Unlocking the Potential of Renewable Energy for E-kerosene Production in Brazil

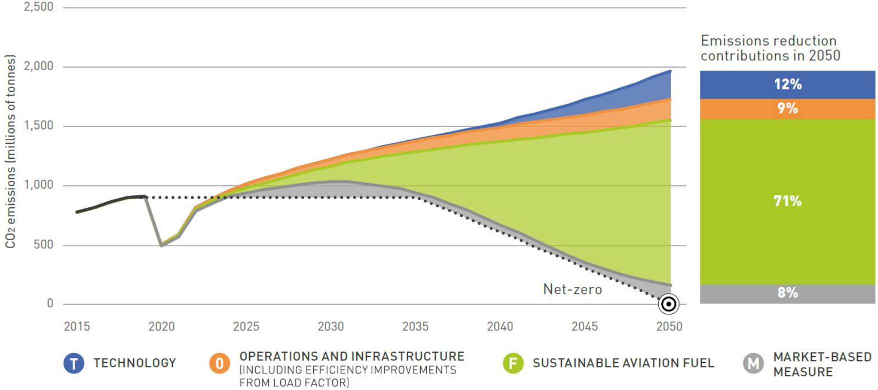
M.Sc. Ying Deng | 9. August 2023

@Mikey Burton

Introduction

- **Challenge:** achieving net-zero CO_2 emissions by 2050 (IPCC, 2022)
- **Aviation sector:** 2.4% of global CO_2 emissions (IEA, 2019, p II.19)
- **Non-CO_2 emissions:** 3 times combined impact on climate warming ~ CO_2 alone (Lee et al., 2021)
- **Hard-to-debate aviation:** heavily reliant on high-density liquid fuels (ICAO, 2018)
- **Aviation commitment:** carbon-neutral growth from 2020, carbon-neutral from 2050 (IATA, 2021)

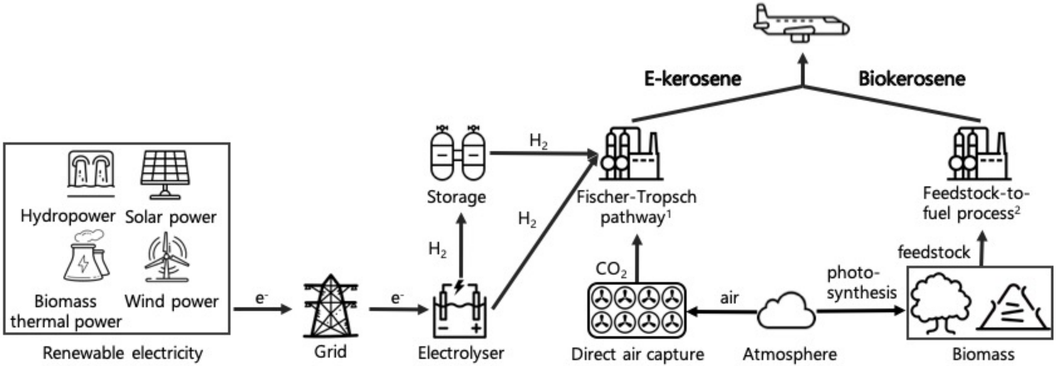
Mitigation strategies



Aviation decarbonisation trajectory to 2050 aligned with 1.5 ℃ goal (ATAG, 2021)[1].

[1] ATAG: Air Transport Action Group

Sustainable aviation fuels (SAF)



[1] syngas production, Fischer-Tropsch (FT) synthesis, fuel refining.
[2] conversion technology, e.g., FT, Hydro-processed Esters and Fatty Acids (HEFA), Alcohol-to-jet (ATJ), etc, and fuel refining

Sustainable aviation fuels – biokerosene and e-kerosene (own illustration based on (Bergero et al., 2023)).

State of the Art

Brazil

- **24%** ethanol export to EU (UDOP, 2023)
- **8,547,404** km^2 extensive territory (IBGE, 2018)
- **46.2% & 72.1%** high renewable share (BP, 2022) but high hydropower reliance (ONS, 2022)
- biokerosene: 58 – 197 $€_{2019}$/MWh for 2030 (Cervi et al., 2020)

Policy regulation on SAF and e-kerosene

	2030	2050
European Commission (2021)	5% (0.7%)	63% (27%)
Federal Republic of Germany (2021)	- (2%)	-
Brazil (Ministry of Infrastructure, 2019)	?	?

Techno-economic assessment (TEA) and energy system analysis (ESA) approach

TEA

- to determine the economic performance of technology value chain
- single technology, site-specific
- static basis without consideration of its integration dynamics

ESA

- to evaluate boarder impacts & informed decisions about cross-sector interactions (cost-effective energy system configurations)
- system-wide
- recognise dynamic interactions

while different, are complementary

E-kerosene production costs: 69 – 434 €/MWh for 2050[2]

[2] cf. Section 5.2.6.3 of dissertation

Research gaps & questions

research gaps

- unclear potential of e-kerosene production in Brazil
- need for a energy system analysis approach
- ...

research questions

- model: How can we model the scale-up of e-kerosene production without jeopardising Brazil's 100% renewable target?
- analysis: What would be the local impacts of e-kerosene production in Brazil?
- ...

Required inputs

Time series

- electricity demand
- kerosene demand
- conventional kerosene price
- ...

