

CHAMBRE DES REPRÉSENTANTS
DE BELGIQUE

27 juin 2023

**LES SMR
DANS UNE PERSPECTIVE
INTERNATIONALE**

Auditions

**Compte-rendu numérique des réunions
de la commission de l'Énergie,
de l'Environnement et du Climat
(art. 32 Rgt. juncto art. 178bis Rgt.)**

BELGISCHE KAMER VAN
VOLKSVERTEGENWOORDIGERS

27 juni 2023

**DE SMR'S
IN EEN INTERNATIONAAL
PERSPECTIEF**

Hoorzittingen

**Digitaal verslag van de vergaderingen
van de commissie voor Energie,
Leefmilieu en Klimaat
(art. 32 Rgt. juncto art. 178bis Rgt.)**

**Composition de la commission à la date de dépôt du rapport/
Samenstelling van de commissie op de datum van indiening van het verslag**
Président/Voorzitter: Christian Leysen

A. — Titulaires / Vaste leden:

N-VA	Wouter Raskin, Yoleen Van Camp, Bert Wollants
Ecolo-Groen PS	Séverine de Laveleye, Kim Buyst, Barbara Creemers Malik Ben Achour, Mélissa Hanus, Daniel Senesael
VB	Kurt Ravyts, Reccino Van Lommel
MR	Mathieu Bihet, Marie-Christine Marghem
cd&v	Nawal Farih
PVDA-PTB	Thierry Warmoes
Open Vld	Christian Leysen
Vooruit	Kris Verduyck

B. — Suppléants / Plaatsvervangers:

Sigrid Goethals, Tomas Roggeman, Anneleen Van Bossuyt, Kristien Van Vaerenbergh
Julie Chanson, Samuel Cogolati, Wouter De Vriendt, Albert Vicaire
Chanelle Bonaventure, Christophe Lacroix, Patrick Prévot, Laurence Zanchetta
Ortwin Depoortere, Nathalie Dewulf, Erik Gilissen
Michel De Maegd, Philippe Goffin, Benoît Piedboeuf
Jan Briers, Leen Dierick
Greet Daems, Raoul Hedeboom
Marianne Verhaert, Kathleen Verhelst
Vicky Reynaert, Joris Vandenbroucke

C. — Membre sans voix délibérative / Niet-stemgerechtigd lid:

Les Engagés	Georges Dallemagne
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N-VA	: Nieuw-Vlaamse Alliantie
Ecolo-Groen	: Ecologistes Confédérés pour l'organisation de luttes originales – Groen
PS	: Parti Socialiste
VB	: Vlaams Belang
MR	: Mouvement Réformateur
cd&v	: Christen-Democratisch en Vlaams
PVDA-PTB	: Partij van de Arbeid van België – Parti du Travail de Belgique
Open Vld	: Open Vlaamse liberalen en democraten
Vooruit	: Vooruit
Les Engagés	: Les Engagés
DéFI	: Démocrate Fédéraliste Indépendant
INDEP-ONAFH	: Indépendant – Onafhankelijk

Abréviations dans la numérotation des publications:		Afkorting bij de nummering van de publicaties:	
DOC 55 0000/000	Document de la 55 ^e législature, suivi du numéro de base et numéro de suivi	DOC 55 0000/000	Parlementair document van de 55 ^e zittingsperiode + basisnummer en volgnummer
QRVA	Questions et Réponses écrites	QRVA	Schriftelijke Vragen en Antwoorden
CRIV	Version provisoire du Compte Rendu Intégral	CRIV	Voorlopige versie van het Integraal Verslag
CRABV	Compte Rendu Analytique	CRABV	Beknopt Verslag
CRIV	Compte Rendu Intégral, avec, à gauche, le compte rendu intégral et, à droite, le compte rendu analytique traduit des interventions (avec les annexes)	CRIV	Integraal Verslag, met links het definitieve integraal verslag en rechts het vertaalde beknopt verslag van de toespraken (met de bijlagen)
PLEN	Séance plénière	PLEN	Plenum
COM	Réunion de commission	COM	Commissievergadering
MOT	Motions déposées en conclusion d'interpellations (papier beige)	MOT	Moties tot besluit van interpellaties (beigekleurig papier)

Lors de sa réunion du 30 mai 2023, la commission de l'Énergie, de l'Environnement et du Climat a tenu une audition sur "Les SMR dans une perspective internationale", avec:

— Prof. dr. Peter Baeten, directeur général du SCK CEN;

— M. Denis Dumont, *Chief Executive Officer*, et M. Anicet Touré, *Head of Nuclear Strategy, Innovation & Business Development*, Tractebel Belgique;

— M. Renaud Crassous, *Executive President* Nuward;

— M. Christopher Goosens et M. Xavier Pitoiset, Westinghouse Electric Company;

— M. Roberto Adinolfi, *Chairman* Ansaldo Nucleare.

Les membres suivants de la commission ont pris la parole: M. Bert Wollants (N-VA), M. Samuel Cogolati (Ecolo-Groen), M. Reccino Van Lommel (VB), M. Mathieu Bihet (MR), Mme Marie-Christine Marghem (MR) et M. Christian Leysen (Open Vld).

