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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IAEA
Ministerial Conference on
Nuclear Science, Technology and Applications and the
Technical Cooperation Programme
26–28 November 2024, Vienna, Austria

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, Economics, Environmental, and Community Effects.

Overview of Brazilian Nuclear Industry

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 – (2 SP, 1 RJ & 1 MG);
- 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;
  - U Prospection and Mining
  - Yellow Cake Production
  - Design and Fuel Fabrication
  - U centrifugate enrichment facility LEU (<5% U235)
- Brazilian Navy Nuclear Program;
  - Submarine Propulsion – Land Prototype under construction (SMR)
  - HALEU U enrichment (<20%)
  - UF6 Production (2025)
- All Brazilian Nuclear Program is under Safeguards agreement with IAEA.

Top 10 countries with the highest uranium reserves 2023

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

Micro Nuclear Reactors (MNR): Space and Terrestrial Developments

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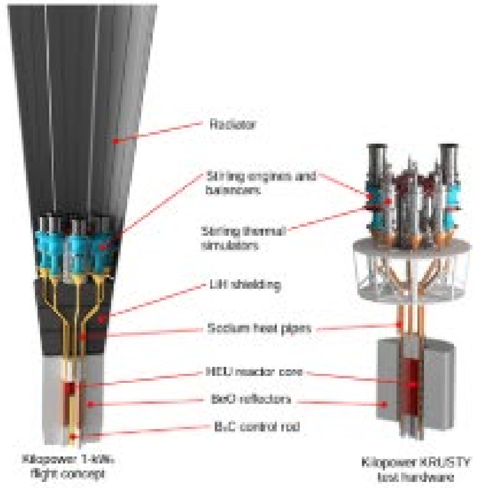
Micro Nuclear Reactors (MNR)



NASA/TM—2018-219941

Thermal Power 4kWt / Electrical Power 1.6 kWe

Main systems

Reactor (core + reflector = control bar)

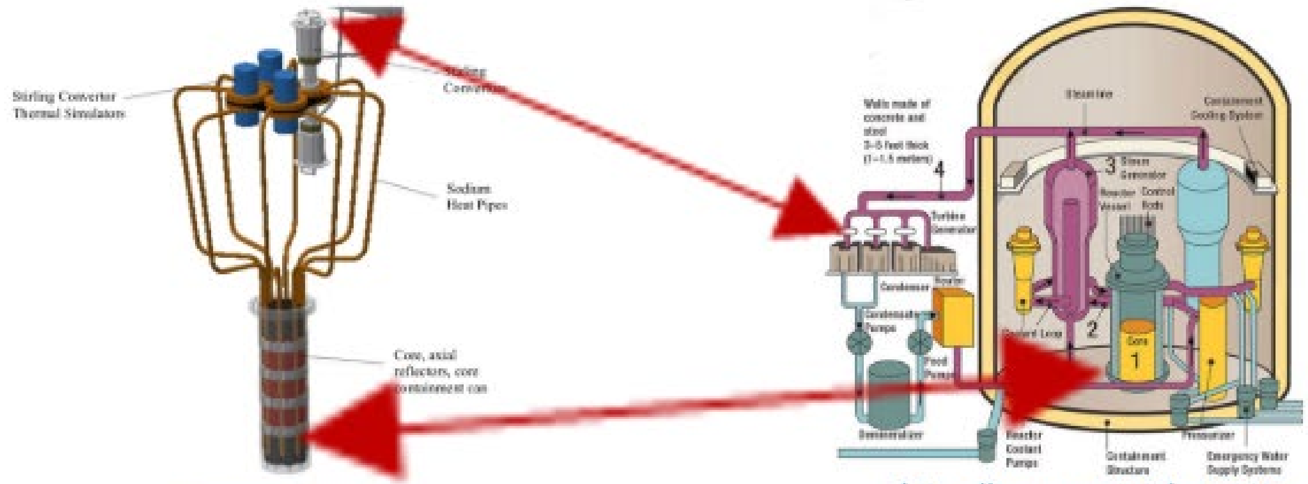
Passive heat transfer system (8 heat pipes)

