SMR – Projects, opportunities and challenges

INAC 2024 - International Nuclear Atlantic Conference

Clayton Silva
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MINISTÉRIO DE MINAS E ENERGIA

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

EPE – Energy Research Office

Brief institutional description of EPE

Governmental agency for energy planning studies

Supports the Ministry of Mines and Energy in its decision-making process

Mission

To carry out high quality studies and research to support planning, development and national energy policy.

Biomass & Biofuels Oil & Gas Electricity

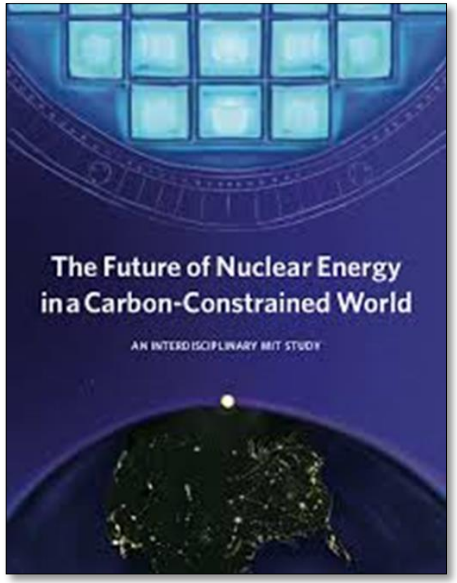
Hydro, Wind, Solar, Nuclear, Bioenergy, Oil, Gas, Coal, etc.

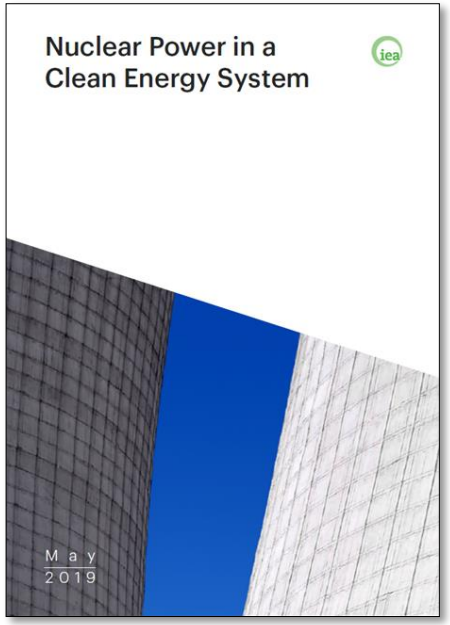
Hydrogen Transmission lines Energy hubs

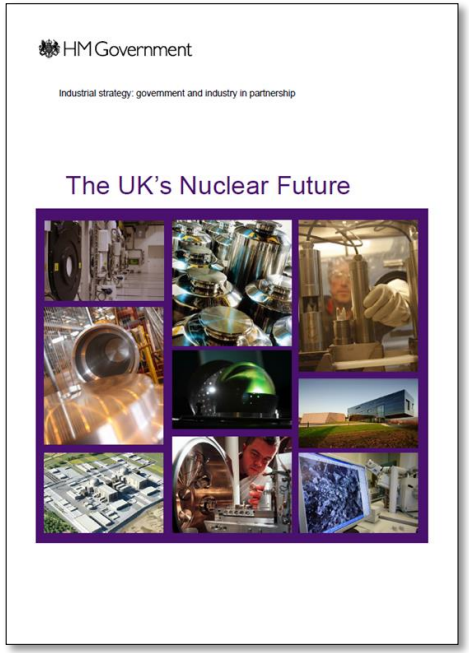
EPE – Energy Research Office

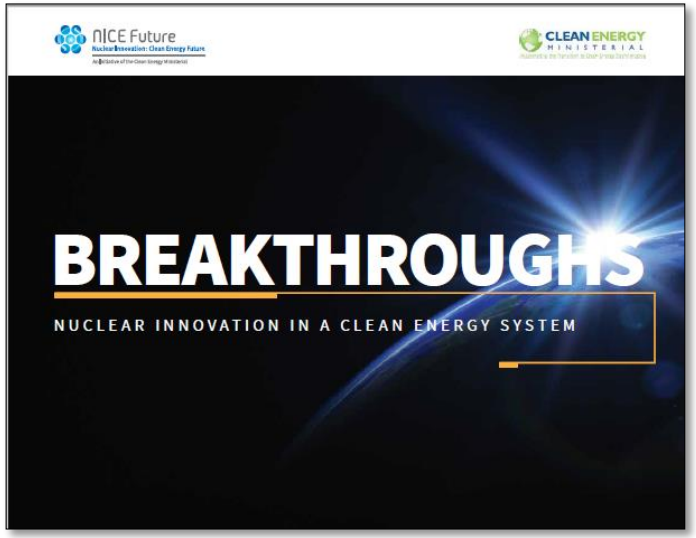
Some of the EPE reports

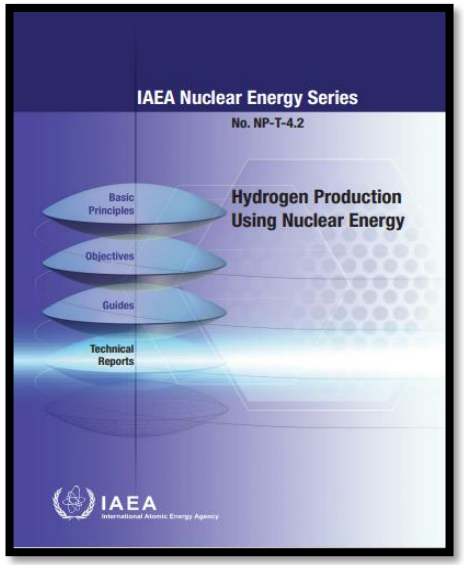
Nuclear energy will play a role in the energy transition