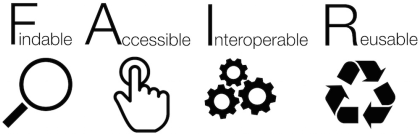
Geospatial data

- power plants
- transmission lines
- ...

Tabular data

- biokerosene production costs
- capacity expansion potential of biomass thermal plants
- ...

Open Brazilian Energy Dataset

- 2012 - 2020
- resolution: hourly, 27 nodes (26 Brazilian federal states + Brasília)
- .csv or .shp format
- 

  Wilkinson et al. (2016)

Example: power plant infrastructure (I)

The types of power plants.

<table>
<tr><th>Harmonised</th><th>National electricity agency (ANEEL)</th><th>Energy research agency (EPE)</th><th>National grid operator (ONS)</th></tr>
<tr><td>PV[1]</td><td>PV</td><td>PV</td><td>PV</td></tr>
<tr><td>Onshore wind</td><td>Onshore wind</td><td>Onshore wind</td><td>Onshore wind</td></tr>
<tr><td>Nuclear</td><td>Nuclear</td><td>Nuclear</td><td>Nuclear</td></tr>
<tr><td rowspan="2">Thermal power plants</td><td rowspan="2">Thermal power plants</td><td>Biomass thermal power plants</td><td rowspan="2">Thermal power plants</td></tr>
<tr><td>Fossil thermal power plants</td></tr>
<tr><td rowspan="4">Hydropower</td><td>Small hydropower[2]</td><td>Small hydropower</td><td rowspan="2">Hydropower</td></tr>
<tr><td>Mini hydropower[3]</td><td>Mini hydropower</td></tr>
<tr><td>Hydropower[4]</td><td rowspan="2">Hydropower</td><td rowspan="2">Pumped hydropower</td></tr>
<tr><td>Wave</td></tr>
</table>

[1] **PV** Photovoltaic [2] 5 - 30 MW and reservoir area < 13 km^2 [3] less or equal 5 MW [4] 5 - 50 MW, excluding small hydropower

Example: power plant infrastructure (II)

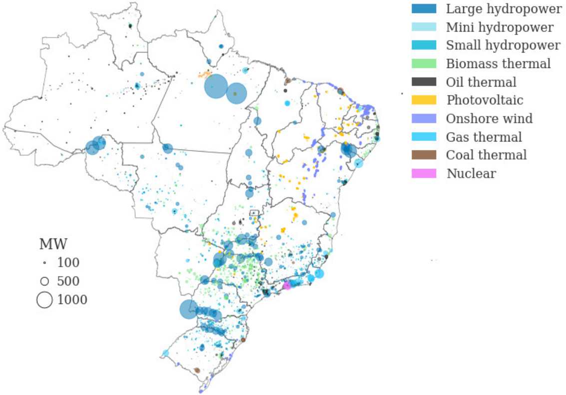
Statistical comparison of data entities between data sets.

Number of	National electricity agency (ANEEL)	Energy research agency (EPE)	National grid operator (ONS)
data entities	10541	3178	4191
attributes	15	11	15
unique plants IDs	10541	3160	1389
unique plants names	10283	2984	1388

Comparison of installed capacity per plant type for 2018.

Type	ANEEL (GW)	EPE (GW)	ONS (GW)
Hydropower	111.37	110.41	110.43
Nuclear	3.34	3.40	1.99
Onshore wind	31.00	20.95	22.35
PV	24.07	4.76	6.43
Thermal power plants	52.45	44.86	34.81

Example: power plant infrastructure (III)



Power plants distribution

Metadata of the records.

field	***type***	***description***
state	string	abbreviation of federal states
type	string	the type of power plants type – biomass, solar_pv, on_wind, mini_hydro, small_hydro, hydro, nuclear, coal, gas, oil
phase	string	operation status – operation or planning
value	number	capacity in MW
reference _year	number	reference year, i.e., YYYY

PyPSA-Brazil model

Input
- Time series
  - demand[1]
  - conventional kerosene price
  - ...
- Geospatial data
  - infrastructure[2]
  - biokerosene production cost
  - ...
- Tabular data
  - carbon price
  - ...

Objective Function
Cost-optimal: long-term investment and short-term operation - linear programming

Model Constraints
- Supply-demand balance
- CO_2 emission mitigation target
- Fix share of kerosene supply
- ...

Resolution
- Hourly, 27 nodes (26 Brazilian federal states + Brasília)
- Base year: 2019
- Target year: 2050

Output
- System cost breakdown
- Distribution of optimum installed capacity
- Kerosene share
- ...

+

[1] electricity and kerosene
[2] power plants, AC/HVDC lines with installed and the scheduled expansion

Overview of the PyPSA-Brazil model.