Le compte-rendu numérique (art. 32 Rgt. juncto art. 178bis Rgt.) de cette audition peut être consulté sur le site web de la Chambre:

<https://www.lachambre.be/media/index.html?language=fr&sid=55U3957>

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* *

Lors de sa réunion du 20 juin 2023, la commission de l'Énergie, de l'Environnement et du Climat a tenu une audition sur "Les SMR dans une perspective internationale", avec:

— Prof. Yves Bréchet, ancien haut-commissaire à l'Énergie atomique et membre de l'Académie des sciences (France);

— M. Bernard ter Haar, ancien président du "Expertteam Énergiesystème 2050" (Pays-Bas);

— M. Brent Wanner, *Head of the Power Sector Unit*, International Energy Agency;

— M. Mycle Schneider, analyste indépendant en politique énergétique et nucléaire, *Project Coordinator World Nuclear Industry Status Report*;

Tijdens haar vergadering van 30 mei 2023 heeft de commissie voor Energie, Leefmilieu en Klimaat over "De SMR's in een internationaal perspectief" een hoorzitting gehouden met:

— Prof. dr. Peter Baeten, directeur-generaal van SCK CEN;

— de heer Denis Dumont, *Chief Executive Officer*, en de heer Anicet Touré, *Head of Nuclear Strategy, Innovation & Business Development*, Tractebel België;

— de heer Renaud Crassous, *Executive President* Nuward;

— de heer Christopher Goosens en de heer Xavier Pitoiset, Westinghouse Electric Company;

— de heer Roberto Adinolfi, *Chairman* Ansaldo Nucleare.

De volgende commissieleden hebben het woord genomen: de heer Bert Wollants (N-VA), de heer Samuel Cogolati (Ecolo-Groen), de heer Reccino Van Lommel (VB), de heer Mathieu Bihet (MR), mevrouw Marie-Christine Marghem (MR), en de heer Christian Leysen (Open Vld).

Het digitaal verslag (art. 32 Rgt. juncto art. 178bis Rgt.) van deze hoorzitting kan worden geraadpleegd op de website van de Kamer:

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* *

Tijdens haar vergadering van 20 juni 2023 heeft de commissie voor Energie, Leefmilieu en Klimaat over "De SMR's in een internationaal perspectief" een hoorzitting gehouden met:

— Prof. Yves Bréchet, voormalig Hoog Commissaris voor Atoomenergie en lid van de Academie van Wetenschappen (Frankrijk);

— de heer Bernard ter Haar, voormalig voorzitter van Expertteam Energiesysteem 2050 (Nederland);

— de heer Brent Wanner, *Head of the Power Sector Unit*, International Energy Agency;

— de heer Mycle Schneider, onafhankelijk analist energie- en nucleair beleid, *Project Coördinator World Nuclear Industry Status Report*;

— M. Navid Samandari, *co-founder & CEO*, Seaborg Technologies.

Les membres suivants de la commission ont pris la parole: M. Bert Wollants (N-VA), M. Samuel Cogolati (Ecolo-Groen), Mme Marie-Christine Marghem (MR), M. Thierry Warmoes (PVDA-PTB) et M. Christian Leysen (Open Vld).

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Annexes:

- Présentation du SCK CEN;
- Présentation de Tractebel Belgique;
- Présentation de Nuward;
- Présentation de Westinghouse;
- Texte de Westinghouse;
- Présentation d'Ansaldo Nucleare;
- Texte d'Ansaldo Nucleare;
- Présentation du Prof. Yves Bréchet;
- Texte de M. Bernard ter Haar;
- Présentation de M. Brent Wanner;
- Présentation de M. Mycle Schneider;
- Présentation de Seaborg Technologies.

— de heer Navid Samandari, *co-founder & CEO*, Seaborg Technologies.

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Bijlagen:

- Presentatie van SCK CEN;
- Presentatie van Tractebel België;
- Presentatie van Nuward;
- Presentatie van Westinghouse;
- Tekst van Westinghouse;
- Presentatie van Ansaldo Nucleare;
- Tekst van Ansaldo Nucleare;
- Presentatie van Prof. Yves Bréchet;
- Tekst van de heer Bernard ter Haar;
- Presentatie van de heer Brent Wanner;
- Presentatie van de heer Mycle Schneider;
- Presentatie van Seaborg Technologies.

ANNEXES

BIJLAGEN



SMRs in an international perspective

SNE-TP (Vice-chair)

SCK CEN SMR-LFR TD (DG)

Prof. dr. ir Peter Baeten

30-05-2023

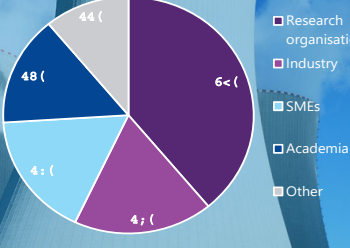
SNETP

The association (AISBL, under Belgian law) gathers more than 110 stakeholders (including SCK CEN, BELV, ENGIE....) from industry, research centers, safety organisations, universities, non-governmental organisations, SMEs ...



Gen II = existing Light water reactor
GEN III = new LWR
GEN IV = advanced (modular reactor)