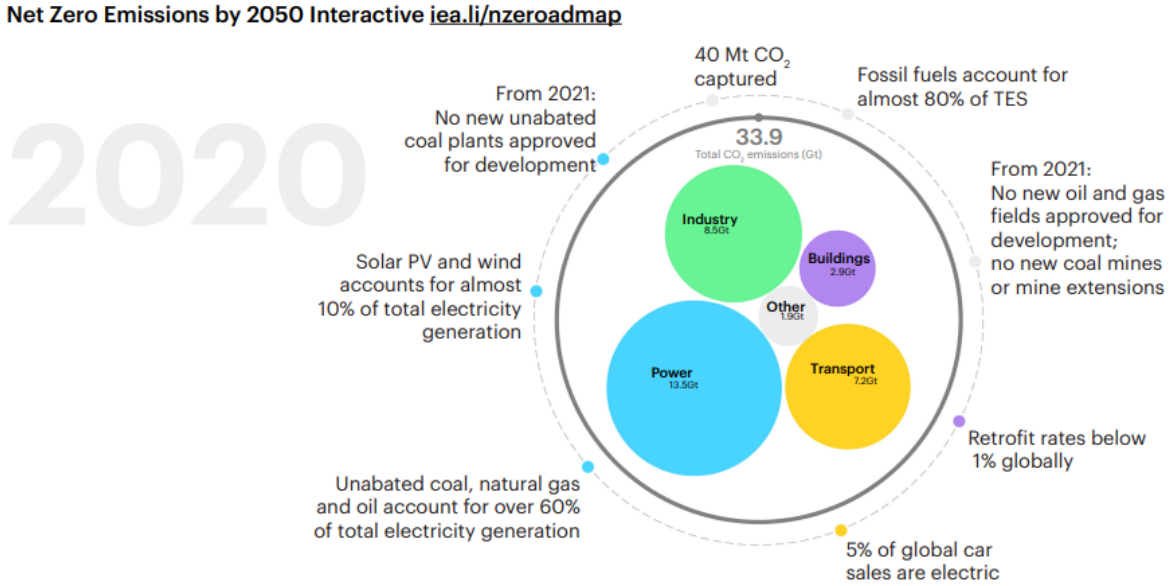






Nuclear energy will play a role in the energy transition

Path to Net Zero 2050



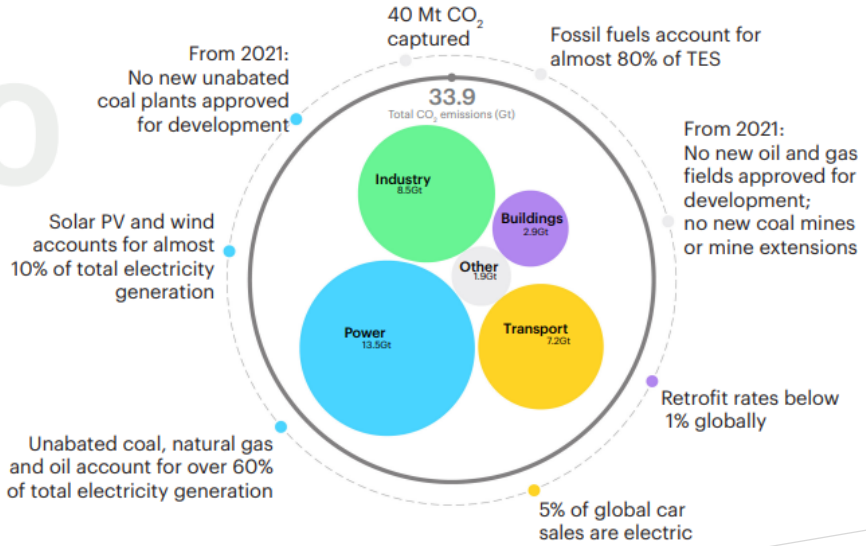
"Hydropower and nuclear, the two largest sources of low-carbon electricity today, provide an essential foundation for transitions."

Source: IEA - Net Zero by 2050 - A Roadmap for the Global Energy Sector

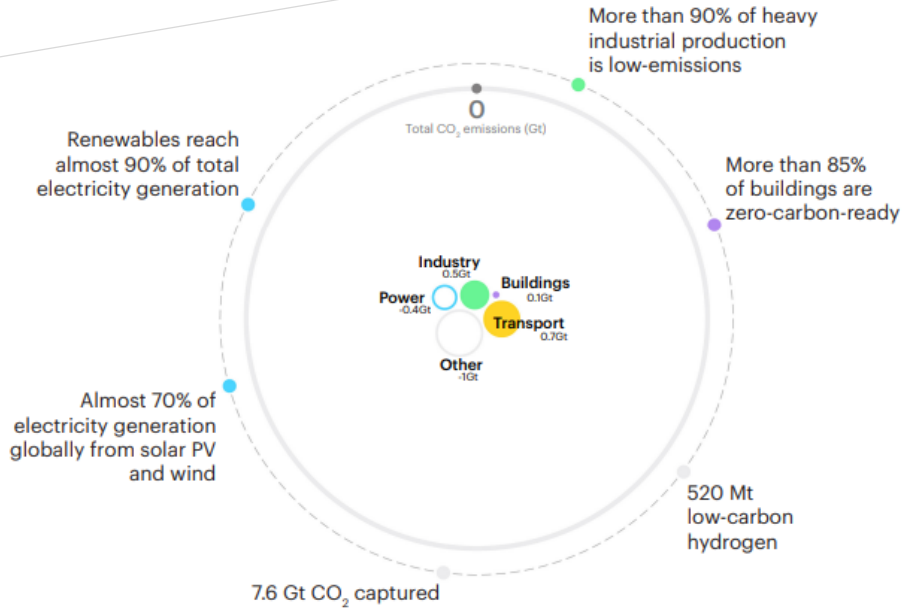
Nuclear energy will play a role in the energy transition