Power conversion system (Stirling Machines) + cold source (space)

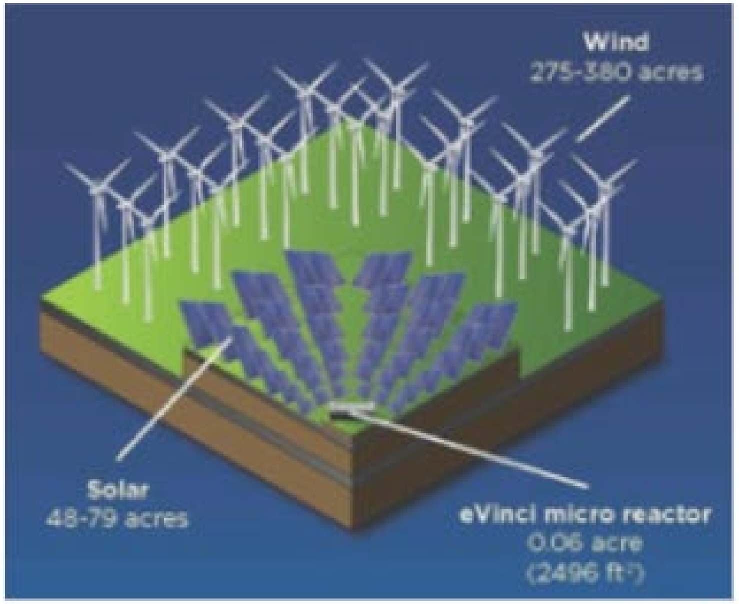
Instrumetation and control (standalone)

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

MNR X PWR NPP SYSTEMS



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



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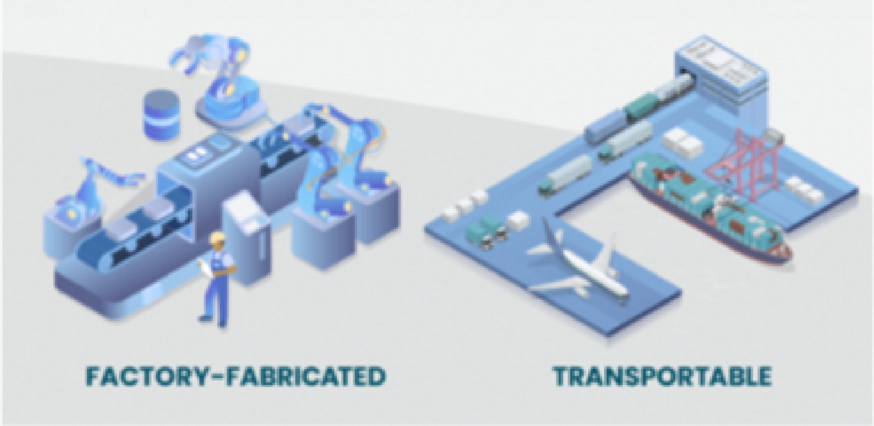
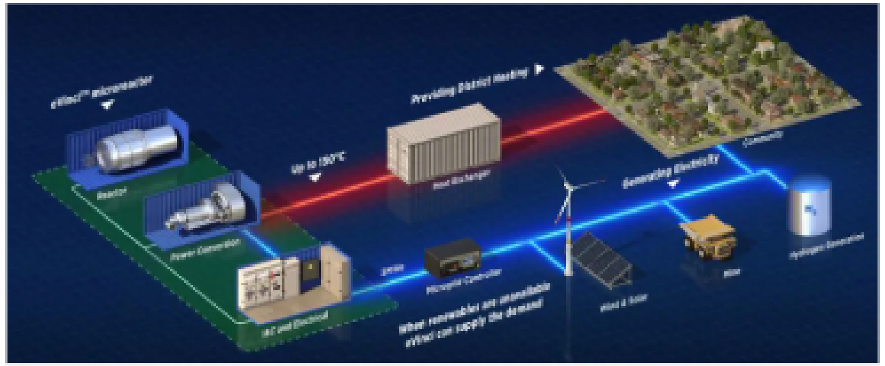
Micro Nuclear Reactors (MNR)