Objectives and constrains

minimise annual system cost

generator storage transmission e-kerosene

$$\min_{G,E,F,P,g,e,f,p} \Bigg\{ \boxed{\sum_{n,r} c_{n,r} \cdot G_{n,r} + \sum_{n,s} c_{n,s} \cdot E_{n,s} + \sum_{l} c_l \cdot F_l + \sum_{k} c_k \cdot P_k}$$

annualised capital costs

operational costs

$$\boxed{+ \sum_{n,r,t} o_{n,r} \cdot g_{n,r,t} + \sum_{n,s,t} o_{n,s} \cdot e_{n,s,t} + \sum_{l,t} o_l \cdot f_{l,t} + \sum_{k,t} o_k \cdot p_{k,t}} \Bigg\} \tag{1}$$

$$0 \leqslant P_k \leqslant \infty \quad \forall\, k \tag{2}$$

$$\underline{p}_{k,t} \cdot P_k \leqslant p_{k,t} \leqslant \bar{p}_{k,t} \cdot P_k \quad \forall\, k, t \tag{3}$$

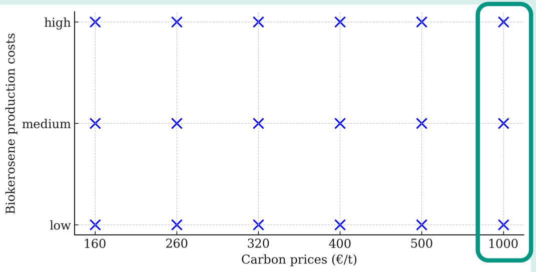
...

Scenario definition

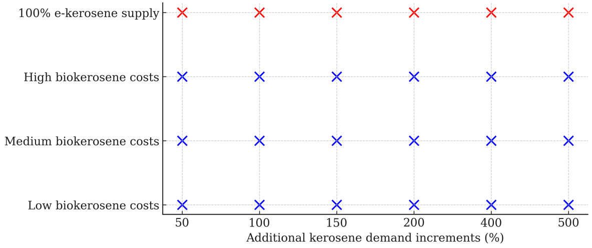
e-kerosene integration

- "Only power system"
- "100% e-kerosene supply"

no export allowed



with export of carbon-neutral kerosene



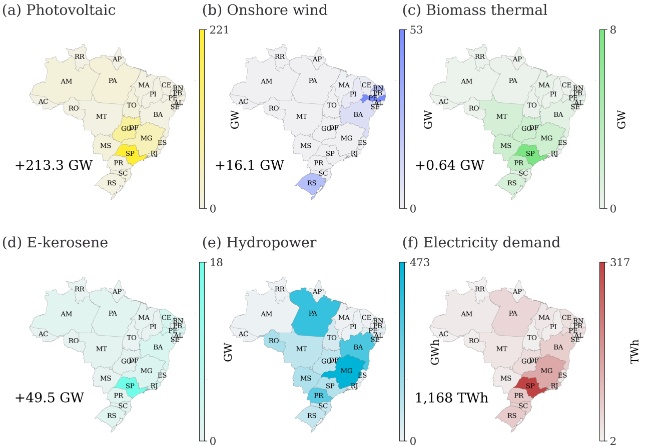
Future carbon-neutral power system with and without e-kerosene production

averaged system cost

50.3 €/MWh

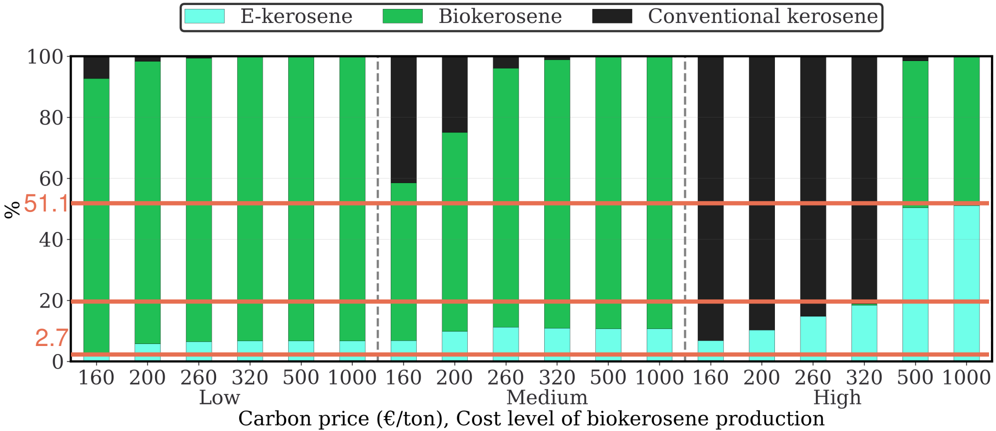
↓ -13.8%

43.4 €/MWh



Capacity distribution of selected technologies.

Share of e-kerosene in Brazil under uncertain biokerosene costs and carbon prices (I)

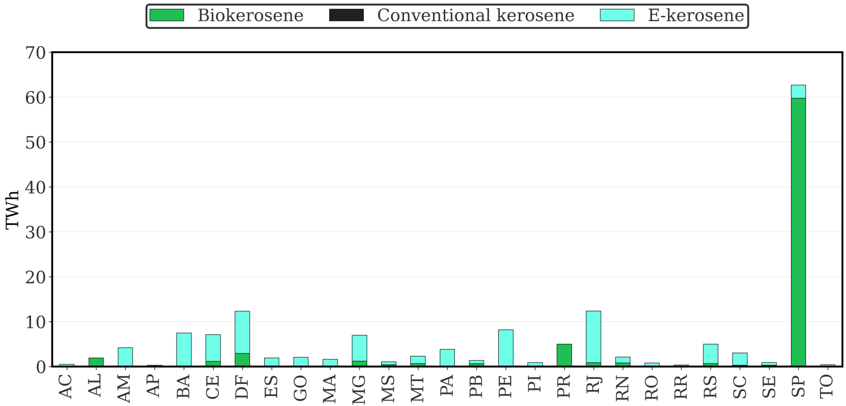


Supply shares of e-kerosene, biokerosene, and conventional kerosene.