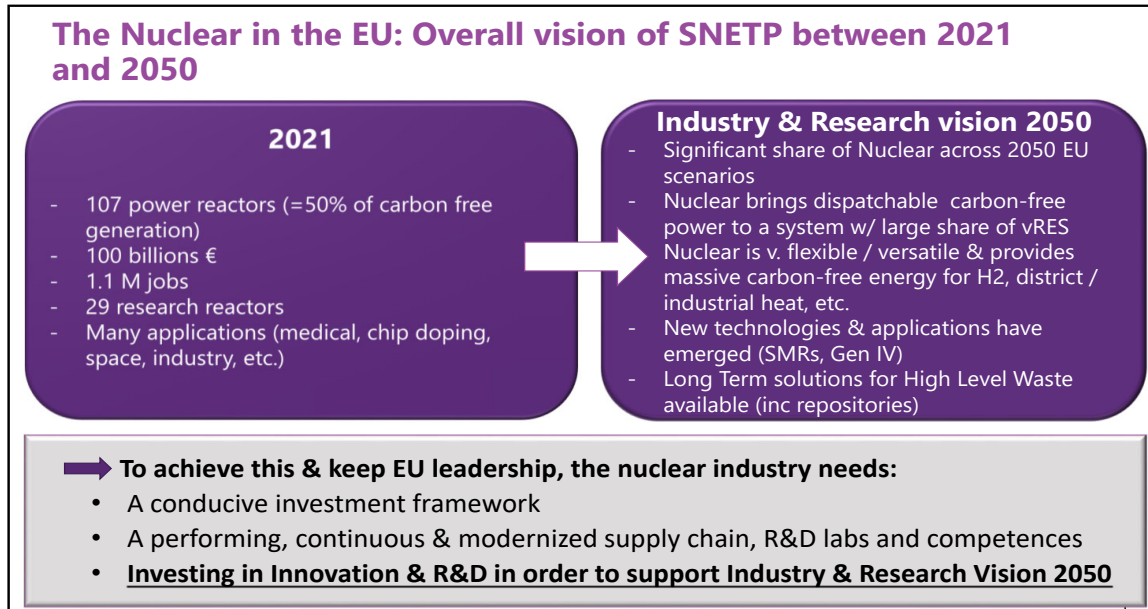
SNETP is the European Technology & Innovation platform for Nuclear Energy focused on Gen II-III and IV reactors with electric and non-electric application



> 110 members

- Research organisations
- Industry
- SMEs
- Academia
- Other

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From Long Term Operation, to new Commercial Light Water Reactors followed by Commercial Advanced Modular Reactors

- **Together with Renewables, Nuclear reactors are a key asset to reach Net Zero by 2050**
 - **Long Term Operation of existing Nuclear Power plant has to be strengthened in a safe and industrial way**
 - New Gen III reactors are to be built: the technology has to be commercial no later than 2030 in order to play a significant role in the Net Zero Objective
 - ➔ **Light Water Reactor (LWR), both big plants and Small Modular Reactors (SMR) is today the unique solution to reach this objective**
- **Nuclear has to be sustainable on the long run at the horizon 2050**
 - Long Life wastes have to be reduced
 - Uranium fuel has to be recycled
 - ➔ **Advanced Modular Reactor , big and small plants (AMR), is the unique solution to reach this objective**
 - ➔ **First demonstration projects could be available by 2035**
- **Continuity in policy is necessary between those two calendars steps:**
 - Nuclear industry is a long leading time industry (20 years from Lab to Industry)
 - Research development for LWR is beneficial to AMR
 - Huge synergies exist for Industrial supply chain and human competences between LWR and AMR

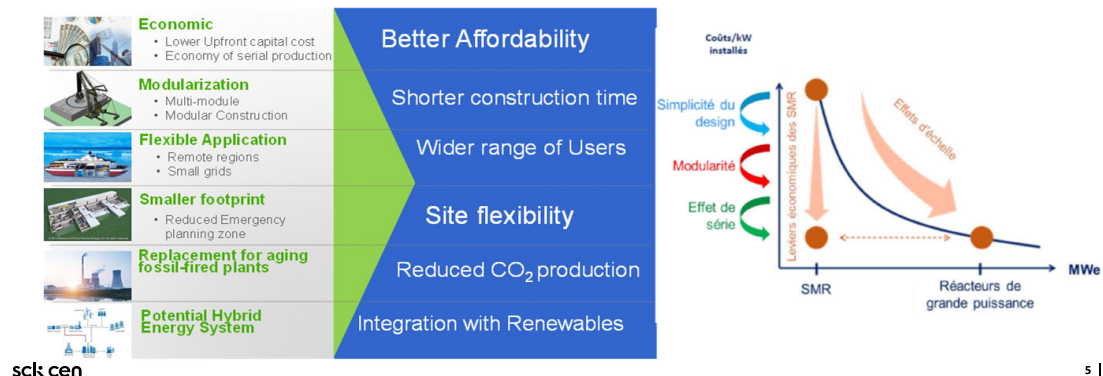
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SMR: definition & rationale for development

Advanced Reactors with an installed capacity up to 300 MW(e), built in factories and transported as modules to sites for installation as demand arises

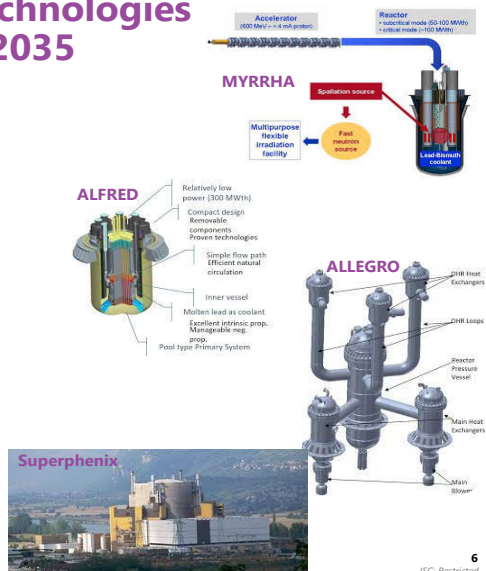
A nuclear option to meet the need for flexible power generation for wider range of users and applications



Advanced (Modular) Reactors Technologies Demo Project at the soonest by 2035

- MYRRHA** (Multi-purpose hYbrid Research Reactor for High-tech Applications), a **lead-bismuth Accelerator Driven System** to demonstrate transmutation of high-level waste, & to support the maturity of ESNII technologies
- The **Lead-cooled Fast Reactor (LFR)** and the **ALFRED** (Advanced Lead-cooled Fast Reactor European Demonstrator) project to build a European demonstrator of the LFR technology
- The **Gas-cooled Fast Reactor (GFR)** and the **ALLEGRO** project (GFR demonstrator), an initiative with the goal to build an experimental facility to demonstrate the technological viability of the concept
- The **Sodium-cooled Fast Reactor (SFR)** is the most internationally mature technology. Its industrial deployment in Europe necessitates still some improvements (safety, economic, ...)