- "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;
- Easily Transportable to the site;
- Plug&Play – Installation < 30 days;
- Lifetime CAPEX > 60 years;
- Fuel lifetime >10 years;
- Factory-Fabricated;
- 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/

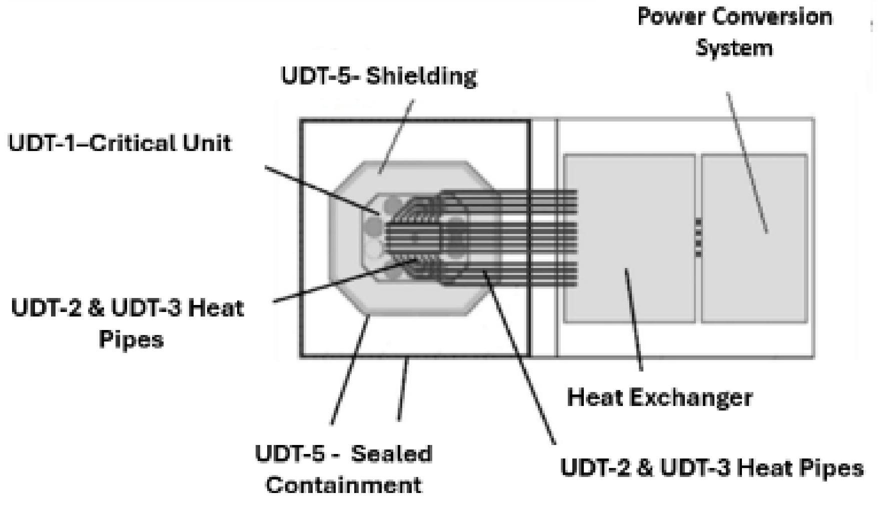
Brazilian MNR Project Structure

Brazilian MNR Project Structure

Project work packages

- **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 special materials (Graphite, Beryllium Oxide, Heat Pipes and B4C) and fuel for micro reactors (UO2, U7Mo or U3Si2 pellets);
- **UDT-7 -** Sustainability studies of micro reactors, Economics, Environmental, and Community Effects;
- **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

