Evaluating the Social Implications and Benefits of Introducing Micro Reactors in Brazil's Electrical Grid: A Comprehensive Analysis of Economic, Environmental, and Community Effects.

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Terminus Research and Development in Energy

IAEA

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SUMMARY

- Overview of Brazilian Nuclear Industry;
- Micro Nuclear Reactors (MNR) – Space and Terrestrial Developments;
- Brazilian MNR Project Structure;
- Potential Applications to MNR in Brazil;
- MNR Role in a Just Energy Transition in Brazil;
- Sustainability Studies of Micro Reactors: Economic, Environmental, and Community Effects; and
- Final Considerations.

Overview of Brazilian Nuclear Industry

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Overview of Brazilian Nuclear Industry

- Brazil is the 8th U Reserve on the planet (276,800 t U in U308).
- Capacity to generate ~ 8,900 TWh (18 Yrs EE Gen, ~ 500 TWh/year).
- CNEN (National Nuclear Energy Commission), since 1956;
- Research Nuclear Reactors in operation 4;
- NPP - Angra I & II in operation (~2,0%), Angra III under construction;
- RMB - Multi-purpose reactor, R&D and Radiopharmaceutical prod.;
- INB - Brazil's Nuclear Industries;
- Brazilian Navy Nuclear Program;
- All Brazilian Nuclear Program is under Safeguards agreement with IAEA.

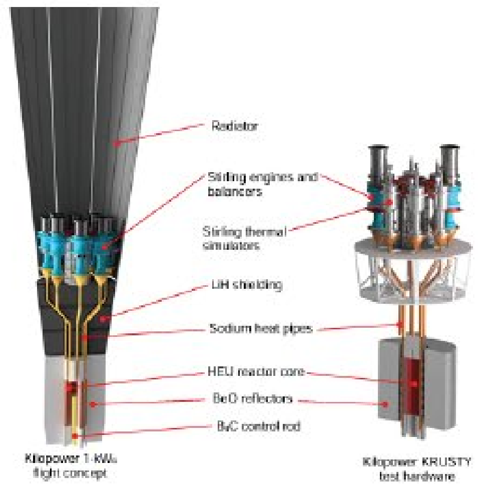
Top 10 countries with the highest uranium reserve

Rank	Country/Region	tons
1	Australia	2,049,400
2	Kazakhstan	969,200
3	Canada	873,000
4	Russia	661,900
5	Namibia	504,200
6	South Africa	447,700
7	Niger	439,400
8	Brazil	276,800
9	China	269,700
10	India	195,900

https://www.geeksforgeeks.org/countries-uranium-reserves-2024/#list-of-uranium-reserves-by-country-2024

Micro Nuclear Reactors (MNR): Space and Terrestrial Developments

Micro Nuclear Reactors (MNR)



NASA/TM—2018-219941

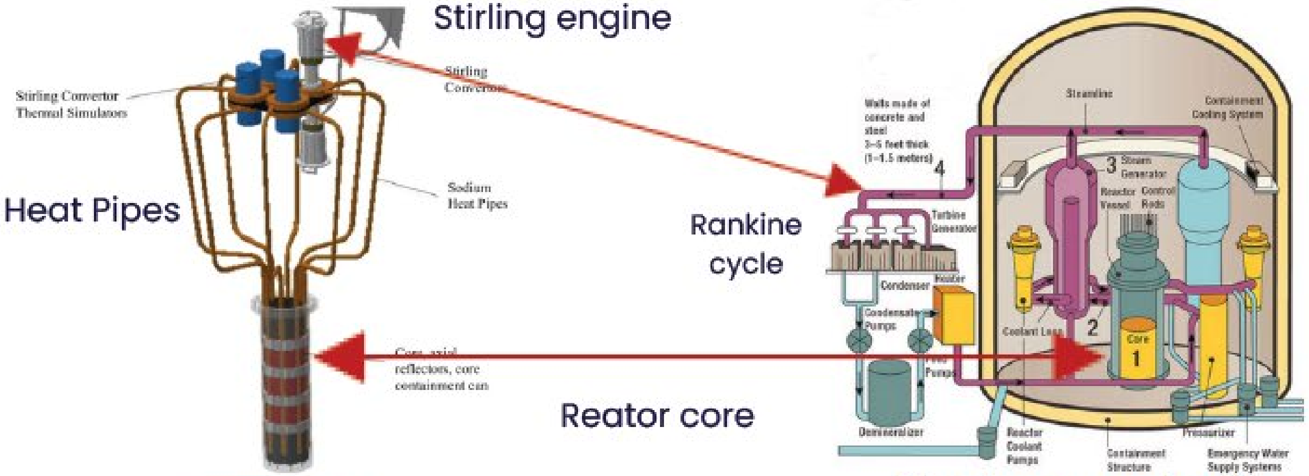
Thermal Power 4kWt / Electrical Power 1.6 kWe