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EU SMR-partnership to start 2023

Scope

- Establishing in the EU a domestic/European SMR programme as defined in the EC's "Vision for a decarbonised energy sector including European Small Modular Reactors"
- creating necessary enabling conditions for the first EU SMRs to start operation in 2030
- co-ordinate MS & industry strategies towards an integrated and Robust supply chain in Europe

Objectives

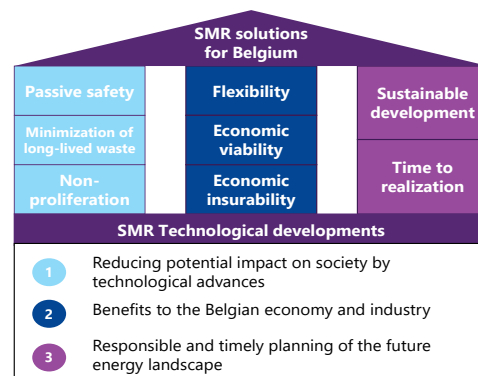
- Develop the necessary industrial supply chain in Europe
- Encourage the implementation of common (harmonized) licensing process across the EU establish a strategic research agenda:
 - LWR-SMR, as a mature technology to be deployed in 2030
 - Advanced SMR (AMR-GENIV) design has to be matured by 2035 for long term prospect (sustainability) of fission technology
- Develop an international marketing strategy of the European SMR value chain

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Technology evaluation - Belgium

- New initiative in Belgium for SMR R&D&I
 - Based on innovative concepts
 - Horizon 2040
 - 100 M€
- 8 criteria for comparing SMRs under development for the production
 - electricity
 - industrial heat
 - Hydrogen
- **SMR-LFR recommended**
- MYRRHA to support the fast-track SMR- LFR roadmap development & licensing



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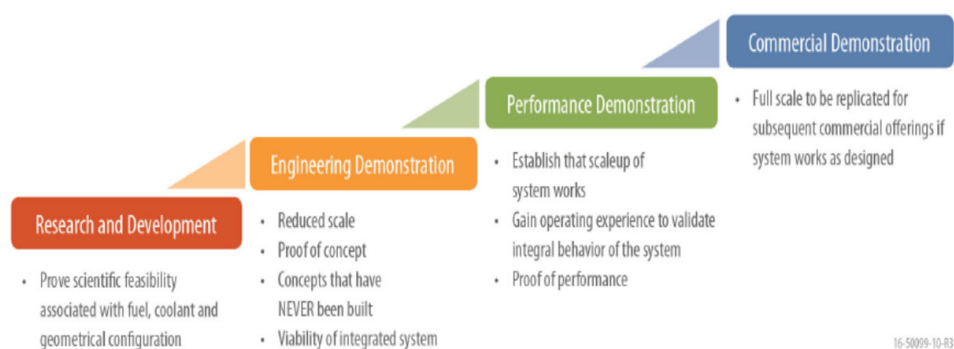
Recommendations

- Assessing **integration of SMR's to the energy mix** in a holistic approach
- Choosing for an **SMR-LFR** building upon the know-how from **MYRRHA** and the **MOX**-technology
- Developing **strategic partnerships** by MYRRHA & SCK CEN in view of the construction of a **SMR-LFR demonstrator** at SCK CEN
- **Contributing to harmonizing of the licensing process** on international level
- Maintaining the **nuclear know-how** in Belgium

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Reactor development and deployment steps based on international experience*



* Petti, D.; Hill, R.; Gehin, J.; Gougar, H.; Strydom, G.; Heidet, F.; Kinsey, J.; Grandy, C.; Qualis, A.; Brown, N.; Powers, J.; Hoffman, E.; Coson, D. "Advanced demonstration and test reactor options study". Idaho National Laboratory Technical Report INL/EXT-16-37867, January 2017 <https://doi.org/10.2172/1364524>

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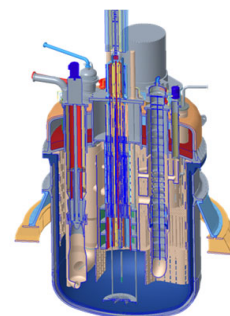
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MYRRHA: World Class Technology complex to serve HLM SMR development



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- LiLiPuTTeR-II
 - HELIOS 3
 - HLM Lab
 - MEXICO
 - CRAFT
 - LIMETS 3
 - RHAPTER
 - COMPILOT
 - ESCAPE
 - Ultrasonic Lab
 - GUINEVERE
- Lead-Bismuth Chemistry & Conditioning
- Material development & testing
- Component testing & Thermal Hydraulics
- Instrumentation & Visualisation
- Lead Zero Power Reactor**



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Assumptions for the construction at SCK CEN of a SMR-LFR Technology Demonstrator

- access to the extensive knowledge accumulated within the MYRRHA programme and the experience gathered during the pre-licensing process of MYRRHA reactor in collaboration with FANC and BeIV
- start the development in collaboration with an international consortium with relevant knowledge in reactor design as well as specific experience and/or technological expertise with lead and lead-systems
- access to an existing LFR design and tested options from the partner(s) in order to limit the conceptual design phase to 3 years
- no show stoppers resulting from the R&D programme results and the preliminary safety assessments

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Proposed Workplan of the first phase

The first phase (Y1 to Y5) consists of 3 pillars:

- **Technology**
 - pre-conceptual and conceptual design in collaboration with international partners of the consortium with experience in Heavy Liquid Metal reactor design,
 - support of the pre-licensing activities in which FANC and BelV will contribute
 - R&D activities in confirmation of the selected design options
 - cost estimate of the technological demonstrator and the cost of basic design phase
- **Industrialization**
 - establishment of requirements of SMR-LFR defined by users
 - compilation of a supply chain list
- **Integration into the energy mix**
 - studies related to the integration of SMR-LFR systems into energy mix

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What's next ?