Path to Net Zero 2050

Net Zero Emissions by 2050 Interactive iea.li/nzeroadmap



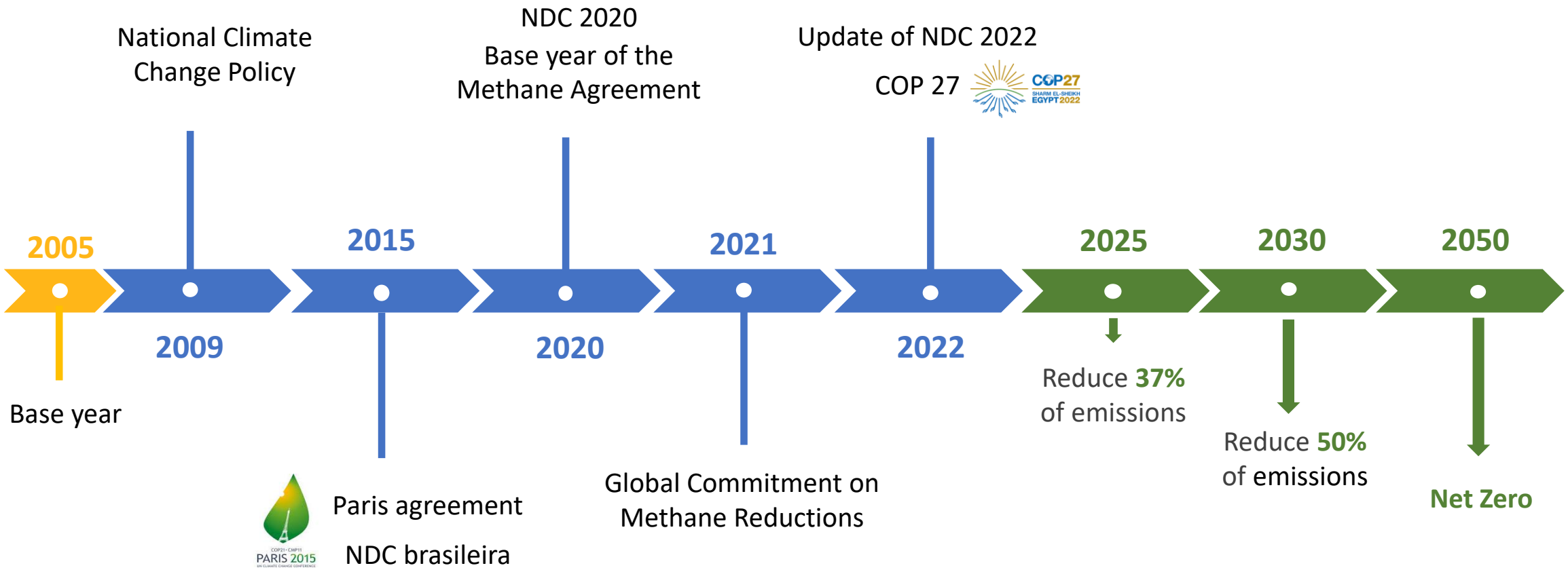
"Hydropower and nuclear, the two largest sources of low-carbon electricity today, provide an essential foundation for transitions."



"By 2050, almost 90% of electricity generation comes from renewable sources, with wind and solar PV together accounting for nearly 70%. Most of the remainder comes from nuclear."

Source: IEA - Net Zero by 2050 - A Roadmap for the Global Energy Sector

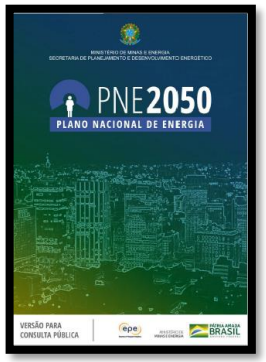
Landmarks of the climate discussion assumed by Brazil:



Nuclear energy in the 2050 Brazilian Energy Planning

PNE 2050 indicate challenges and recommendations -> **PNE 2055 in progress!**

PNE 2050
Nuclear Energy



Main Challenges:

Communication; improvements on institutional, legal and regulatory arrangements; implementing the National Nuclear Policy; Security & Safety; useful life and decommissioning of facilities; knowledge on related minerals resources.

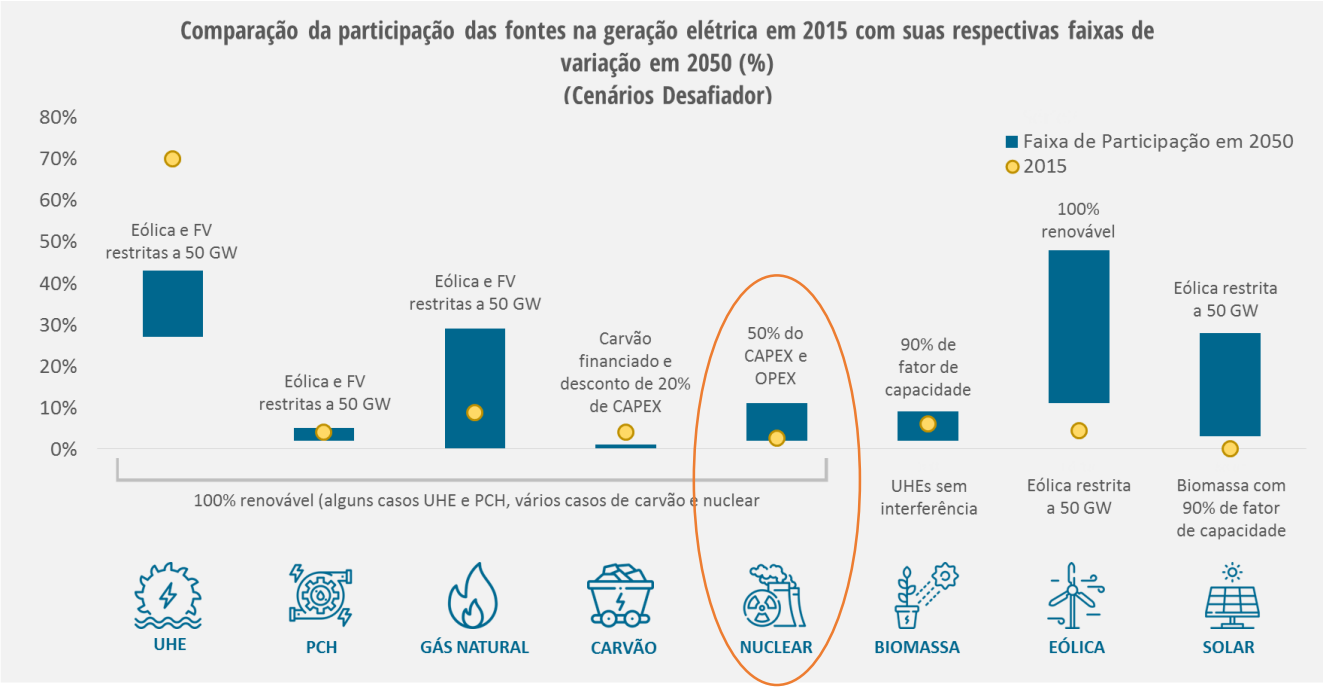
Recomendations:

To enhance communications with Brazilian society; To improve regulation framework; To estimate benefits related to spillovers and economies of scope; To standardize projects to get scale and learning economies; To seek synergies in public policies; To assure good housekeeping of waste and used fuel; To improve culture on security and safety; To guarantee fuel supply; To evaluate implications of expanding useful life.

Simulações para o Setor Elétrico Brasileiro

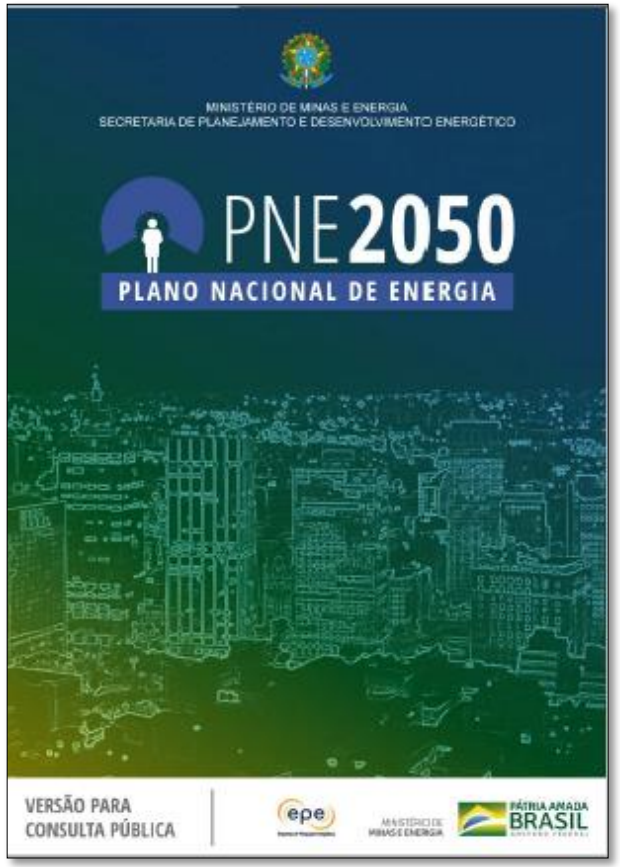
Dois casos básicos para nuclear nas 64 simulações :

1. Redução significativa de custos (CAPEX and/or OPEX) para plantas termonucleares
2. Política pública estabelece expansão de plantas termonucleares de **8-10 GW até 2050**