Share of e-kerosene in Brazil under uncertain biokerosene costs and carbon prices (II)

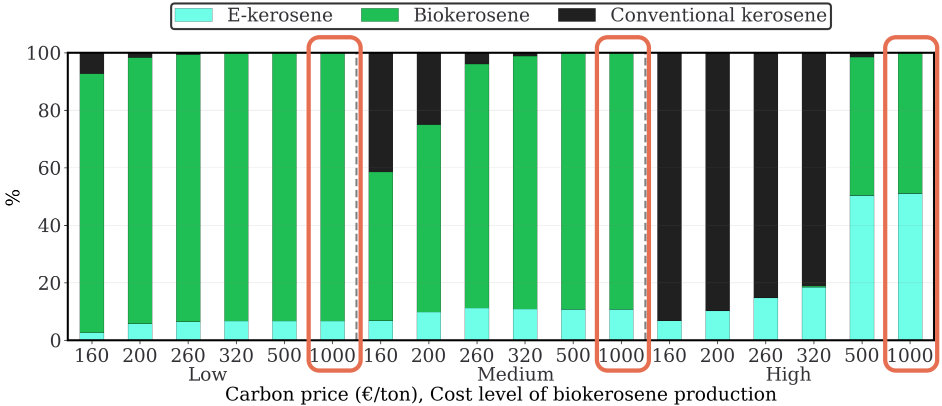
São Paulo

- biokerosene: 184 €/MWh
- e-kerosene: 215 €/MWh



Kerosene supply at federal state: carbon price (1000 €/t) & high biokerosene costs.

Share of e-kerosene in Brazil under uncertain biokerosene costs and carbon prices (III)

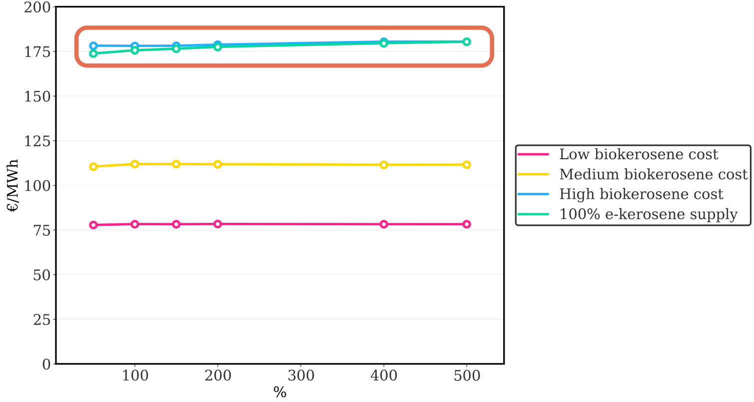


Supply shares of e-kerosene, biokerosene, and conventional kerosene.

Export costs of carbon-neutral kerosene from Brazil

181 €/MWh

78 €/MWh



Export Cost

Limitation & Outlook

- Comprehensive, open-access biokerosene potential exploration
  - lack of biokerosene generation potential
  - not reproducible in existing research
- Incorporation of emissions through life-cycle assessment
  - current assumption: carbon-neutrality of biokerosene and e-kerosene
  - e-kerosene emissions: 33.9 – 35.5 g CO_2/MJ (Sacchi et al., 2023)
  - biokerosene emissions: 6 – 72 g CO_2/MJ (De Jong et al., 2017)
  - exclusion of non-CO_2 emissions

Summary & Conclusion

Summary

- provide Open Brazilian Energy Dataset
- apply & extend PyPSA framework to Brazil: new PyPSA-Brazil model
- integration of e-kerosene into energy system

Conclusions

- Feasible e-kerosene production in Brazil: expensive but efficient
- Costs for carbon-neutral kerosene export between 78-181 €/MWh
- E-kerosene contribution: 2.7-51.1%
- Determinant: biokerosene production costs

Appendix

Average system cost

$$\text{ASC} = \frac{\mathcal{C}^*}{\Gamma^*} \tag{4}$$

where

$\mathcal{C}^*$: optimised total system cost, €
Γ^* : optimised total dispatch, MWh. It includes the amount of energy produced by renewable generation technologies and the supply of kerosene in the system.

Levelised cost of fuel

$$\mathrm{LCOF} = \frac{\sum_{n}\left\{\sum_{k,t}(c_{n,k}\cdot P_{n,k}+o_{n,k}\cdot p_{n,k,t})+\sum_{s,t}(c_{n,s}\cdot E_{n,s}+o_{n,s}\cdot e_{n,s,t})+\overline{\lambda_n^{\text{electricity}}}\cdot\Gamma_n^{\text{electricity}}\right\}}{\sum_{n}\Gamma_n^{\text{e-kerosene}}} \tag{5}$$

where

$c_{n,*}$: annualised capital expenditures
$P_{n,k}$: installed capacity of e-kerosene production unit k at node n
$o_{n,*}$: variable operational expenditure
$p_{n,k,t}$: e-kerosene dispatch at hour t at node n
$e_{n,s,t}$: storage dispatch of e-kerosene tank
$E_{n,s}$: power capacity of storage technology s at node n
$\overline{\lambda_n^{\text{electricity}}}$: median Karush-Kuhn-Tucker multiplier of electricity at node n
$\Gamma_n^{\text{electricity}}$: total electricity consumption for e-kerosene production at node n
$\Gamma_n^{\text{e-kerosene}}$: total e-kerosene supply at node n.