Main systems

Reactor (core + reflector + control bar).
Passive heat transfer system (8 heat pipes).
Power conversion system (Stirling Machines) + cold source (space).
Instrumetation and control (standalone).

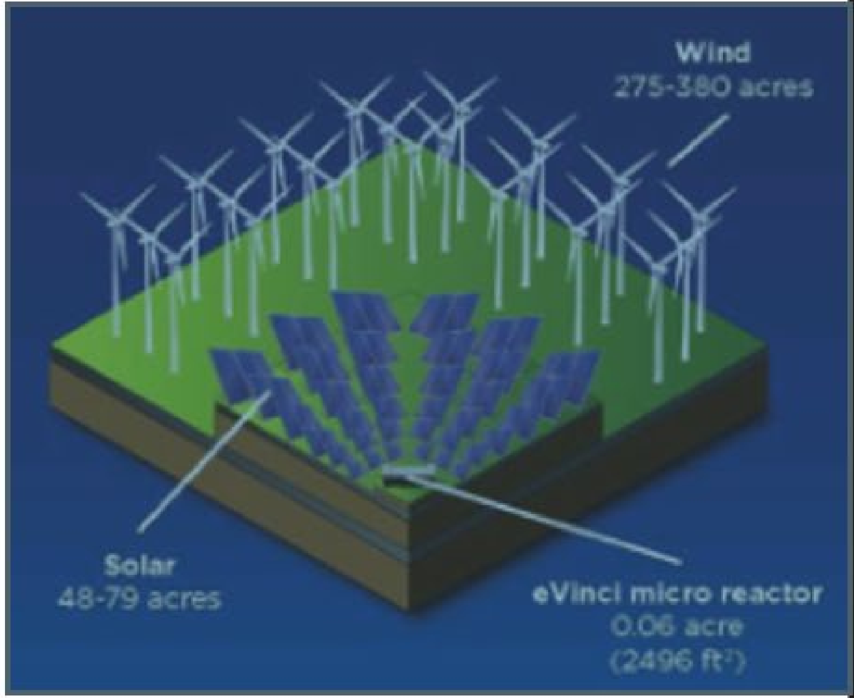
https://www.lanl.gov/media/news/1102-nuclear-reactors-in-space

MNR X PWR NPP Systems



https://www.researchgate.net/figure/Kilopower-Assembly-Ten-with-core-sodium-heat-pipes-hot-end-conduction-plate-Stirling_fig2_269208033