Mandate

End of June 2023:
prepare a work-plan (scope, budget, timeline, ...)
with the vision to construct a SMR-LFR demonstrator

"Let's do great things together!"

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TRACTEBEL
ENGIE

**Unlocking the potential of
Small Modular Reactors**
A vision from the industry

30 May 2023

Denis Dumont
Chief Executive Officer Tractebel Belgique

Anicet Touré
Head of Nuclear Strategy and Innovation

1



TRACTEBEL
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Key figures

- 60+ years**
Responsible designer
- 28**
Countries
- 1,000**
Employees globally
- €180M**
Revenues

**Architect
Engineer of the
Belgian Nuclear
Fleet**

30 May 2023 Belgian Parliament_Energy, Environment and Climate Committee_hearing

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- 1** **Why Belgium needs new energy options**
- 2** **How SMRs enable new solutions**
- 3** **Belgium's nuclear industry legacy**
- 4** **How to make it happen**

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Why Belgium needs new energy options

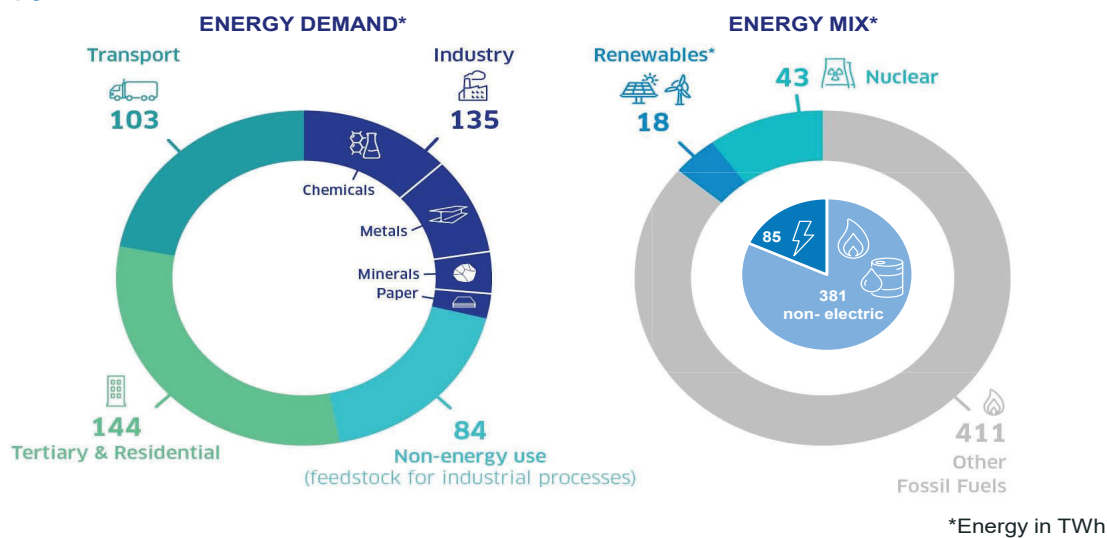


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Current Belgian energy landscape 2019

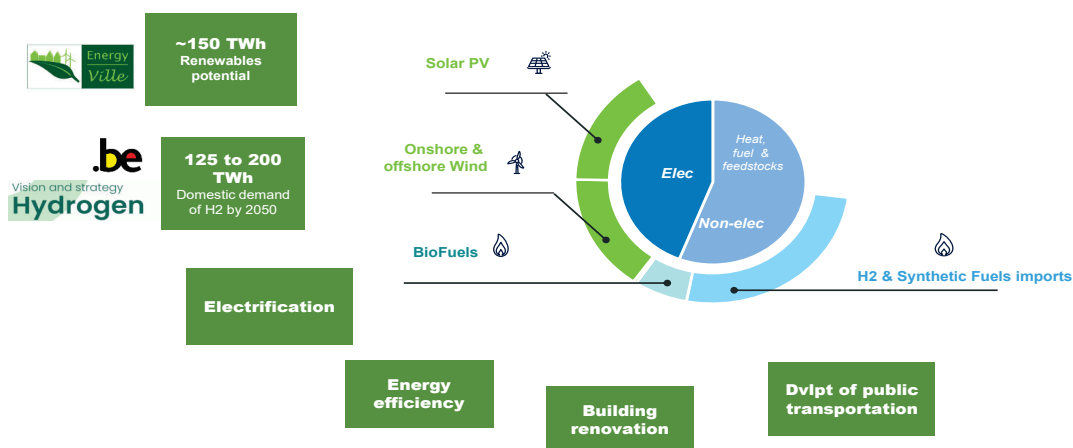
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2050 Belgian energy landscape will require new solutions

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How SMRs enable new solutions