Export cost

$$\mathcal{E}_{\beta,\delta} = \frac{\mathcal{C}_{\beta,\delta} - \mathcal{C}^{\text{Ref.}}}{d_{\beta,\delta}^{\text{kerosene}} - d^{\text{Ref.,kerosene}}} = \frac{\mathcal{C}_{\beta,\delta} - \mathcal{C}^{\text{Ref.}}}{\delta \cdot d^{\text{Ref.,kerosene}}} \tag{6}$$

where

$\mathcal{E}_{\beta,\delta}$	: export cost for the scenario given β, δ
β	: level of production cost for biokerosene, $\beta \in \{\text{low, medium, high}\}$
δ	: additional kerosene demand for export, $\delta \in \{50\%, 100\%, 150\%, 200\%, 400\%, 500\%\}$
$\mathcal{C}_{\beta,\delta}$	: total system cost of the scenario given β, δ
$\mathcal{C}^{\text{Ref.}}$	: total system cost of the reference scenario
$d_{\beta,\delta}^{\text{kerosene}}$	: total kerosene demand of export scenario given β, δ, $d_{\beta,\delta}^{\text{kerosene}} = (1+\delta) \cdot d^{\text{Ref.,kerosene}}$
$d^{\text{Ref.,kerosene}}$	: total kerosene demand in the reference scenario, i.e., 157 TWh.

Export amount of the e-kerosene

$$\mathcal{P}_{\beta,\delta} = p_{\beta,\delta} - p^{\text{Ref.}} \tag{7}$$

where

$\mathcal{P}_{\beta,\delta}$: e-kerosene for export given β, δ
$p_{\beta,\delta}$: generation of e-kerosene given β, δ
$p^{\text{Ref.}}$: generation of e-kerosene in the reference scenario.

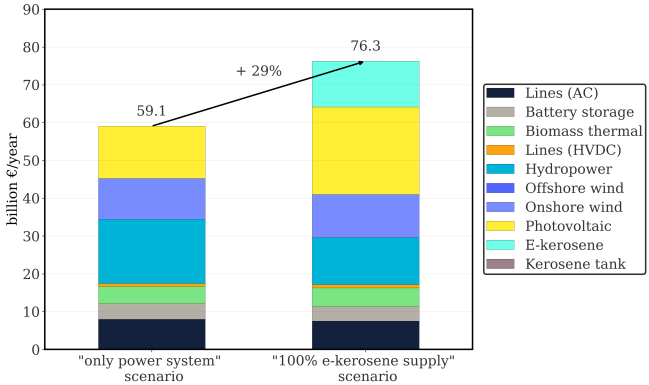
LCOF for e-kerosene in 2050

Study	**Country**	**LCOF (€$_{2019}$/MWh)**	**LCOE (€$_{2019}$/MWh)**
This dissertation	Brazil	214.7	100% e-kerosene (36-74)
This dissertation	Brazil	113.3 – 215.5	no export
This dissertation	Brazil	117.9 – 227.3	export, 1000 €/t CO_2
Batteiger et al., 2022	Germany	186.9	43
Drünert et al., 2020	Germany	244.8 – 284.3	LT-EL, 35-55
Drünert et al., 2020	Germany	188.4 – 227.1	HT-EL, 35-55
Gonzalez-Garay et al., 2022	Spain	188.4 – 416.4[1]	30-80
Batteiger et al., 2022	Spain	148.2	35
Batteiger et al., 2022	Morocco	145.9	32
Agora Energiewende, 2018	North Africa	75 – 137.5	H_2 (5)
Breyer et al., 2022	EU-27	75	–
Breyer et al., 2022	US	69	–
Sherwin, 2021	US	84.8	solar (10), wind (16), grid (54.6)
Becattini et al., 2021	—	217.0 – 434.1[2]	61

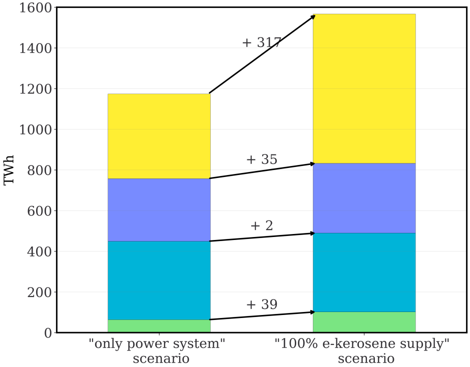
[1] The variation depends on the inclusion of emission costs and the electricity source.

[2] The initial cost of DAC, H_2 production, CO_2 conversion, the LCOE, the revenue resulting from the sale of diesel, and the CO_2 transport and storage costs are randomly sampled between ±20% of their reference values.

Future carbon-neutral power system with and without e-kerosene production



Breakdown of annual total system costs.



A comparison of annual electricity generation.