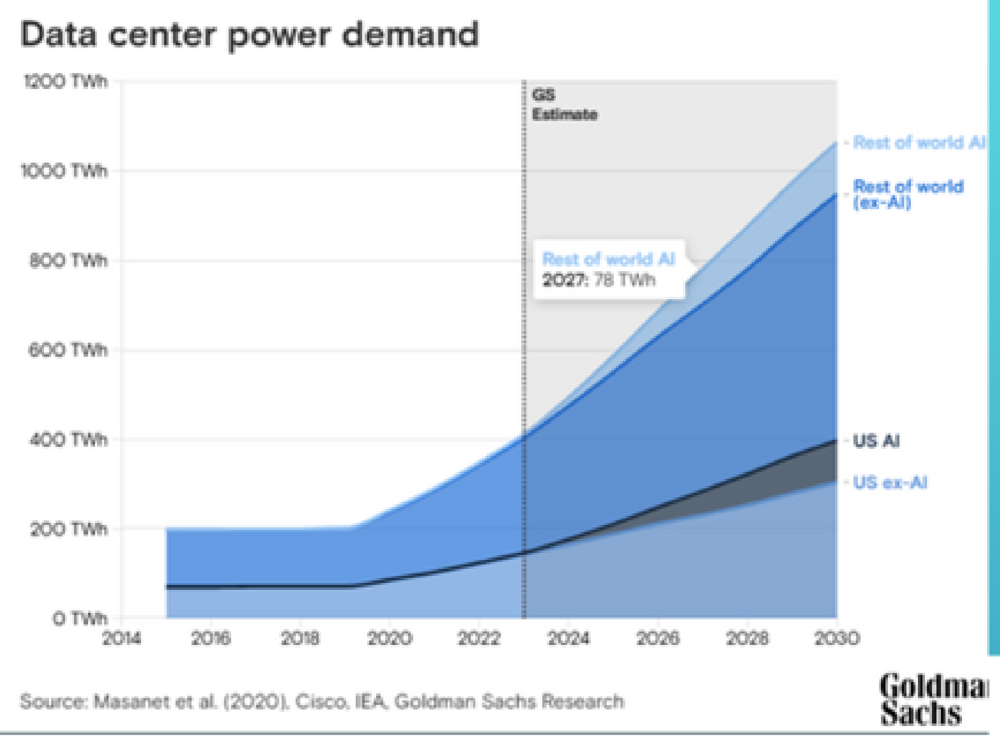
Sustainable electric mobility

- 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%

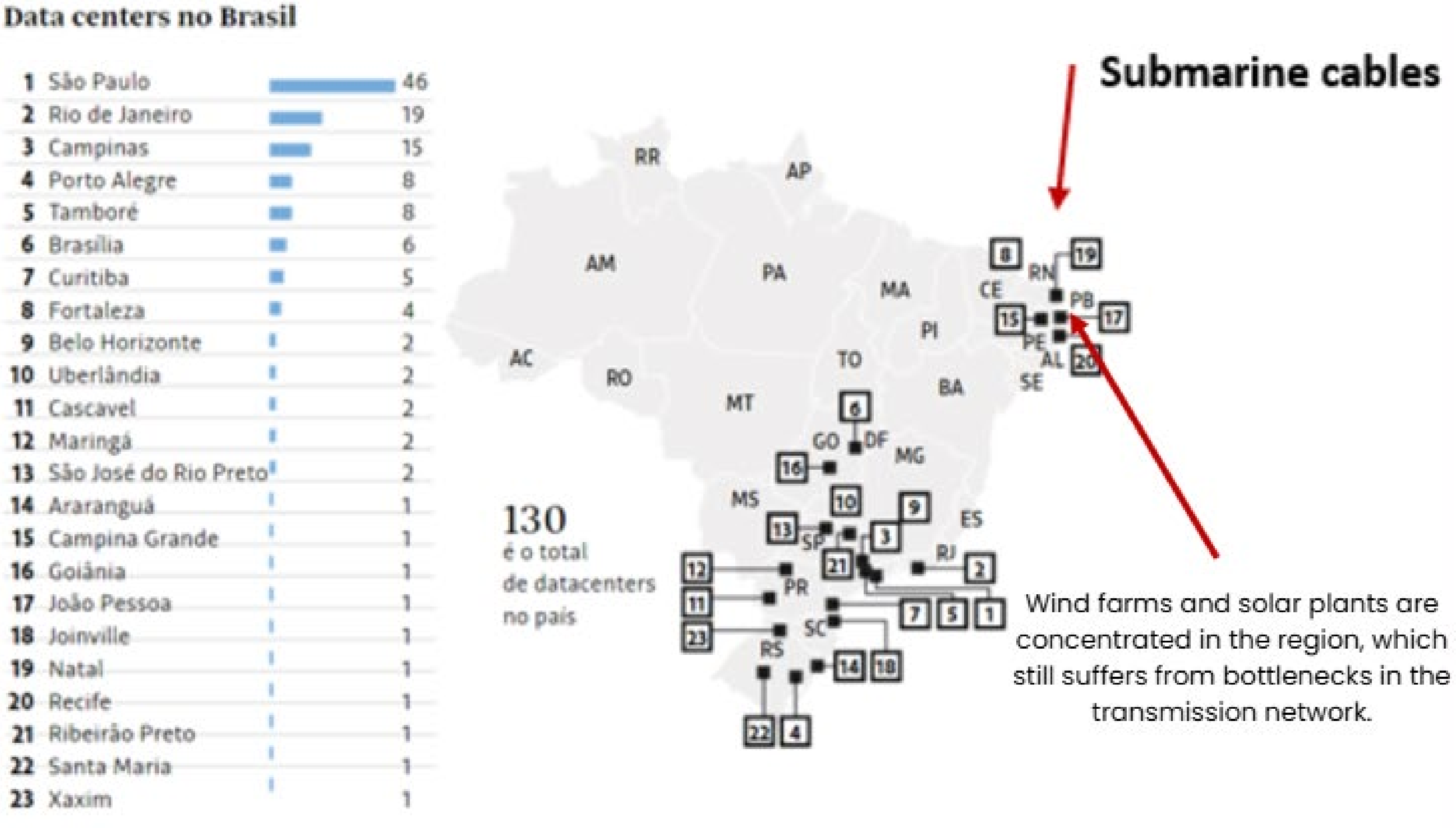
Data centers - DC / AI / Cryptocurrency Mining

