

100% Renewable Energy Supply for Brazil—The Role of Sector Coupling and Regional Development

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Supplementary Material

The supplementary material provides detailed result tables for the scenarios considered in this work. It is focused on the model-endogenous capacity installation (Table S1) and power generation structure (Table S2 to Table S9), disaggregated either by technology or scenario. Table S10 provides the endogenous grid capacity installation across all scenarios. The operation of other balancing options is summarized in Table S11 for power transmission, in Table S12 for hydrogen storage, in Table S13 for thermal energy storage and Table S14 for controlled BEV charging.

Table S1. Model-endogenous capacity installation of wind onshore, PV and CSP capacity for 2050 for all scenarios

Scenario Technology Region	Base			PV-Plan			CSP-Plan			Red-Inflow		
	Wind	PV	CSP	Wind	PV	CSP	Wind	PV	CSP	Wind	PV	CSP
	GW (el)			GW (el)			GW (el)			GW (el)		
Nordeste	71.1	10.4	0	71.1	0	0	71.1	6.4	0	71.1	20.8	0
Norte 1	0	6.4	1.1	0	0	1.4	0	6.1	1.2	0	8.8	0.7
Norte 2	0	0	0	0	0	0	0	0	0	0	0	0
Norte 3	0	0	0	0	0	0	0	0	0	0	0	0
Centro-Oeste	0	17.9	0	0	0	0	0	15.3	0	0	15.7	0
Sudeste	0	24.2	23.2	0	0	21.1	0	32.0	14.4	0	20.4	31.2
Sul	13.9	4.6	0	5.9	0	0	12.1	4.7	0	18.4	8.1	0

Table S2. Annual hydro power generation in scenario Base for 2050

Technology Region	RoR hydro S	RoR hydro M	RoR hydro L	Res. hydro S	Res. hydro M	Res. hydro L
	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	0.5	0	32.6	0	1.6	9.1
Norte 1	0.9	1.0	12.6	0	0	5.9
Norte 2	0	2.1	4.3	0.11	0.6	26.7
Belo Monte	0	1.4	48.9	0	0	0
Norte 3	0.8	0.4	22.8	0	0.6	0
Teles Pires	0	0	8.0	0	0	0
Centro-Oeste	7.5	8.7	39.7	0.06	5.5	78.6
Sudeste	8.6	11.7	5.3	0	6.4	1.4
Itaipu	0	0	54.1	0	3.0	0
Sul	7.9	9.0	38.3	0	4.7	33.9

Table S3. Annual other power generation in scenario Base for 2050

Technology Region	Biomass CHP	Fuel Cells	CSP	Wave	PV	Wind
	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	9.9	0.73	0	2.2	17.2	239.1
Norte 1	3.1	0.21	2.7	2.4	9.8	0
Norte 2	1.6	0.13	0	0	0	0
Norte 3	1.7	0.13	0	0	0	0
Centro-Oeste	3.3	0.24	0	0	27.5	0
Sudeste	45.3	2.81	89.5	2.7	37.5	0
Sul	13.3	0.86	0	3.3	5.7	38.5

Table S4. Annual hydro power generation in scenario PV-Plan for 2050

Technology	RoR hydro S	RoR hydro M	RoR hydro L	Res. hydro S	Res. hydro M	Res. hydro L
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	0.5	0	31.6	0	1.5	8.9
Norte 1	0.9	0.9	12.5	0	0	5.6
Norte 2	0	2.1	4.3	0.11	0.6	25.1
Belo Monte	0	1.4	48.9	0	0	0
Norte 3	0.8	0.4	22.0	0	0.5	0
Teles Pires	0	0	8.0	0	0	0
Centro-Oeste	6.9	8.2	39.6	0.05	5.3	77.7
Sudeste	8.5	11.5	5.0	0	6.2	1.3
Itaipu	0	0	54.1	0	2.9	0
Sul	7.9	9.0	38.3	0	4.6	33.9