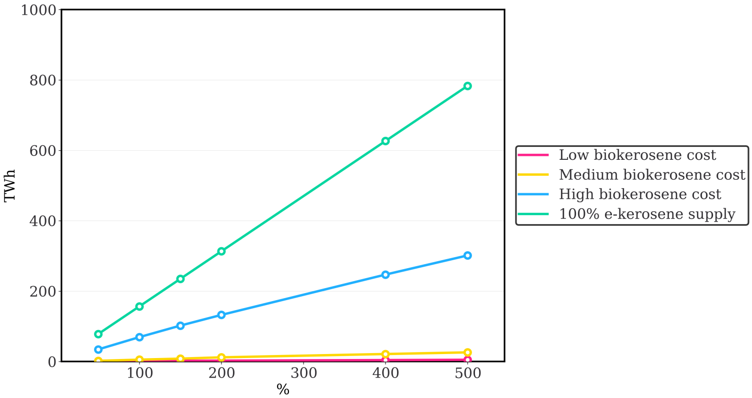
Departure scenarios: other extreme cases

Comparison of additional theoretical costs on a carbon-neutral power system basis [a].

Kerosene options		Absolute difference (billion€/year)	Relative difference[b] (%)
Conventional	No carbon price	11.4	19.3
	Carbon price: 500 €/t	32.3	54.7
	Carbon price: 1000 €/t	53.2	90.0
Biokerosene	Low costs	13.3	22.5
	Medium costs	19.3	32.7
	High costs	33.3	56.3
"100% e-kerosene supply" scenario		17.2	29.1

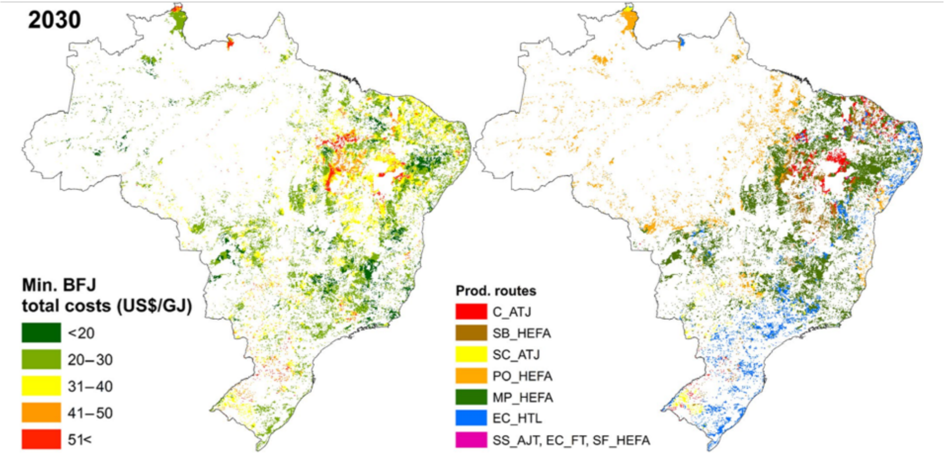
[a] Results are obtained by post-processing, except for the "100% e-kerosene supply" scenario.
[b] The "only power system" scenario projects a system cost of 59.1 billion€/year.

Export costs of carbon-neutral kerosene from Brazil (II)

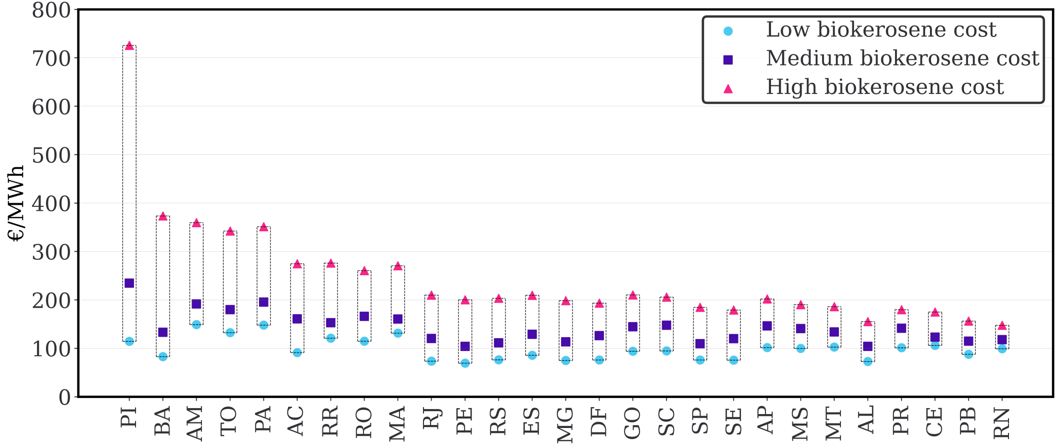


E-kerosene generation for export

Biokerosene production costs (I)

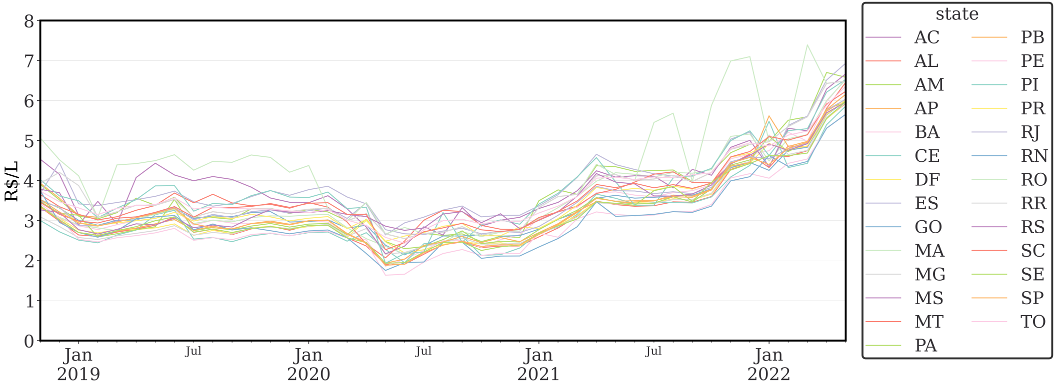


Biokerosene production costs (II)