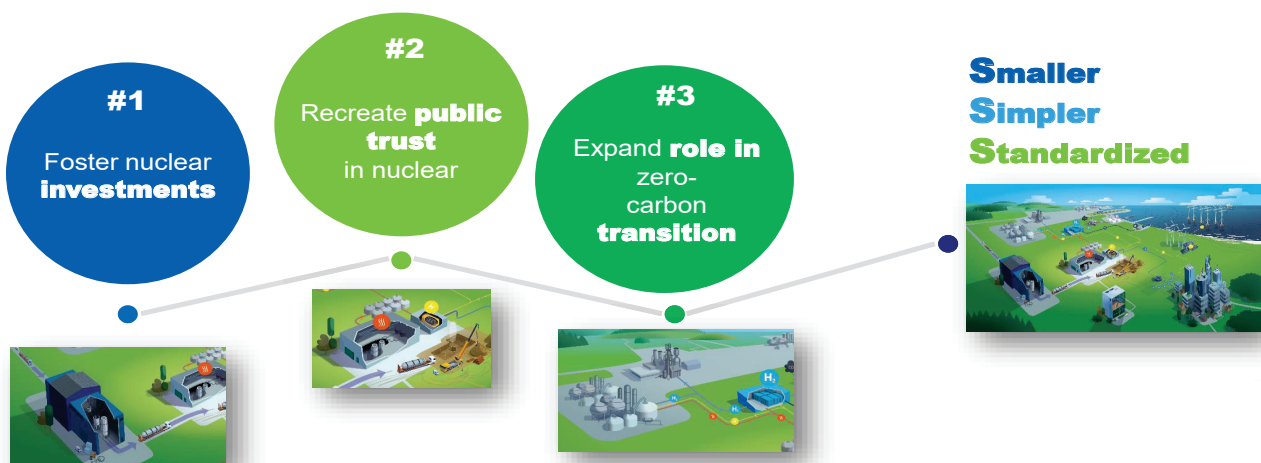
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Small Modular Reactors

A business model that addresses the right questions

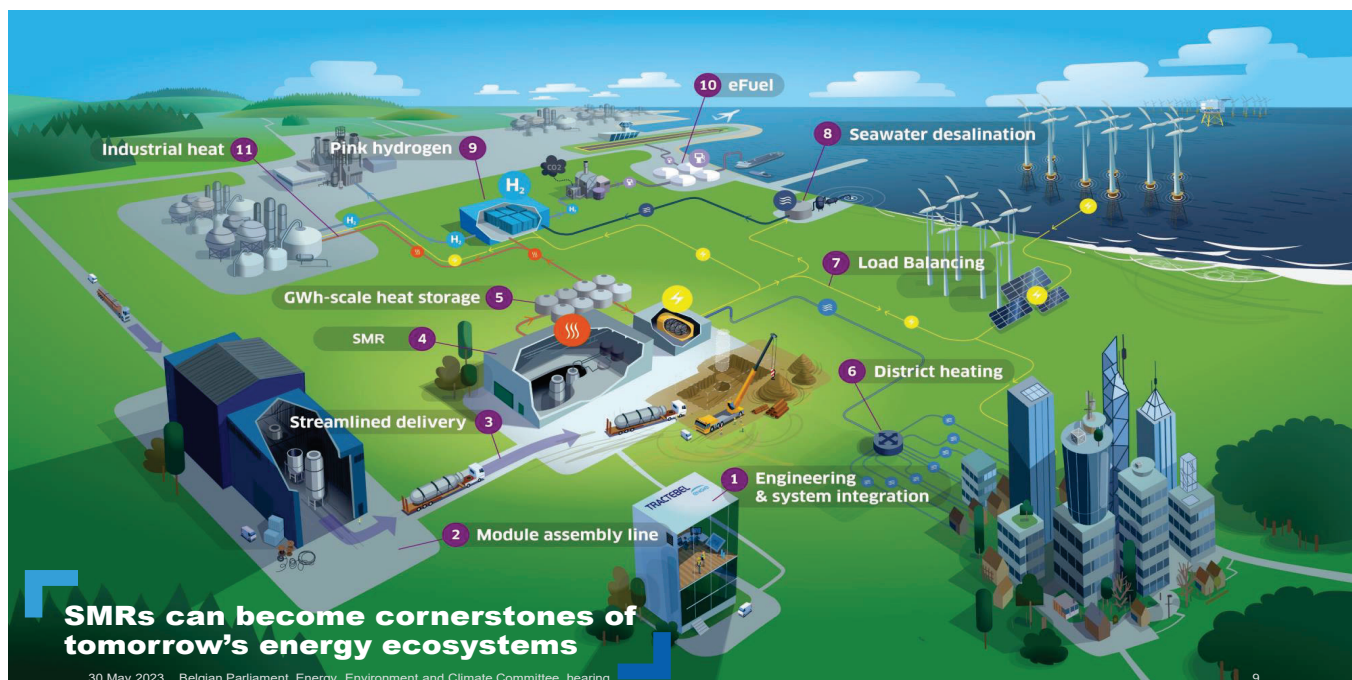
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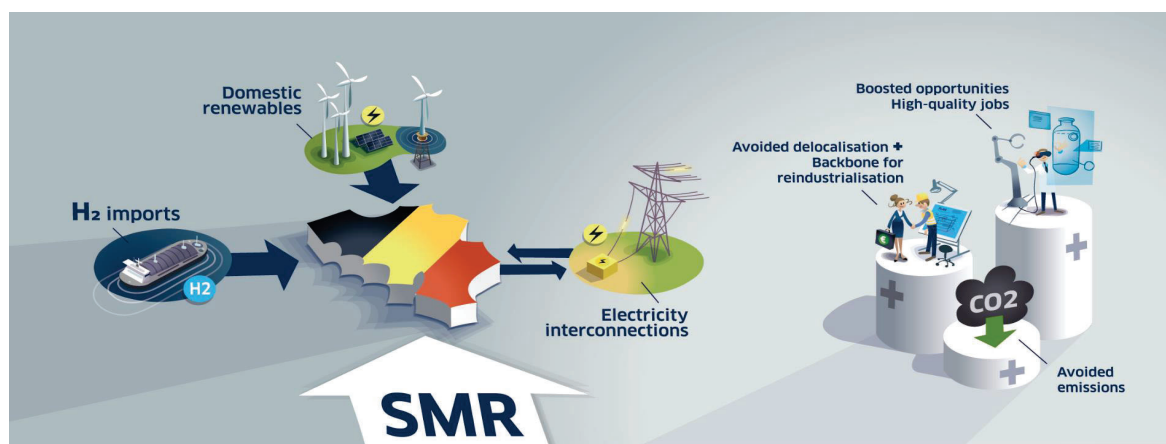
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Benefits of SMR in an integrated system