Table S5. Annual other power generation in scenario PV-Plan for 2050

Technology	Biomass CHP	Fuel Cells	CSP	Wave	PV	Wind
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	9.1	0.73	0	2.2	41.4	237.7
Norte 1	2.8	0.21	2.6	2.3	4.6	0
Norte 2	1.5	0.13	0	0	0	0
Norte 3	1.5	0.13	0	0	0	0
Centro-Oeste	3.0	0.24	0	0	18.5	0
Sudeste	41.8	2.81	71.0	2.6	78.0	0
Sul	13.3	0.86	0	3.3	12.4	16.3

Table S6. Annual hydro power generation in scenario CSP-Plan for 2050

Technology	RoR hydro S	RoR hydro M	RoR hydro L	Res. hydro S	Res. hydro M	Res. hydro L
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	0.5	0	33.0	0	1.6	9.2
Norte 1	1.0	1.1	12.6	0	0	5.8
Norte 2	0	2.2	4.3	0.11	0.6	26.6
Belo Monte	0	1.4	48.9	0	0	0
Norte 3	0.8	0.4	22.7	0	0.6	0
Teles Pires	0	0	8.0	0	0	0
Centro-Oeste	7.3	8.5	39.8	0.06	5.5	78.5
Sudeste	8.5	11.7	5.3	0	6.4	1.4
Itaipu	0	0	54.1	0	3.0	0
Sul	7.9	9.0	38.3	0	4.7	33.9

Table S7. Annual other power generation in scenario CSP-Plan for 2050

Technology	Biomass CHP	Fuel Cells	CSP	Wave	PV	Wind
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	9.5	0.73	47.4	2.3	10.6	240.1
Norte 1	3.0	0.21	2.7	2.5	9.5	0
Norte 2	1.6	0.13	0	0	0	0
Norte 3	1.7	0.13	0	0	0	0
Centro-Oeste	3.2	0.24	0	0	23.7	0
Sudeste	44.3	2.81	46.6	2.7	50.1	0
Sul	13.3	0.86	0	3.4	5.9	34.0

Table S8. Annual hydro power generation in scenario Red-Inflow for 2050

Technology	RoR hydro S	RoR hydro M	RoR hydro L	Res. hydro S	Res. hydro M	Res. hydro L
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	0.4	0	24.1	0	1.4	7.1
Norte 1	0.7	0.9	9.4	0	0	5.3
Norte 2	0	2.4	3.6	0.11	0.6	25.9
Belo Monte	0	1.0	36.7	0	0	0
Norte 3	0.6	0.3	18.0	0	0.6	0
Teles Pires	0	0	6.0	0	0	0
Centro-Oeste	5.7	6.6	29.9	0.05	4.4	60.3
Sudeste	6.4	8.8	4.3	0	5.1	1.2
Itaipu	0	0	40.7	0	2.4	0
Sul	5.9	6.8	28.9	0	3.6	25.5

Table S9. Annual other power generation in scenario Red-Inflow for 2050

Technology	Biomass CHP	Fuel Cells	CSP	Wave	PV	Wind
Region	TWh	TWh	TWh	TWh	TWh	TWh
Nordeste	10.5	0.73	0	2.2	34.5	237.8
Norte 1	3.3	0.21	2.9	2.5	13.6	0
Norte 2	1.9	0.13	0	0	0	0
Norte 3	1.9	0.13	0	0	0	0
Centro-Oeste	3.5	0.24	0	0	24.2	0
Sudeste	47.6	2.81	157.0	2.9	31.7	0
Sul	15.5	0.86	0	3.4	10.3	51.7

Table S10. Model-endogenous installation of transfer capacities between grid nodes for 2050