Nuclear energy in the 2050 Brazilian Energy Planning

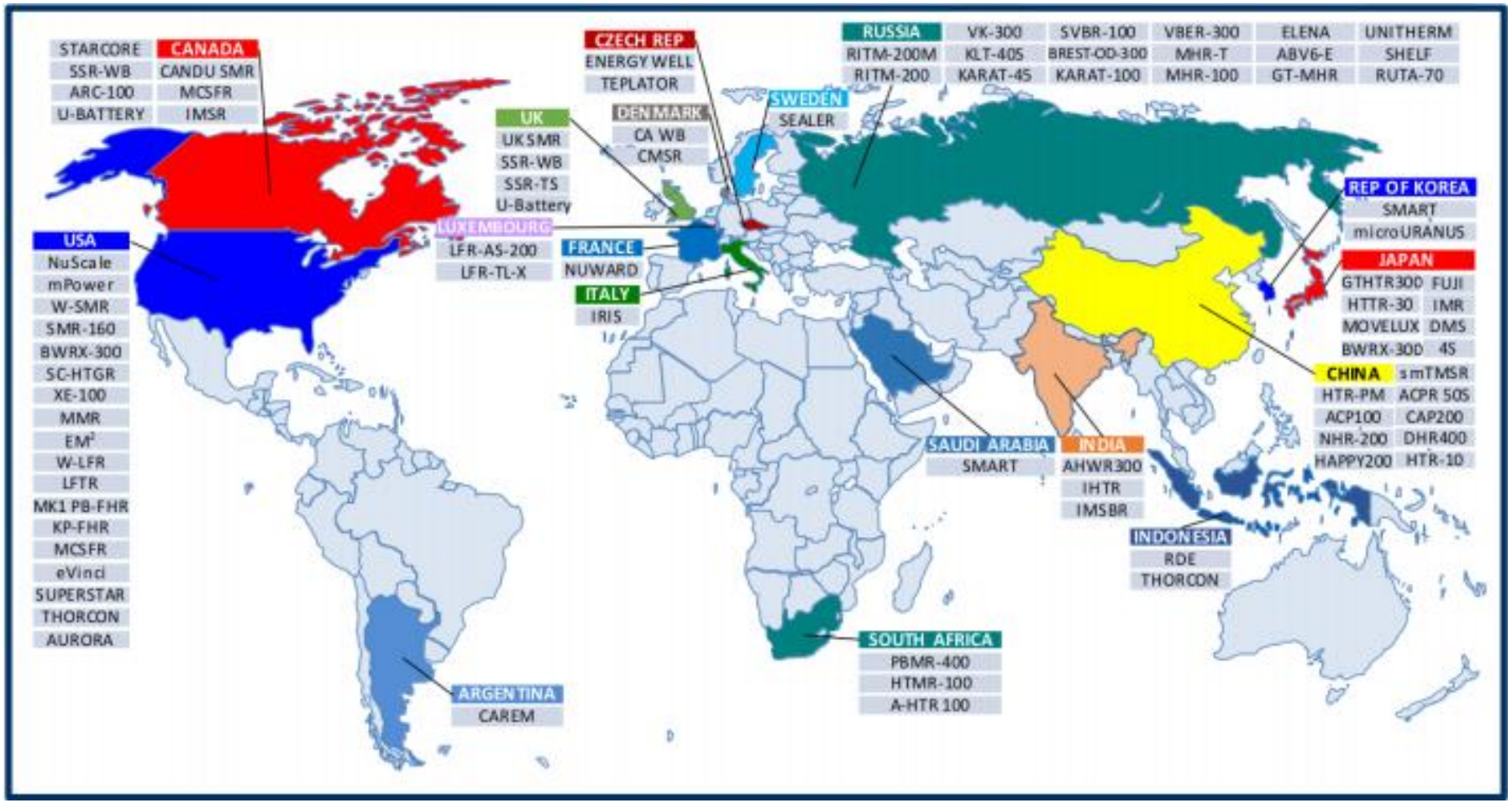
SMR brings new opportunities to nuclear industry



PNE 2050
Nuclear Energy

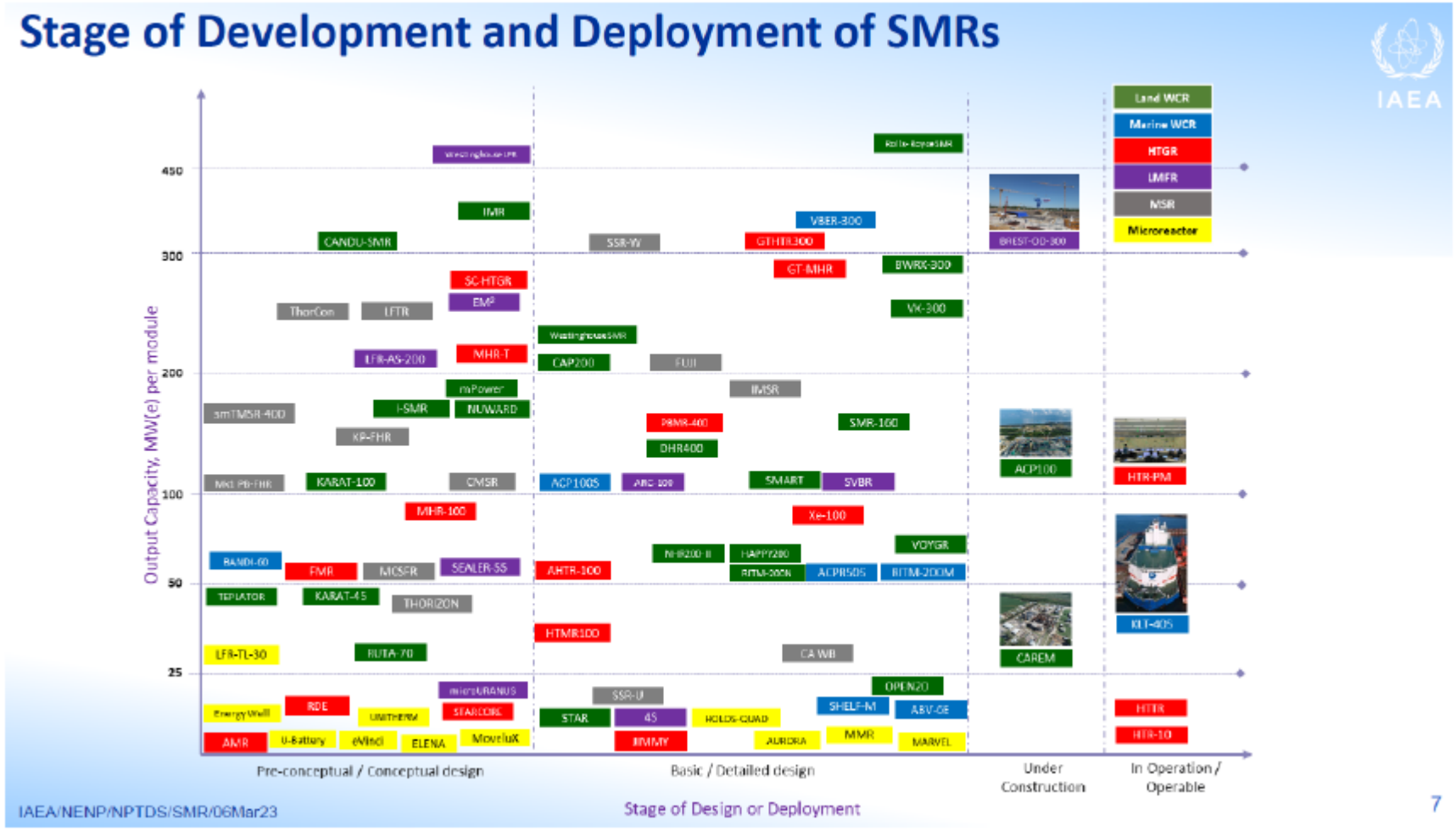
In Brazil, the technological option was for pressurized water reactors (PWR), the most adopted technology in the world, with more than 60% of the plants in operation. This option will be maintained for Angra III and for new power plant projects that are eventually defined throughout the 2020s. ***After 2030, new projects may be based on*** *PWR,* ***SMR*** *and fourth-generation reactor technologies, if the latter reach technological maturity and competitiveness.*

Are the SMRs a feasible alternative?