https://www.nrc.gov/reactors/power/pwrs.html



Zohuri, B. 2020 Nuclear Micro Reactors, Pg. 53, Fig. 2.12

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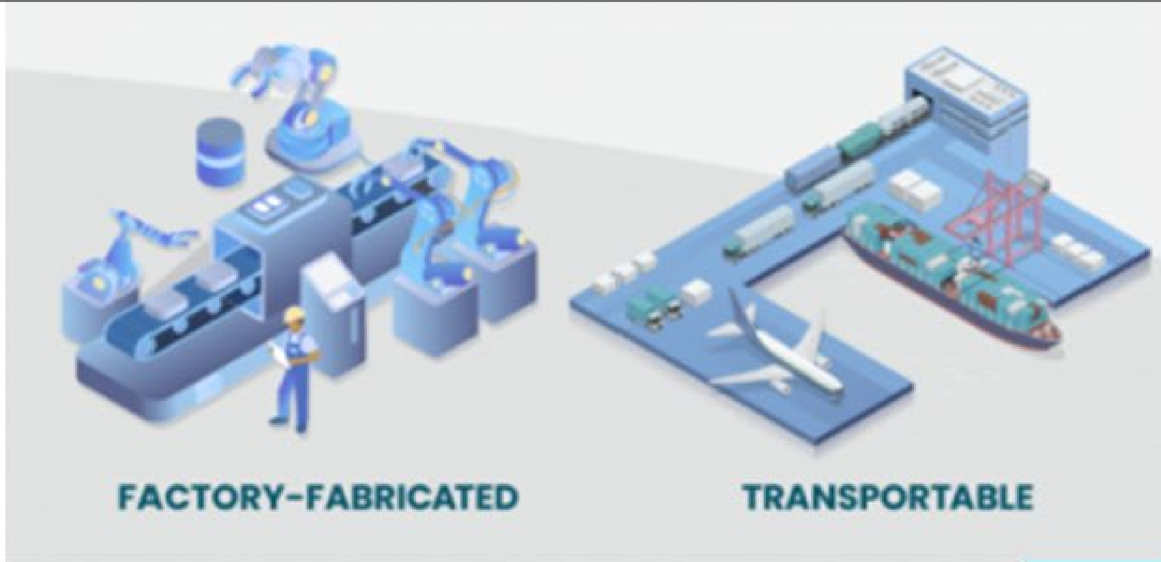
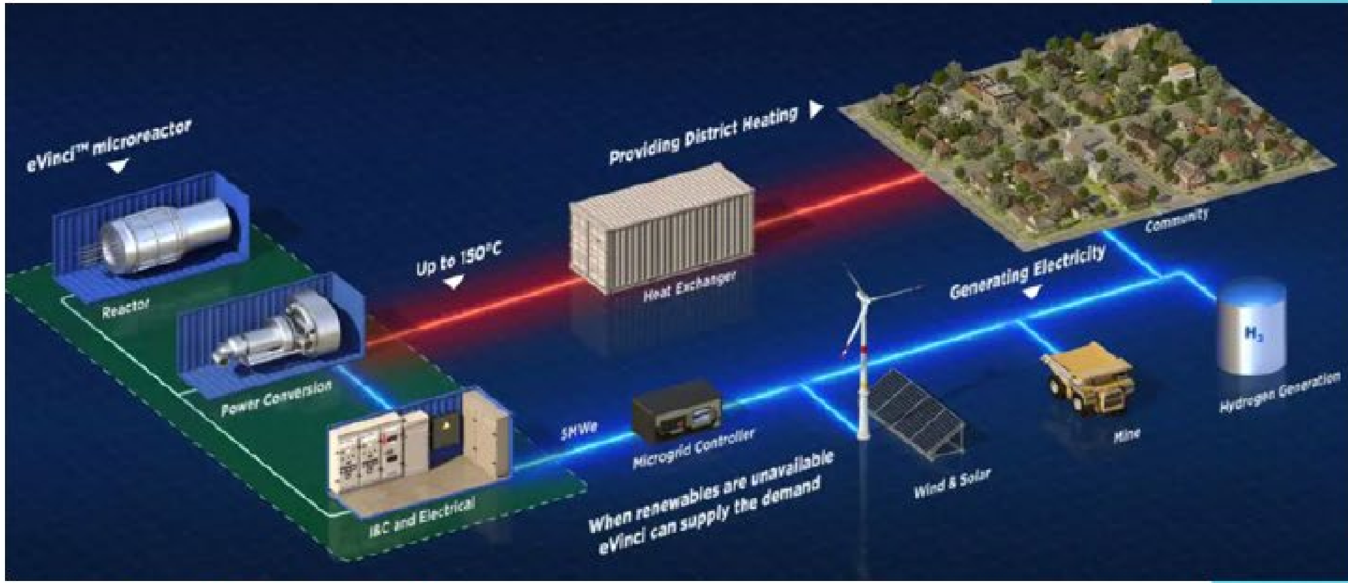
Micro Nuclear Reactors (MNR)

- "Safe by Design";
- "Defense in Depth";
- "Remote Operation";
- "Non-Proliferation" (HALEU);
- "Economics-by-Design Approach";
- Power ~ 5,0 MWe -> container 40`;
- Capacity Factor ~100% 24/7/365;
- **Factory-Fabricated**;
- **Easily Transportable to the site;**
- Plug&Play – Installation < 30 days;
- Lifetime CAPEX > 60 years;
- **Fuel lifetime >10 years**;
- **Sustainable – Non-GHG emissions**; and
- **Can be fully designed, fabricated and operated in Brazil.**