Scenario		Base		PV-Plan		CSP-Plan		Red-Inflow	
Technology		AC	DC	AC	DC	AC	DC	AC	DC
Start (S)	End (E)	GW	GW	GW	GW	GW	GW	GW	GW
XIN	Norte 1	0	1.0	0	1.5	0	1.0	0	1.2
XIN	Norte 2	2.2	1.4	1.9	1.3	2.2	1.4	2.7	1.8
XIN	Belo Monte	1.5	0	1.9	0	1.4	0	0	0
XIN	Sudeste	2.7	0	2.5	0	2.7	0	1.8	0
IMP	Nordeste	2.3	0.8	3.0	1.1	2.3	0.6	0.8	2.0
IMP	Norte 1	0	0.2	0	0.4	0	0.1	0	0.9
IV	Sul	0.6	0	1.0	0	0.7	0	0.2	0
Sudeste	Nordeste	0	25.2	0	26.3	0	30.5	0	25.7
Centro-Oeste	Teles Pires	0	0.3	0	0.3	0	0.3	0	0.3
Sudeste	Itaipu	2.6	0.1	1.5	0	2.3	0	2.5	0
Itaipu	Sul	3.0	1.2	2.8	1.2	2.6	1.3	1.8	3.8
Sudeste	Centro-Oeste	0	10.0	0	8.5	0	9.6	0	8.7

Table S11. Annual power export and import by model region. Positive values represent a net import, negative a net export for 2050

1Scenario	Base	PV-Plan	CSP-Plan	Red-Inflow
Region	TWh	TWh	TWh	TWh
Nordeste	-158	-178	-199	-164
Norte 1	11	17	11	11
Norte 2	-21	-19	-21	-20
Belo Monte	-46	-46	-46	-36
Norte 3	-18	-16	-17	-13
Teles Pires	-5	-4	-5	-3
Centro-Oeste	-95	-83	-91	-59
Sudeste	356	338	390	294
Itaipu	-56	-56	-56	-42

<i>Sul</i>	21	37	25	24
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Table S12. Annual energy input to decentralized hydrogen storage for industry and transport for 2050

Scenario	Base	PV-Plan	CSP-Plan	Red-Inflow
Region	TWh	TWh	TWh	TWh
<i>Nordeste</i>	1.2	1.3	1.1	1.3
<i>Norte 1</i>	0.38	0.38	0.38	0.39
<i>Norte 2</i>	0.15	0.20	0.14	0.18
<i>Norte 3</i>	0.17	0.23	0.15	0.21
<i>Centro-Oeste</i>	0.38	0.41	0.33	0.38
<i>Sudeste</i>	4.8	5.1	4.5	4.8
<i>Sul</i>	1.2	1.4	1.1	1.4

Table S13. Annual energy input to thermal energy storage in electric heating (hot water storage) and CHP for 2050

Scenario	Base	PV-Plan	CSP-Plan	Red-Inflow
Region	TWh	TWh	TWh	TWh
<i>Nordeste</i>	3.4	3.1	3.7	4.5
<i>Norte 1</i>	0.9	0.8	1.0	1.2
<i>Norte 2</i>	0.5	0.5	0.6	0.7
<i>Norte 3</i>	0.7	0.6	0.8	0.8
<i>Centro-Oeste</i>	1.0	0.9	1.1	1.4
<i>Sudeste</i>	11.0	10.8	11.6	10.9
<i>Sul</i>	3.6	3.3	4.0	4.2

Table S14. Annual amount of BEV charging power shifted to a later time for 2050

Scenario	Base	PV-Plan	CSP-Plan	Red-Inflow
Region	TWh	TWh	TWh	TWh
<i>Nordeste</i>	0.9	0.9	0.9	0.9
<i>Norte 1</i>	0.11	0.09	0.11	0.11
<i>Norte 2</i>	0.02	0.02	0.02	0.02
<i>Norte 3</i>	0.02	0.02	0.02	0.02
<i>Centro-Oeste</i>	0.4	0.4	0.4	0.4
<i>Sudeste</i>	5.3	4.9	6.7	4.3
<i>Sul</i>	1.9	2.0	2.0	1.8