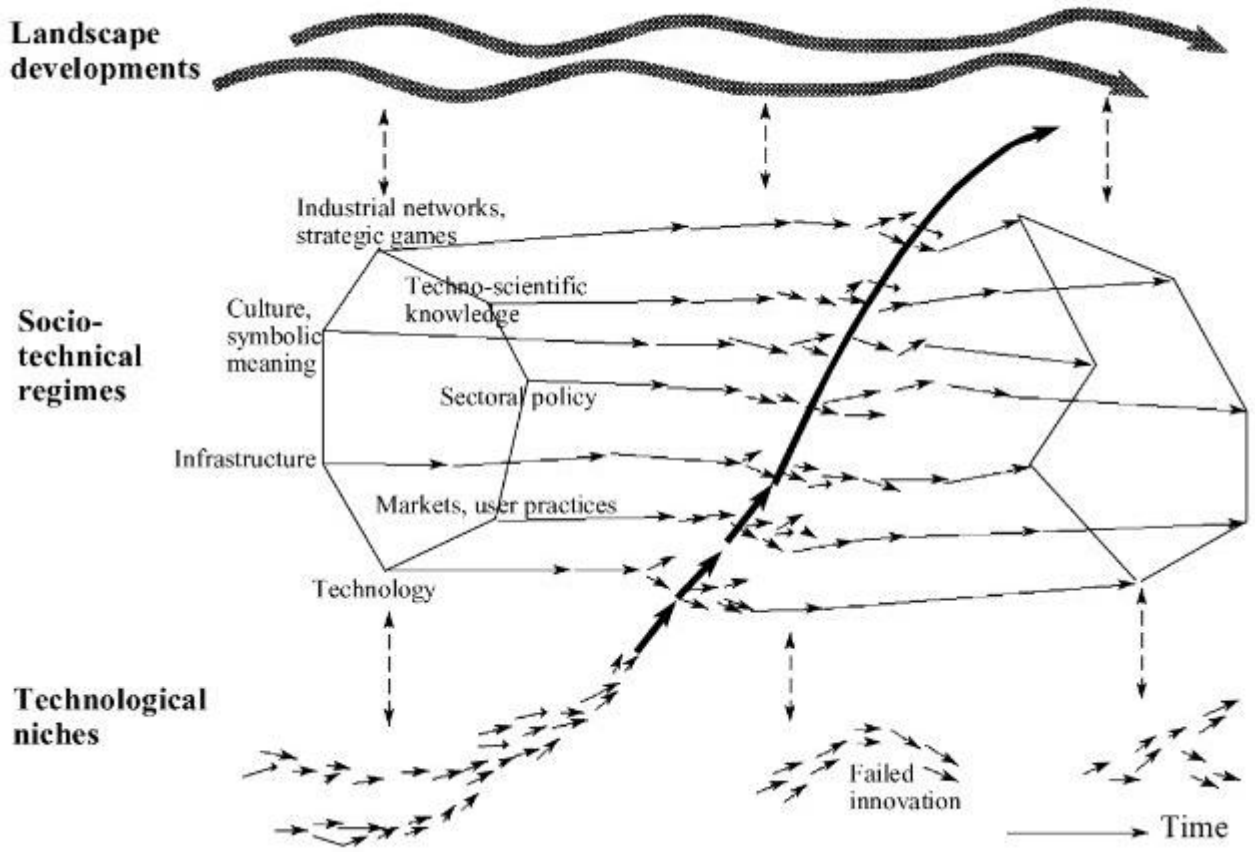
Source: IAEA (2020). "Advances in Small Modular Reactor Technology Developments (A Supplement to IAEA ARIS)".

Are the SMRs a feasible alternative?



Source: IAEA, 2023.

Technological transition



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Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study

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Abstract

This paper addresses the question of how technological transitions (TT) come about? Are there particular patterns and mechanisms in transition processes? TT are defined as major, long-term technological changes in the way societal functions are fulfilled. TT do not only involve changes in technology, but also changes in user practices, regulation, industrial networks, infrastructure, and symbolic meaning or culture. This paper practices 'appreciative theory' [R.R. Nelson, S.G. Winter, An Evolutionary Theory of Economic Change, Bellknap Press, Cambridge, MA, 1982] and brings together insights from evolutionary economics and technology studies. This results in a multi-level perspective on TT where two views of the evolution are combined: (i) evolution as a process of variation, selection and retention, (ii) evolution as a process of unfolding and reconfiguration. The perspective is empirically illustrated with a qualitative longitudinal case-study, the transition from sailing ships to steamships, 1780–1900. Three particular mechanisms in TT are described: niche-cumulation, technological add-on and hybridisation, riding along with market growth.

Keywords: Technological transitions; Regime shifts; Evolutionary theory; Multi-level analysis; Sailing ships and steamships

1. Introduction

Technological Transitions (TT) are defined as major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled. TT do not only involve technological changes, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and symbolic meaning. An example is the transition in offices from punched card technology and small office technology to digital computers, 1930–1960 (Van den Ende and Kemp, 1999).