Historical jet fuel price

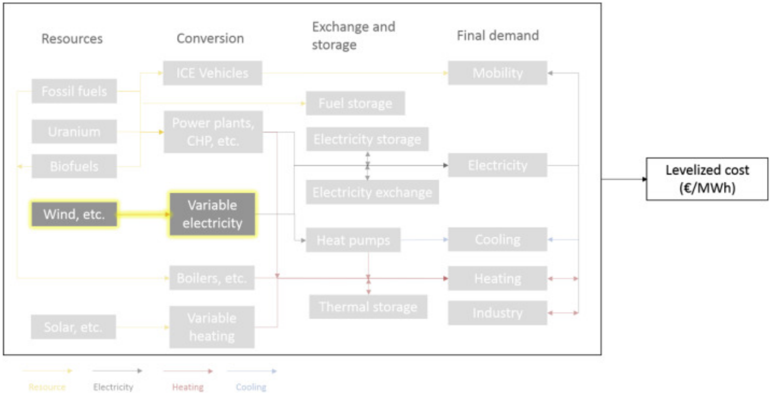
- R$/L →€$_{2019}$/MWh: * 24.6
- 3-5 R$/L →73.8-123.0 €$_{2019}$/MWh



Brazilian energy system model

Study	Model name	Temporal resolution	Spatial resolution	Open source
Nogueira et al. (2014)	MESSAGE-Brazil	typical time slices	3 subsystems	No
Rochedo et al. (2018)	BLUES	typical time slices	5 regions	No
Fichter et al. (2017)	REMix-CEM	typical time slices	4 regions	No
Dranka and Ferreira (2018)	EnergyPLAN	hourly	4 regions	No
Gils et al. (2017)	REMix	hourly	13 nodes	No
Barbosa et al. (2016)	LUT Energy System Transition model	hourly	5 regions	No
This dissertation	PyPSA-Brazil	hourly	27 federal states	Yes

TEA and ESA



Comparison of Energy System Elements (Hansen, 2019, Fig. 2).

Bibliography I

[1] IPCC. “Mitigation Pathways Compatible with 1.5 °C in the Context of Sustainable Development”. en. In: *Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. 1st ed. Cambridge University Press, 2022, p. 82. DOI: 10.1017/9781009157940. URL: https://www.cambridge.org/core/product/identifier/9781009157940/type/book (visited on 02/24/2023).

[2] ICAO. *Sustainable Aviation Fuels Guide*. en. Tech. rep. International Civil Aviation Organization (ICAO), 2018, p. 66. URL: https://www.icao.int/environmental-protection/Documents/Sustainable%5C%20Aviation%5C%20Fuels%5C%20Guide_100519.pdf.

[3] IATA. *Net-Zero Carbon Emissions by 2050*. en. 2021. URL: https://www.iata.org/en/pressroom/pressroom-archive/2021-releases/2021-10-04-03/ (visited on 02/16/2023).

Bibliography II

[4] ATAG. *Waypoint 2050: An Air Transport Action Group Project*. en. Tech. rep. Geneva, Switzerland, ATAG, 2021, p. 110. URL: https://aviationbenefits.org/media/167417/w2050_v2021_27sept_full.pdf.

[5] IBGE. *Áreas Territoriais*. pt. Territorial Areas. 2018. URL: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15761-areas-dos-municipios.html?edicao=24050&t=acesso-ao-produto (visited on 02/25/2023).

[6] BP. *bp Statistical Review of World Energy: 2022 | 71th edition*. en. Tech. rep. The British Petroleum Company (BP), 2022. URL: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (visited on 03/06/2023).

Bibliography III

[7] European Commission. *REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL: on ensuring a level playing field for sustainable air transport: SEC(2021) 561 final - SWD(2021) 633 final - SWD(2021) 634 final*. 2021. URL: https://ec.europa.eu/info/sites/default/files/refueleu_aviation_-_sustainable_aviation_fuels.pdf (visited on 09/26/2022).

[8] Ministry of Infrastructure. *Brazil's Action Plan on CO2 Emissions Reduction from Aviation: Base Year 2018*. en. Govermental. Ministry of Infrastructure, 2019, p. 92. URL: https://www.gov.br/anac/pt-br/assuntos/meio-ambiente/arquivos/BrazilsActionPlanonCO2EmissionsReductionfromAviation3rdEditionBaseYear2018.pdf (visited on 10/25/2021).

Bibliography IV

[9] R. Sacchi et al. “How to make climate-neutral aviation fly”. en. In: *Nature Communications* 14.1 (July 2023). Number: 1 Publisher: Nature Publishing Group, p. 3989. ISSN: 2041-1723. DOI: `10.1038/s41467-023-39749-y`. URL: `https://www.nature.com/articles/s41467-023-39749-y` (visited on 07/11/2023).