https://nanonuclearenergy.com/microreactors/?v=dc634e207282



https://westinghousenuclear.com/energy-systems/evinci-microreactor/

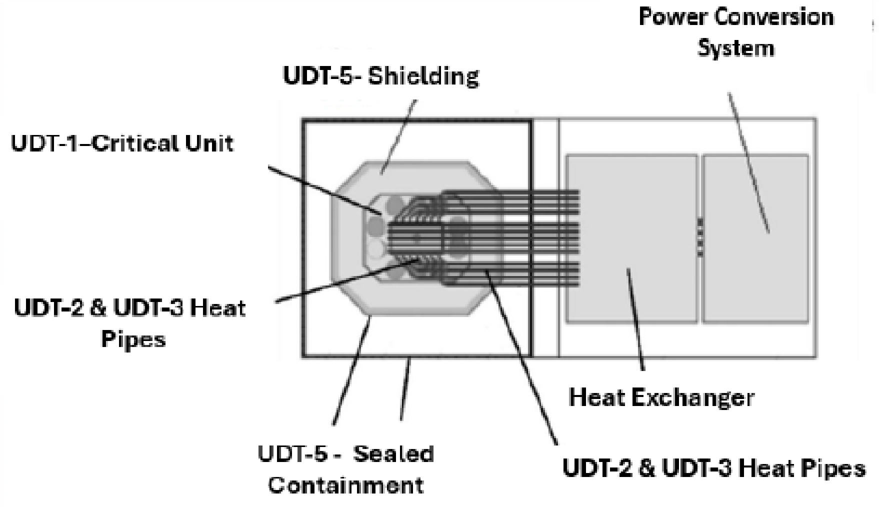
Brazilian MNR Project Structure

Brazilian MNR Project Structure

Project work packages: Demonstrate critical microreactor technologies

- **UDT-1 –** Critical Unit;
- **UDT-2 –** Heat transfer, separate effects for heat pipes;
- **UDT-3 –** Heat transfer, integrated effects reactor-heat; pipes-heat exchanger power conversion system;
- **UDT-4 –** Protection, control and remote supervision; systems to operate in microgrids ;
- **UDT-5 -** Development of shielding and containment;
- **UDT-6 -** Development of Supply Chain materials: fuel for micro reactors (UO_2, U7Mo or U_3Si_2 pellets), Heat Pipes, Beryllium Oxide, Graphite and B_4C;
- **UDT-7 - Sustainability studies of micro reactors, Economic, Environmental, and Community Effects**; and
- **UDT-8 -** Quality Assurance System.

ESTIMATED COST US$ 10 MILLIONS/TIMEFRAME 3Yrs



UDT-4 Reactor instrumentation, control and protection system

UDT-3 Integrated heat transfer, with electrically heated fuel rods

Present to the Nuclear Authority a set of Standards to be used in the Project

Potential Applications to MNR in Brazil

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Potential Applications to MNR in Brazil

Sustainable electric mobility

https://usafacts.org/articles/how-much-electricity-would-it-take-to-power-all-cars-if-they-were-electric/