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SMR deployment

Complementarity of technologies

SHORT-TERM DEPLOYMENT

Well-established technologies

Market initiators by the end of 2020s for electricity and hydrogen



WATER-COOLED REACTORS

DEEP DECARBONIZATION

Heavy industry

Heat and hydrogen production



HIGH-TEMPERATURE REACTORS

CIRCULAR ECONOMY

Reduction of nuclear waste

Spent fuel recycling



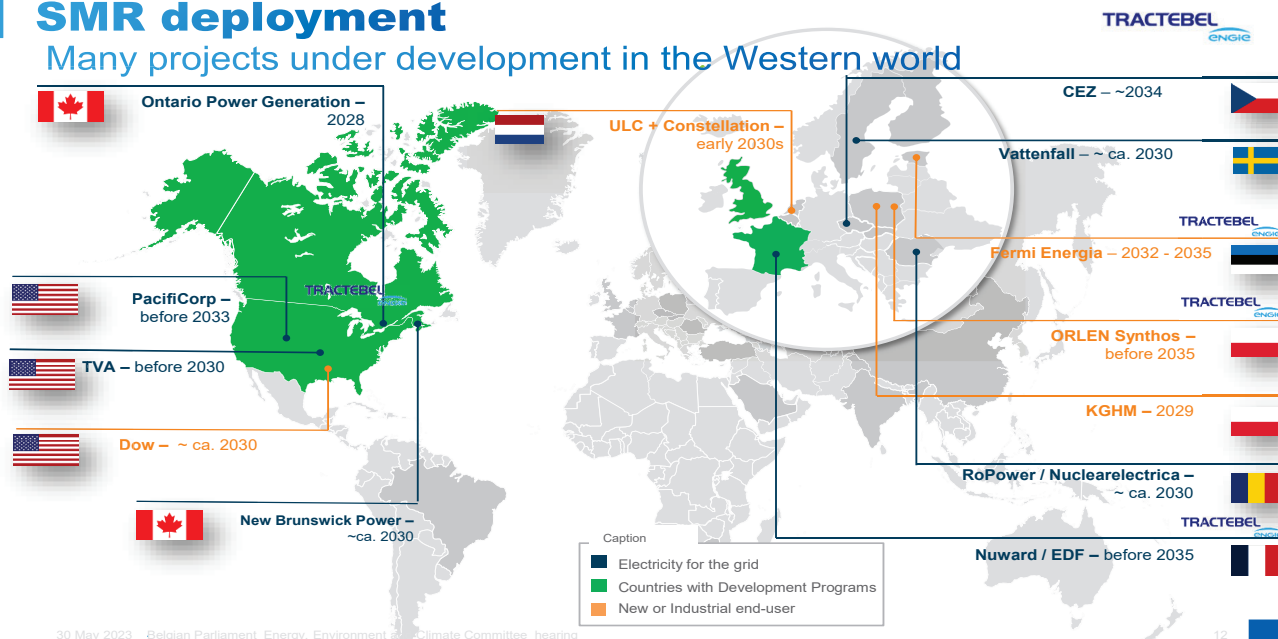
FAST REACTORS

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SMR deployment

Many projects under development in the Western world



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Belgium's nuclear industry legacy

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13

Belgium's world-class expertise

More than half of century of nuclear excellence

TRACTEBEL
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NUCLEAR QUALIFIED COMPANIES