- 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 CO2 emissions of DC may more than double between 2022 and 2030.



Data centers - DC / AI / Cryptocurrency Mining

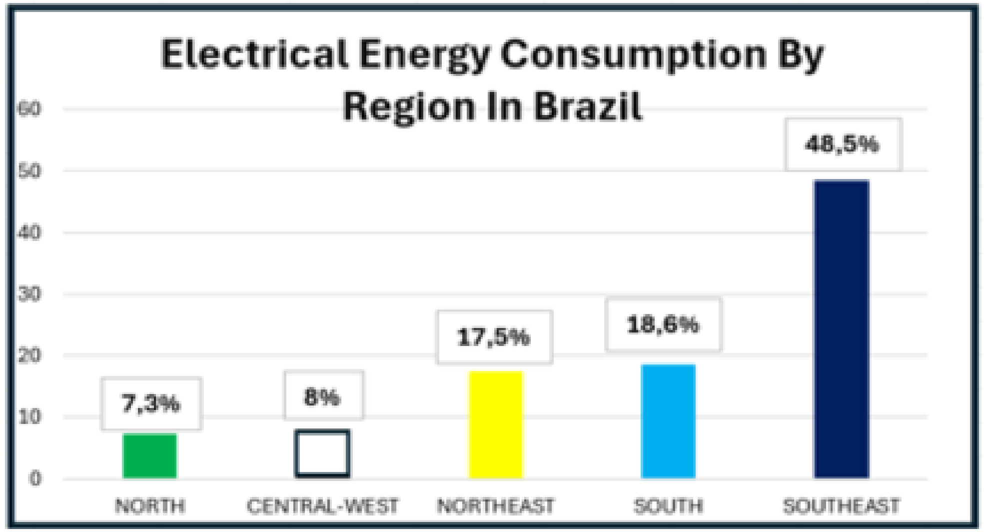
- Big Techs: commercial strategies before any social impact.
- Each of these structures consumes between 150 MW (megawatts) and 500 MW.