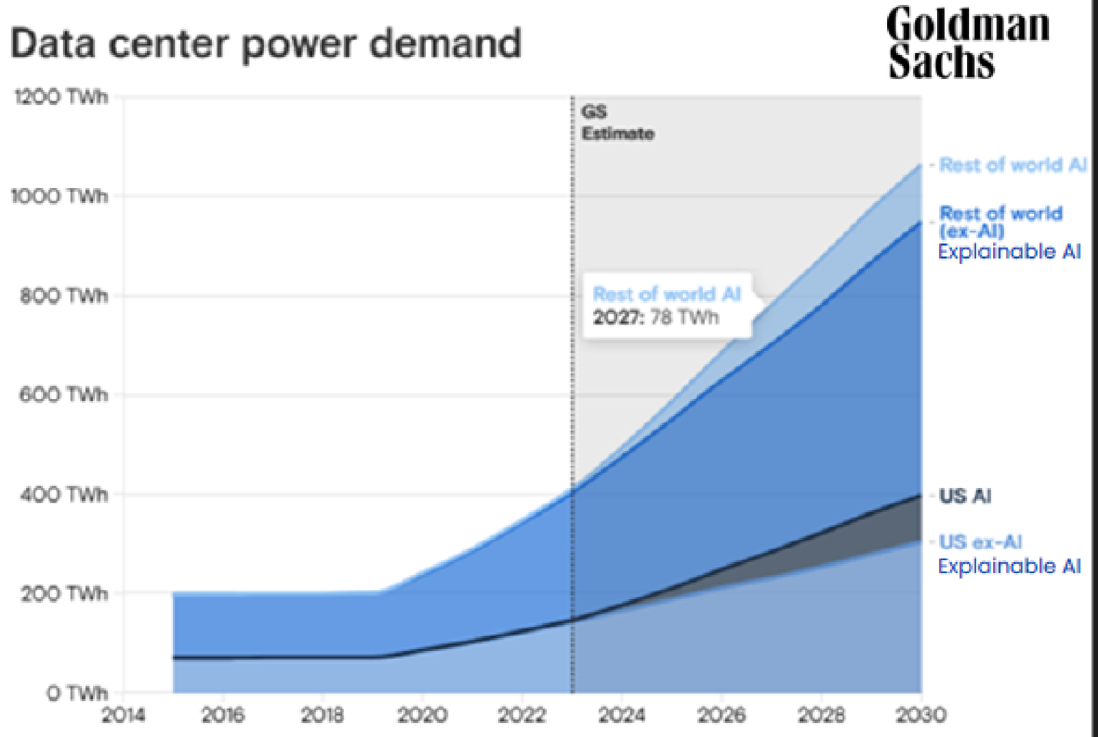
- The US would need to produce 20 to 50% more electricity per year if all cars were electric.

4,800 tWh ~= 10x Electric Energy Consumption in Brazil in 2021

There would be an increase in GHG emissions of more than 20%.

Data centers - DC / AI / Cryptocurrency Mining

- On average, AI data centers can consume up to 10 times more electricity than traditional data centers;
- **DC worldwide consume 1-2% of overall power;**
- **This percentage will likely rise to 3-4% by the end decade;**
- The CO_2 emissions of DC may more than double between 2022 and 2030.



https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand

Data centers - DC / AI / Cryptocurrency Mining

Region	# Data Centers	% DC
SE	124	76.5%
NE	15	9.3%
S	13	8.0%
CW	8	4.9%
NE	2	1.2%
Total	162	100%

- Big Techs: commercial strategies before any social impact;
- They want to have the Green Seal for their operations;
- Latency time is shorter when DCs are close to the consumption centers;
- Friction between native populations and entrepreneurs of new wind farms;
- **Cumbe community** - Controversial case of Quilombola people (fishing village - disrespect of Convension 169 ILO).

https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:55:0::NO::P55_TYPE,P55_LANG,P55_DOCUMENT,P55_NODE:REV,en,C169,/Document

https://reporterbrasil.org.br/2024/09/eolicas-offshore-encurrala-enxu-queimado-pesca/
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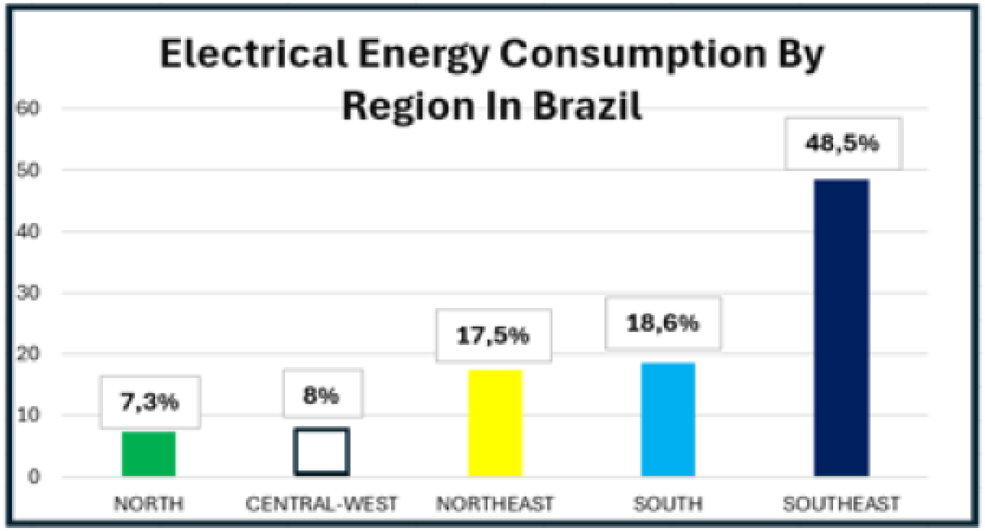
https://www.opendemocracy.net/pt/energia-eolica-brasil-conflitos-comunidades-indigenas/
https://icleconomia.com.br/impactos-provocados-empresas-de-energia-eolica/

