APPENDIX B - BESMM input data

Figure B-1 presents the installed capacity values added for each technology and subsystem. Southeast/Midwest has 52% of the total installed capacity of Brazil and at the same time 58% of the total electricity demand of Brazil. The other subsystems' demand rate is: 17% in the South region, 16% in the Northeast, and 8% in the North region.

	Technology	North [GW]		Northeast [GW]		Southeast/Midwest [GW]		South [GW]	
	Hydro	19.8	82%	11.02	34%	63.21	73%	16.99	73%
	Termo	3.93	16%	7.33	23%	20.71	24%	4.22	18%
	Wind	0.328	1%	12.61	39%	0.03	0%	2.02	9%
	Solar	0.05	0%	1.40	4%	0.68	1%	0.04	0%
	Nuclear					1.99	2%	-	
	Total	24.11	100.0%	32.36	100.0%	86.61	100.0%	23.27	100.0%

Figure B-1 – Installed capacity of each node according to historical values from 2019 [Adapted from EPE, 2020a].

The transmission lines in BESMM are described in **Error! Reference source not found.** In this representation there are four transmission lines, one connecting the North node with the Northeast node, one connecting the Northeast with the Southeast/Midwest, on connecting the Southeast/Midwest node with the North node, and one connecting the South node with the Southeast/Midwest node.

Table B-1 - Transmission lines capacity for each node [Adapted from ONS, 2022c].

Node	GW
North ↔ Northeast	44.1
Northeast ↔ Southeast/Midwest	22.1
Southeast/Midwest ↔ North	83.1
South ↔ Southeast/Midwest	48.5

Table B-2 shows the energy generation activity in Brazil in 2019 used as case activity input in BESMM.

Table B-2 – Energy generation activity of each subsystem according historical values from 2019 [Adapted from EPE, 2020a].

	North [GWa]	Northeast [GWa]	Southeast [GWa]	South [GWa]	Total [GWa]
Hydro	7.5	2.5	29.7	8.0	47.7
Termo	1.8	2.1	6.1	1.2	11.2
Wind	0.2	5.5	0.0	0.7	6.4
Solar	0.0	0.4	0.2	0.0	0.6
Nuclear			1.8		1.8
Total	9.5	10.5	37.9	9.9	67.8

Demand projections used the rate of the SSP2-45 for Latin America developed by Huppmann et al., 2019a, for MESSAGE-GLOBIOM 1.0. Overall, an SSP socioeconomic pathway describes the drivers of how the future might unfold in terms of population growth, governance efficiency, inequality across and within countries, socio-economic developments, institutional factors, technology change, and environmental conditions that are influenced by these factors [Riahi et al., 2017]. And, SSP2 outlines a middle-of-the-road approach to mitigating and adapting to climate change [Fricko et al., 2017]. Figure B-2 shows the projections for each node of the BESMM based on the growth rates of SSP2-45 for Latin America. According to this projection, the energy demand in Brazil in 2100 will be 368 GWa, with almost 60% of that demand coming from the Southeast/ Midwest alone.
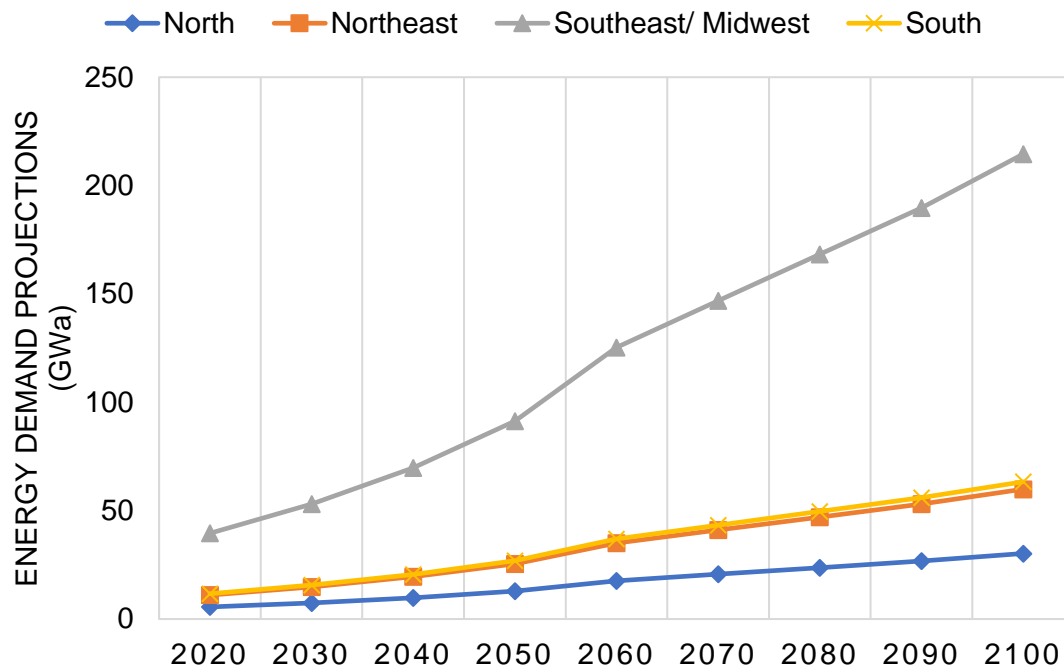
Figure B-2 – Energy demand projections for each node based on SSP2-45 scenario.