This paper addresses the following questions: How do TT come about? Are there particular patterns and mechanisms in transition processes? My analysis of TT is based on a particular perspective on technology, stemming from sociology of technology. In this perspective technology, of itself, has no power, does nothing. Only in association with human agency, social structures and organisations does technology fulfil functions. In this respect, Hughes (1987) coined the useful metaphor of a 'seamless web' in which physical artefacts, organisations, natural resources, scientific elements, legislative artefacts are combined in order to achieve functionalities. Rip and Kemp (1998) analyse technology as 'configurations that work'. While the term 'configurations' refers to the alignment between a heterogeneous set of elements, the addition

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PII: S0048-7333(02)00062-8

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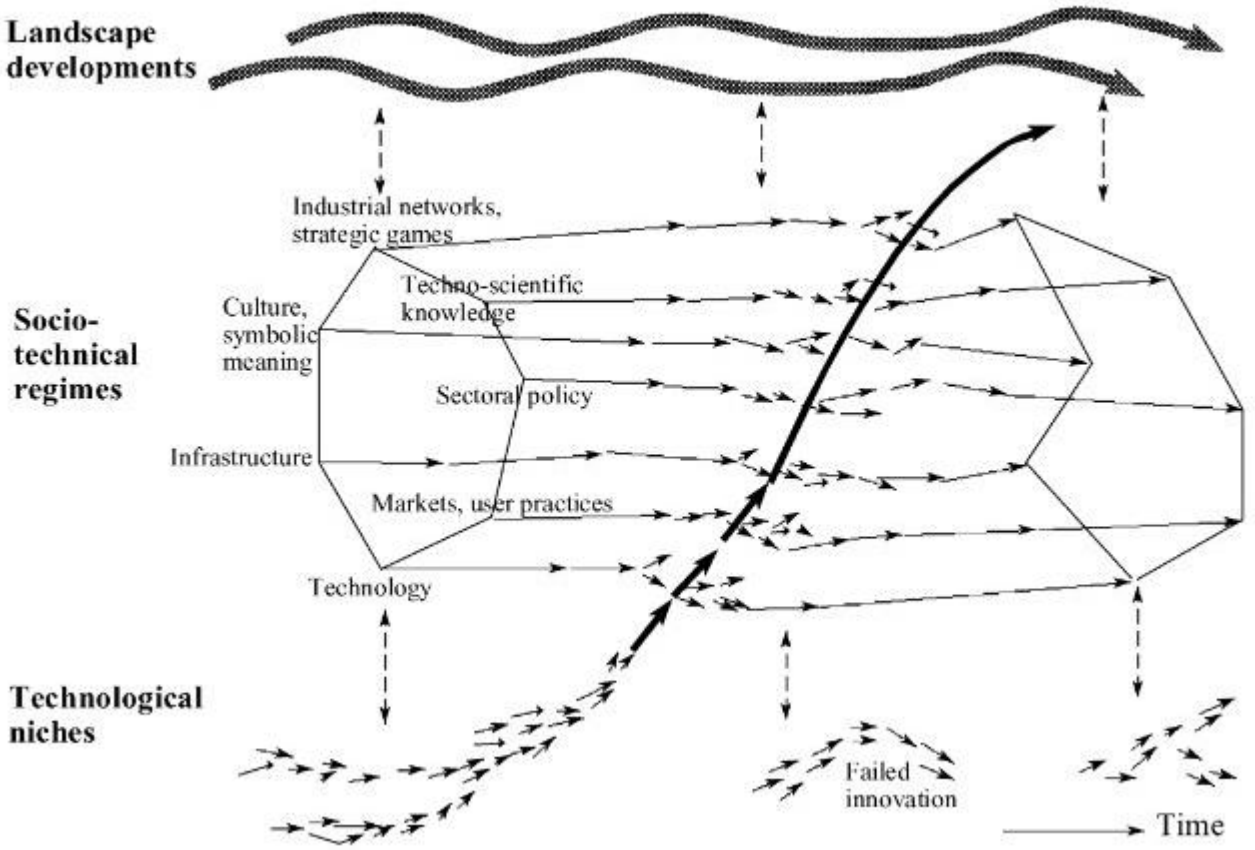
Technological transition

- Culture and symbolic meanings
- Regulation Framework,
- Infrastructure,
- Maintenance network, support industries
- Sectorial Policy
- Techno-scientific knowledge
- Technology



Small Modular Reactor – SMR in Brazil

Underlying objectives of EPE's current research

IAEA Coordinated Research Project – CRP

"Economic Assessment of the Potential for Small Modular Reactors on a National Level"

To develop a framework that considers more properly the specificities of SMR when assessing its potential for planning purposes

To better understand the economic impacts that different technology pathways (both national and international) would have on the potential deployment of SMR on a national level

IAEA

Brazil – United States Joint study

- Partnership with the **US Department of Energy** and **Idaho National Laboratory (INL)**;
- Released:
  - United States – Brazil Joint Studies: A Preliminary Assessment of Opportunities and Challenges for Small Modular Reactors in Brazil.

  - Analysis of **challenges and opportunities** in the Brazilian market for SMRs manufactured by North American companies.

https://www.epe.gov.br/sites-pt/sala-de-imprensa/noticias/Documents/INL-RPT-22-67191_%202023-02-21%20FINAL.pdf

SMR Forum

- Objective: develop knowledge about SMR technology and its potential;
- Participation of national and international institutions;

- **Topics covered:**
  - TOPIC I: **Construction approaches** for SMR-based power plants (2022);
  - TOPIC II: Distinctive **design and operational characteristics** of SMR (2022);
  - TOPIC III: **Critical siting aspects** for SMR-based power plants (2022 e 2023);
  - TOPIC IV: Specificities of **heat applications** for industrial processes and **hydrogen production** (2023);
  - TOPIC V: Specificities of **remote and off-grid** applications (2023);
  - TOPIC VI: Potential implications for the **nuclear fuel cycle** (2024).