https://www.datacentermap.com/brazil/

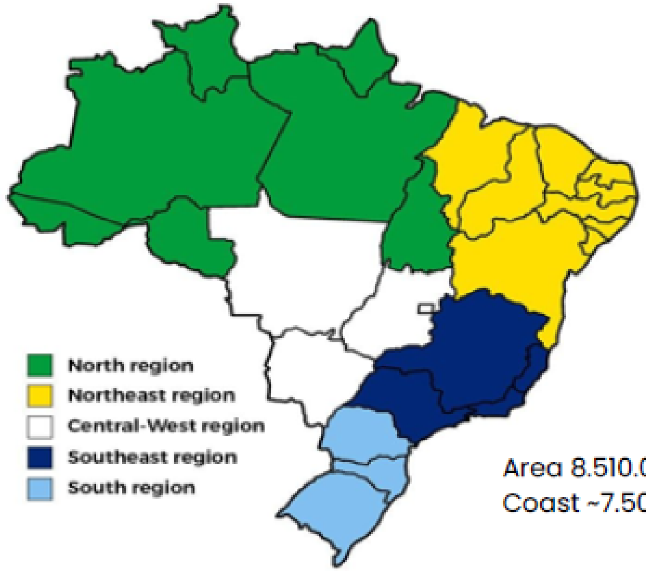
Potential Applications to MNR in Brazil

Brazil Population 212.6 million inhabitants

1st	Southeast Region	88,617,693 Inhabitants	41,7%
2nd	Northeast Region	57,112,096 Inhabitants	26,9%
3rd	South Region	31,113,021 Inhabitants	14,6%
4th	North Region	18,669,345 Inhabitants	8,8%
5th	Central-West Region	17,087845 Inhabitants	8%



BRAZIL REGIONS



Area 8.510.000km²
Coast ~7.500km

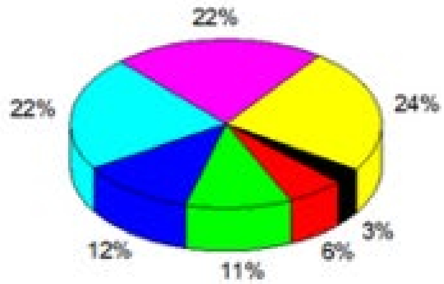
Northeast region is the second largest population. Moreover, it is almost twice as larger than the population of South Region, and both have almost the same electrical energy consumption.

Energy Poverty

- Poor health and well-being
- Education exclusion
- Social exclusion
- Gender inequality

Population distribution on the municipalities in Brazil

POPULATION DISTRIBUTION OF BRAZIL IN 5.570 MUNICIPALITIES



https://www.mapchart.net/brazil-municipalities.html

Population	> 50.000 Hab	12%
40.000<	<50.000 Inhab.	3%
30.000<	<40.000 Inhab.	6%
20.000<	<30.000 Inhab.	11%
10.000<	<20.000 Inhab.	24%
5.000<	<10.000 Inhab.	22%
1.000<	<5.000 Inhab.	22%

AVERAGE INSTALLED POWER PER INHABITANT

CONSIDERING BRAZIL'S PRESENT POWER INSTALLED CAPACITY AND POPULATION.

POWER (MW)	#INHABITANTS
~1	1.000
~5	5.000

A SINGLE NUCLEAR BATTERY OF 5MWe CAN SUPPLY ELECTRICAL ENERGY TO A MUNICIPALITY UP TO 5,000 INHABITANTS. IT WOULD SUPPLY 1,225 (22%) MUNICIPALITIES IN BRAZIL.

A COMBINATION OF 1 TO 4 NUCLEAR BATTERIES COULD SUPPLY ELECTRICAL ENERGY UP TO 68% OF BRAZIL'S MUNICIPALITIES (~3,788).