Technology prices were based on the PNE 2050 [BRASIL, 2020]. According to Brasil (2020) The investment costs and fix costs, for each source, were obtained from the EPE database, constituted from information on energy purchase auctions and national and international references. Investment costs include all direct costs (civil works, equipment, connection and environment) and indirect costs of the development. The variable cost values reflect the sum of the fixed and variable values, except for dispatchable sources (where the variable O&M is contemplated in the unit variable cost). Table B-3 present all the values used in the BESMM.

Table B-3 - Technologies costs, including investments costs, fix costs and variable costs [Adapted from BRASIL, 2020].

Technology	Investment costs [106USD[1]/GW]	Fix cost [106USD[1]/GW]	Variable cost [106USD[1]/GW]
Hydropower	1352	12.8	
Biomass power plant	1200	23.1	
Natural Gas power plant	900	220.0	25
Coal power plant	2500	100.0	30
Oil power plant	1100	220	35
Nuclear power plant	5000	110	
Wind power	1400	25.6	
Solar power plant	1100	5.1	

SPHS tunnel and plant	600	6.4
SPHS dam and land	*	-
Grid (transmission lines)	1000	36.0

With regard to wind and solar power, the investment costs have been adapted to take into account future technological developments. Hence, a linear regression was used to calculate the prices up to 2090 based on the future price trends up to 2050. Figure B-3 shows the future prices defined for wind onshore, wind offshore and solar power based on PNE 2050 [BRASIL, 2020].
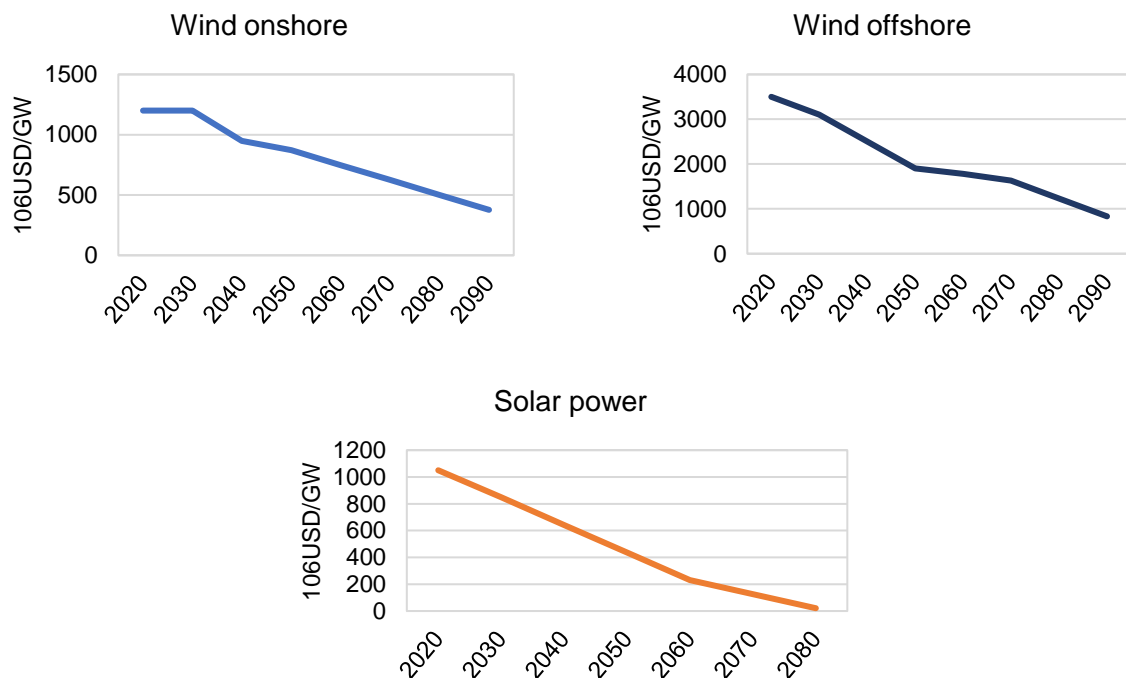
Figure B-3 – Wind power onshore and offshore and solar power defined future prices up to 2099 for the BESMM.

Boundaries and constraints were applied to the BESMM to better incorporate the Brazilian electrical system characteristics. For wind and solar power it was applied boundaries on the total installed capacity based on the energy potential of each node [BRASIL, 2020]. For hydropower it was considered no change in the capacities. By keeping the hydropower capacity constant, it will be possible to assess the SPHS's contribution to the BESMM. Based on the difference between the quantity of hydropower generated with and without SPHS, this evaluation will be conducted. The

SPHS simulate scenarios will also demonstrate how the BESMM can increase its hydroelectric capacity without having to build additional plants.

The units used in the BESMM model are as follows:

- activities: GWa
- capacity: GW
- cost related to activity, e.g., var_cost: USD2019/GWa = $2019/GWa
- cost related to capacity, e.g., inv_cost: USD2019/GW = $2019/GW
- water inflow: m^3s^{-1}