[10] S. De Jong et al. “Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production”. en. In: *Biotechnology for Biofuels* 10.1 (Dec. 2017), p. 64. ISSN: 1754-6834. DOI: `10.1186/s13068-017-0739-7`. URL: `http://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-017-0739-7` (visited on 07/03/2023).

[11] E. D. Sherwin. “Electrofuel Synthesis from Variable Renewable Electricity: An Optimization-Based Techno-Economic Analysis”. en. In: *Environmental Science & Technology* 55.11 (June 2021), pp. 7583–7594. ISSN: 0013-936X, 1520-5851. DOI: `10.1021/acs.est.0c07955`. URL: `https://pubs.acs.org/doi/10.1021/acs.est.0c07955` (visited on 02/23/2023).

Bibliography V

[12] P. R. R. Rochedo et al. "The threat of political bargaining to climate mitigation in Brazil". en. In: *Nature Climate Change* 8.8 (Aug. 2018), pp. 695–698. ISSN: 1758-678X, 1758-6798. DOI: 10.1038/s41558-018-0213-y. URL: http://www.nature.com/articles/s41558-018-0213-y (visited on 02/22/2023).

[13] Y. Deng, K.-K. Cao, W. Hu, et al. "Harmonized and Open Energy Dataset for Modeling a Highly Renewable Brazilian Power System". en. In: *Scientific Data* 10.1 (Feb. 2023). Nature Publishing Group, p. 103. DOI: 10.1038/s41597-023-01992-9. URL: https://www.nature.com/articles/s41597-023-01992-9 (visited on 02/22/2023).

[14] Y. Deng, K.-K. Cao, M. Wetzel, et al. *E-kerosene Production and Export in Carbon-neutral Power Systems - A Solution for Sustainable Aviation?* Submitted to Journal of Energy for Sustainable Development. 2023.

Bibliography VI

[15] S. Brynolf et al. "Electrofuels for the transport sector: A review of production costs". en. In: *Renewable and Sustainable Energy Reviews* 81 (Jan. 2018), pp. 1887–1905. ISSN: 13640321. DOI: 10.1016/j.rser.2017.05.288. URL: https://linkinghub.elsevier.com/retrieve/pii/S1364032117309358 (visited on 02/21/2023).

Prepared questions I

- What are the suggestions to Lula?
  1. clear guidance on biokerosene and biomass; install more renewable energy of wind and solar; 3. introduce carbon price to discourage the use of conventional kerosene; 4. not only the carbon-neutrality in power sector but also include it in aviation sector in Brazil due to the bad access to alternative infrastructure for long-distance travel.
- Is the data validated?
  Data mostly come from government sources and, quite frankly, they're reliable enough that I don't usually need to check them again. However, there are some datasets, such as the potential for renewable energy generation, that might need to be doubly sure about.
  So, what do I do? I've got two methods of validation. One, I check the findings against well-established models like GSA and GWA. Two, I compare the simulation results to real-world data from specific locations. The photovoltaic, or PV, data in this dissertation checks out pretty well with these methods. When we compare it to reference data for each PV park (12), I find a good match (correlation at 0.8). However, wind

Prepared questions II

data isn't as straightforward, with correlation values only falling between 0.23 and 0.58. I think this might be because I am not considering things like elevation and special wind patterns, such as hot winds that blow between land and sea.
Lastly, let's talk about the model, EnDAT, and how it compares to GSA and GWA. We find that EnDAT's a bit optimistic, calculating higher PV generation than GSA. On the other hand, it underestimates onshore wind potential, but it's more bullish on offshore wind generation than GWA.

- Why is the life cycle assumption of exploiting biokerosene as carbon neutral, as well as for e-kerosene?
  Due to the scope of our research, we use assumptions from reputable sources for the LCA. Our assumption of carbon neutrality, although ambitious, aligns with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) method and is supported by other researches, such as Prussi et al. (2021) and Bergero et al. (2023), which also assume zero CO2 emissions for both biogenic biokerosene and e-kerosene.

Prepared questions III

- Why do you study the highly ambitious scenario of complete e-kerosene?
  to study the weak ability to scale-up the biokeosene.
- Why do you set up new model?
  The existing model does not meet the requirement: 1. open source, 2. high spatial and temporal resolution, 3. allows integration of e-kerosene
- Why is state-level resolution is necessary? 1. It is the administration level in Brazil that the regulations are formatted; From the modelling perspective, having resolution at federal states ensure the computation capability on personal computers

Prepared questions IV

- Is it useless to evaluate shares of e-kerosene, biokerosene, and conventional kerosene in total jet fuel demand based on their input cost sensitivity? As the ratio of them may not only driven by cost. Just looking at the costs isn't enough to understand the shares of e-kerosene, biokerosene, and conventional kerosene in jet fuel demand. Yes, costs matter, but so do many other factors like the environment, technology, and government policies. We need a broader, more holistic view to really get it.
  Our work helps shed light on this issue, taking into account things like carbon pricing and emission budgets. Similar views come from groups like IRENA and the IEA, who suggest a heavy lean towards sustainable fuels. Even Brazil is getting on board, making its own plans for these fuels, though it's a bit behind Europe's goals (63% SAF by 2050) and Germany's aim for 2% e-kerosene by 2030. SAF ratios may not be readily accessible from authoritative regulations in the context of Brazil.