7	2,6	0,7	-1,3	-1,4	-2,7
Case 5	-4,7	-0,1	2,9	4,2	5,3	-2,2	7,1	4,6	-5,0	-4,7	0,8

Source: model results.

Table A-06 – Real wage: % cumulative deviation (2016-2035) from baseline, by region and policy scenarios

	RestNO	**Para**	**MaranPiaui**	**CearaRGNorte**	**PEparaibAL**	**BahiaSE**	**RestSE**	**SaoPaulo**	**RestSUL**	**RGSul**	**CentroOest**
Case 1	0,35	0,21	0,56	0,67	0,64	0,19	0,18	0,12	0,05	0,02	0,24
Case 4	1,29	0,75	2,07	2,75	2,35	1,29	0,48	0,38	0,24	0,12	0,72
Case 5	-0,05	0,12	0,36	0,51	0,52	0,09	0,25	0,09	-0,16	-0,16	0,19

Source: model results.

Table A-07 – Real wage: % cumulative deviation (2016-2035) from baseline, by skill level and policy scenarios

	1 OCC1	**2 OCC2**	**3 OCC3**	**4 OCC4**	**5 OCC5**	**6 OCC6**	**7 OCC7**	**8 OCC8**	**9 OCC9**	**10 OCC10**
Case 1	0,52	0,27	0,20	0,16	0,16	0,17	0,19	0,17	0,20	0,19
Case 4	2,26	1,03	0,68	0,49	0,56	0,60	0,67	0,62	0,73	0,65
Case 5	0,29	0,17	0,14	0,12	0,12	0,11	0,12	0,11	0,12	0,13

Source: model results.