MNR role in a Just Energy Transition in Brazil

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Alignment of MNR with the 5 Ds of the Energy Transition

1 - Decarbonization:	- Non-GHG emissions.
2 - Decentralization:	-Distributed energy - No transmission line required. -Easily Transportable.
3 - Digitization:	-Easily connectable with other energy sources (Solar, Wind and others). -Remotely operated/monitored.
4 - Market Design:	-Competitive with other energy sources, especially Diesel Generators.
5 - Democratization:	-Easily transportable to any location (Truck/Train/Ship/Plane). -Small-scale or distributed generation democratize supply.

Alignment with the 5 Ds of the energy transition is not enough, social issues must be addressed

- The transitioning towards low-carbon energy is a long-term, non-linear evolving process, with **multiple actor's participation** (Geels, 2011; Kohler et al., 2019).

"Actors – Stakeholders"

Native populations <-> Entrepreneurs <-> Local and Federal Government <-> Justice <-> Earth

Factors to be considered

- **Social Discussions – create tensions on how to address the problem:**

-Discussions on **rights**

-**Ethics** for the future generations

-Individual **obligation** and **collective** action.

- A **just energy transition** must be based on :

-**Distributional Justice**: A just distribution of **costs** and **benefits**;

-**Procedural Justice:** Equitable Procedures, engage stakeholders in a non-discriminatory way;

-**Recognition justice**: **recognize** those who are **harmed** in the process.

- Integrative practices can **bridge stakeholders** by **allocating transparent roles (trust), addressing mutually beneficial goals, and collectively solving problems.**

Sustainability studies of micro reactors, Economic, Environmental, and Community Effects

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Economic Effects: Verify the economic impacts and feasibility of implementing microreactors and distributed electric energy.

- Insertion of micro reactors:

-In Municipalities with l**ess than 20,000 inhabitants;**

-In **Electricity-intensive industries, service companies, and electric vehicle charging stations;**

-**Integration with renewable sources (solar and wind) and energy quality.**

- Assessment of the **resilience and impact of microreactors** on the stability of the electrical system.

Environmental Effects: Our Contribution of nuclear micro reactors to the reduction of long-lasting radioactive waste generated by the nuclear sector in Brazil.

- Study to **recycle long-term waste** material in microreactors
- Design MNRs for **maximum reuse** of reactor components.
- Develop processes for **maximum recovery of unburned nuclear fuel.**

Community Effects – Public acceptance is a key step towards realizing the potential benefits of micro reactors.

- Assessments for implementing micro reactors are **comprehensive and meticulous**, ensuring that **sustainable development aspects** are considered.
- **Strong focus on regulation, standards, and public policies**. This emphasis on governance provides a secure framework for the deployment of microreactors.
- Identify **indicators for monitoring environmental and social impacts,** taking into account the growth of municipalities' and communities' local economies.
- Create a **roadmap for planning and implementing nuclear micro reactors**, including a public policy monitoring system and an evaluation of the public consultation process (**convention 169 ILO**) with local communities that will receive the micro reactors.

Final Considerations

Final Considerations

Micro Nuclear Reactors Social Acceptance Advantages

- Distributed source of energy - benefits local population (Microgrid)
- Micro Nuclear Reactors:

- Firm energy source 24/7/365;
- Electric Energy / Heat / Energy Storage (H2);
-Water purification / piped water;
-Schools – Internet / Access to education (long distance);
-Easily transportable;
-Plug&Play – Installation < 30 days (violence reported - installation of wind farms);
-Safe by Design & Remoted Operated; and
-MNR Footprint -> Area < 1 acre / Solar ~ 80 acre / Wind ~ 380 Acre;

- Do not change site characteristics

“Simplicity is the Ultimate Sophistication.”

Leonardo Da Vinci

ACKNOWLEDGEMENTS

CNEN

https://www.gov.br/cnen/pt-br

https://www.marinha.mil.br/om/diretoria-de-desenvolvimento-nuclear-da-marinha

UNIVERSIDADE FEDERAL DO CEARÁ

https://www.ufc.br/

INB

INDÚSTRIAS NUCLEARES DO BRASIL

https://www.inb.gov.br/A-INB/

ien

https://www.gov.br/ien/pt-br

DIAMANTE

GERAÇÃO DE ENERGIA

https://diamanteenergia.com/

UFABC Universidade Federal do ABC

https://www.ufabc.edu.br/

ipen

nuclear and energy research institute

https://www.ipen.br/portal_por/portal/default.php

AMAZUL

https://www.amazul.mar.mil.br/

INATEL FUNDAÇÃO

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Thank you!

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