- **Technical note being prepared.**

Decree # 9,600/2018: the Brazilian Nuclear Policy

Directives for the Brazilian Nuclear Policy

DIÁRIO OFICIAL DA UNIÃO

DECRETO Nº 9,600, DE 5 DE DEZEMBRO DE 2018

Consolida as diretrizes sobre a Política Nuclear Brasileira.

O PRESIDENTE DA REPÚBLICA, no uso das atribuições que lhe confere o art. 84, caput, inciso VI, alínea "a", da Constituição,

DECRETA:

CAPÍTULO I

DISPOSIÇÕES PRELIMINARES

Finalidade

Art. 1º A Política Nuclear Brasileira tem por finalidade orientar o planejamento, as ações e as atividades nucleares e radioativas no País, em observância à soberania nacional, com vistas ao desenvolvimento, à proteção da saúde humana e do meio ambiente.

Definições

Art. 2º Para fins do disposto neste Decreto, considera-se:

I - combustível nuclear - dispositivo capaz de produzir energia, por meio de processo autossustentado de fissão nuclear;

II - combustível nuclear usado - combustível nuclear utilizado no reator nuclear e removido do seu núcleo, que será armazenado em local apropriado para futura reutilização;

III - elemento nuclear - urânio, tório, plutônio ou qualquer elemento químico que possa ser utilizado na produção de energia em reatores nucleares;

IV - estoque estratégico de material nuclear - estoque constituído pelo volume de material nuclear necessário para atender, por determinado período, à demanda do Programa Nuclear Brasileiro;

V - material nuclear - compreende os elementos nucleares ou os seus subprodutos em qualquer forma de associação;

VI - material radioativo - material que emite, espontaneamente, radiação ionizante;

VII - mineral - substância sólida, de ocorrência natural, homogênea e com composição química e estrutura cristalina constantes e definidas;

VIII - mineral nuclear - mineral que contém em sua composição um ou mais elementos nucleares;

IX - minério nuclear - concentração natural de mineral nuclear no qual o elemento ou elementos nucleares ocorrem em proporção e condições tais que permitam sua exploração econômica;

X - Programa Nuclear Brasileiro - conjunto de projetos e atividades relacionados com a utilização, para fins pacíficos, da energia nuclear sob a orientação, o controle e a supervisão do Governo federal;

XI - proteção física - conjunto de medidas destinadas a:

a) evitar atos de sabotagem contra materiais, equipamentos e instalações;

b) impedir a remoção não autorizada de material, em especial material nuclear;

c) estabelecer meios para localização e recuperação de material desviado; e

d) proteger o patrimônio e a integridade física do pessoal que integra a instalação nuclear;

Art 1°. ***The Brazilian Nuclear Policy has the purpose of guiding planning, actions and nuclear and radioactive activities in the homeland***, according to the national sovereignty, focusing on the development and on the protection of the human health and of the environment.

"Art 5°. The objectives of the Brazilian Nuclear Policy are:
I - **preserve the domain of nuclear technology** in the country;
II - **meet future decisions of the energy sector regarding the supply of clean and firm energy through the generation of nuclear power**;
(...)"

Nuclear energy: from Energy Planning to Policy

Legislations & Resolutions

1988 Federal Constitution,

Art. 21 The Union shall have the power to:
XXIII – operate nuclear energy services and facilities of any nature and exercise state monopoly over research, mining, enrichment and reprocessing, industrialization and trade in nuclear ores and their by-products, taking into account the following principles and conditions:
(…)

Art. 225
§ 6º Power plants operated by nuclear reactor must have their location defined by federal law, otherwise they cannot be installed.

Law # 14,120/2021

Establish competences to CNPE regarding authorization of Angra III; electricity price must be approved by CNPE based on a study carried out by BNDES for Eletronuclear, considering feasibility, financial conditions and affordability to consumers (EPE will be heard); Stocks from INP and Nuclep will be transferred to Union, etc.

CNPE Resolution nº 2, Feb, 10, 2021

Guidelines for energy R&DI public & public oriented funds to allocate resources in priority areas, which includes **nuclear energy**.

Law # 14,222/2021

Establish the National Authority for Nuclear Safety – ANSN and its competences.

Decree # 10,861/2021 [Law # 14,222/2021]

Associate the National Authority for Nuclear Safety – ANSN to the MME.

Decree # 10,791/2021 [Law # 14,182/2021]

Establish the Brazilian Nuclear and Binational Energy Holding Company – ENBPar.

CNPE Resolution nº 23, Oct, 20, 2021

Establish directives for defining energy price for Angra 3 Nuclear Power Plant.

Provisory Measure nº 1,133, Aug, 12, 2022

Relax the monopoly of INB on the exploration, mining, and sale of nuclear minerals, allowing for partnership with private companies.

Opportunities

- **Hydrogem** production
- Integrating **energy hubs** with electrical and non-electrical services
- Replacing **coal power stations** and hard to abate sectors such as **steel mills** and **chemical industries**
- **Mining**
- Electric service for **off-grid systems** and **specific industries** replacing diesel generators
- Opportunity to Brazilian industries related to fuel (**Thoriun, LEU, Haleu, Triso**)

Challenges

- **Integration** with **renewable** sources
- Previous **regulatory paradigms** and may require more **flexible approaches**
- Future **supply of advanced fuels** such as HALEU or Triso fuel **requires upgrades in the current nuclear fuel cycle infrastructure.**
- Stakeholder involvement and **Public Communication**

Conclusion

The stage of maturity of SMRs depends not only on their own technological development.
It also depends on the organizational environment such as business models, lines of financing, the regulatory framework, maintenance networks and other operational aspects.

It will take time to assess whether this business model will become dominant in the nuclear sector or if it will only occupy specific market niches.

Thank you

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