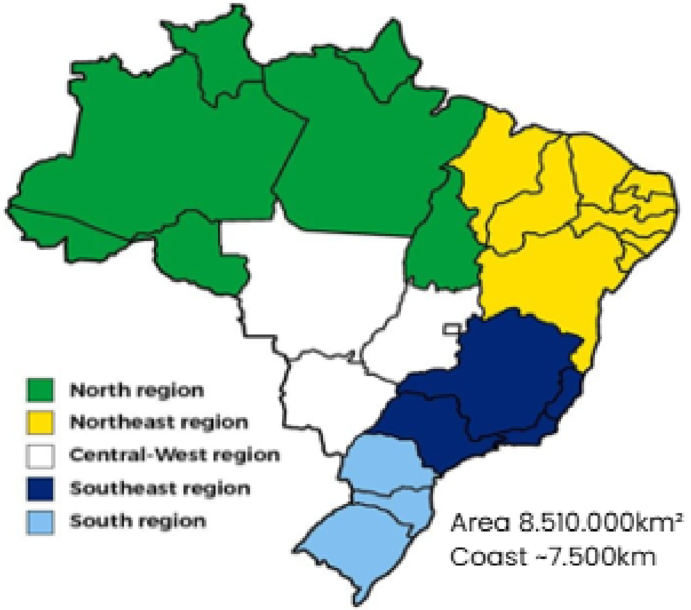
Fonte: Data Center Map (consultado em 22 mar 2024)

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



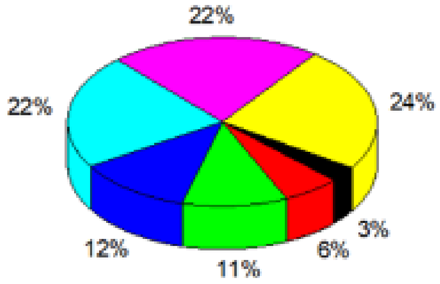
Northeast region is the second largest population. And it is almost twice as much larger than the population of South Region, and both have almost the same electrical energy consumption.

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



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%

AVARAGE 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 (3,787)

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 debate on climate change is **more than environmental issues**, it includes:

-Discussions on **rights**;

-**Ethics** for the future;

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

All of which create tensions on how to address the problem.

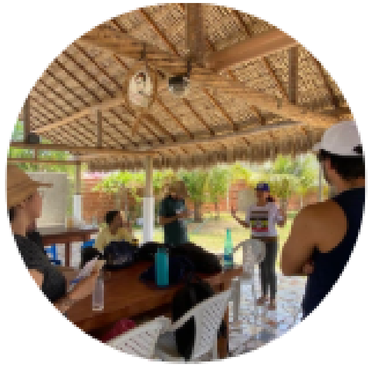
- Interventions in energy systems are more than technology and economic development; they are about:

-Exerting **political power and social cohesion**;

- Making **ethical and moral decisions regarding equity**;

-**Due process**; and

-**Justice**.



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

- A **just energy transition** must be based on :
  -**Distributional Justice:** A just distribution of cost and benefits;
  -**Procedural Justice:** the use of equitable procedures that engage all stakeholders in a non-discriminatory way;
  -**Recognition justice:** recognize those who are harmed in the process.

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

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

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

- Insertion of micro reactors into the electrical grid and in cities with l**ess than 20,000 inhabitants and planning of Electricity Distribution Networks** (RDEE).
- Insertion of micro reactors in **electricity-intensive industries, service companies, and electric vehicle charging stations.**
- Interaction of **electrical generation from micro reactors 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.

- Quantify the **volume of transuranic in irradiated fuel from the Angra 1 and 2 nuclear power plants**, a material normally considered long-term waste, and study how to recycle them in microreactors.
- **Select waste with the appropriate physical and chemical properties** to maximize the efficiency of electricity generation, reduce the radiotoxicity of radioactive waste in Brazil, and reduce the storage time required for this waste.
- **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.

- Our site assessments for implementing micro reactors are comprehensive and meticulous, ensuring that **sustainable development aspects** are considered.
- Our scenario for implementing micro reactors in Brazil is designed with a **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** in the implementation and operation of nuclear micro reactors, 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.

ACKNOWLEDGEMENT

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
instituto de engenharia nuclear
https://www.gov.br/ien/pt-br

DIAMANTE
GERAÇÃO DE ENERGIA
https://diamanteenergia.com/

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“Simplicity is the Ultimate Sophistication.”

Leonardo Da Vinci

Thank you!

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