+300

NUCLEAR PROFESSIONALS

> 10,000



SUPPLY CHAIN



1st



**PRESSURIZED-WATER REACTOR
IN EUROPE**

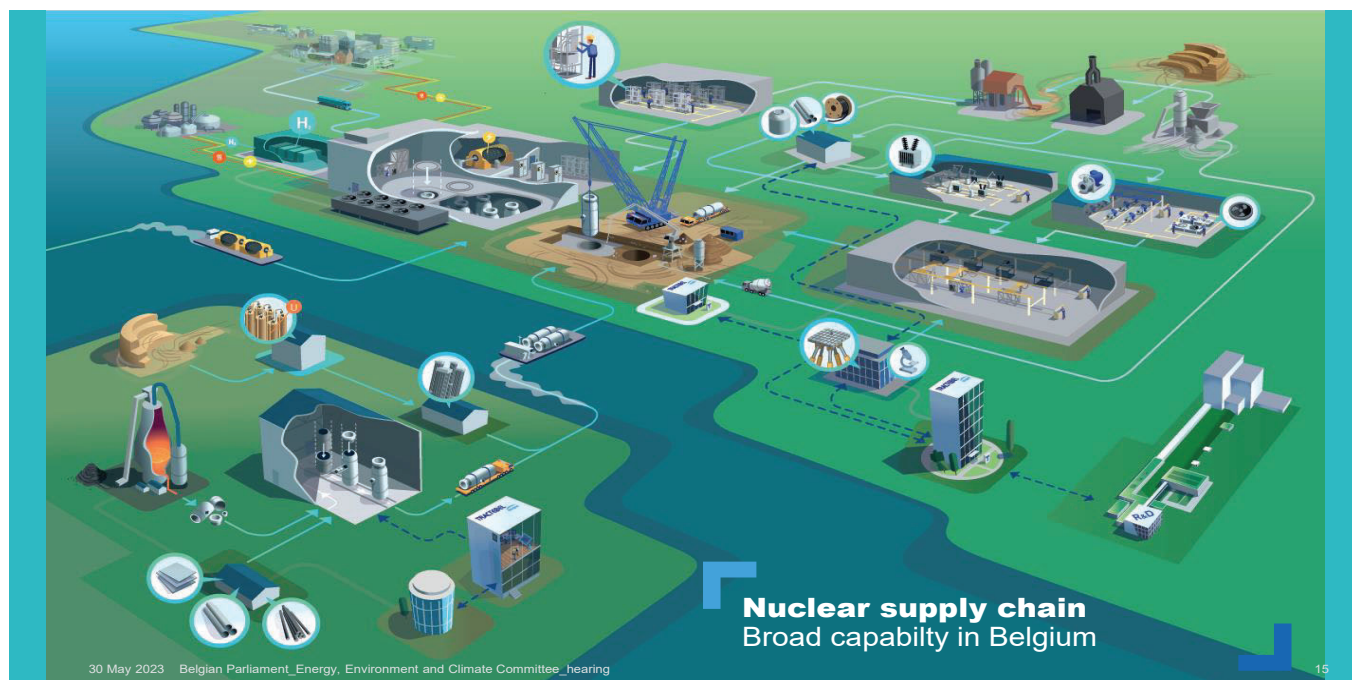
NUCLEAR EXPERIENCE

**> 70
YEARS**

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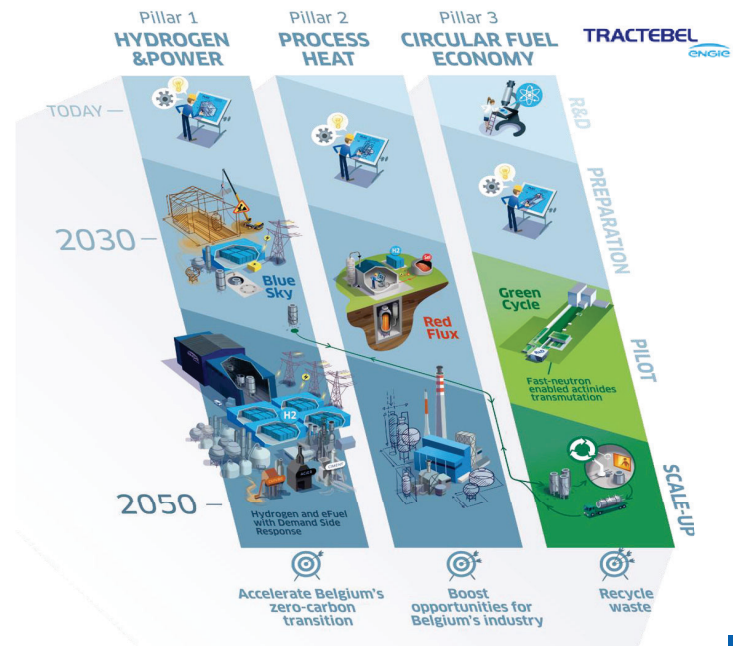
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How to make it happen

Three Pillars

- **Integrated vision:** ecosystem with all energy solutions (renewables, hydrogen, electrification, interconnections)
- **“Blended fleet”** approach: no single SMR technology can address alone all Belgian energy challenges



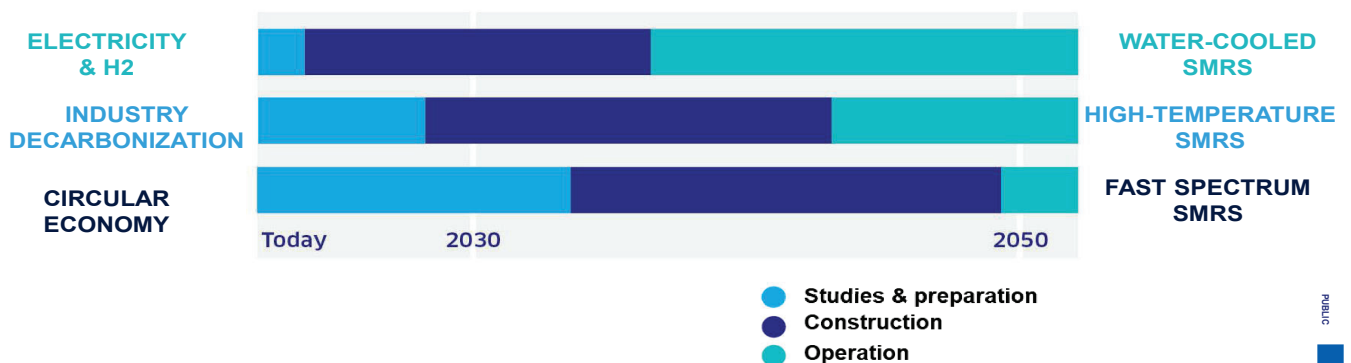
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A first pilot SMR is possible in Belgium by 2035

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CREDIBLE TIMELINE FOR SMRs IN BELGIUM



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nuward SMR

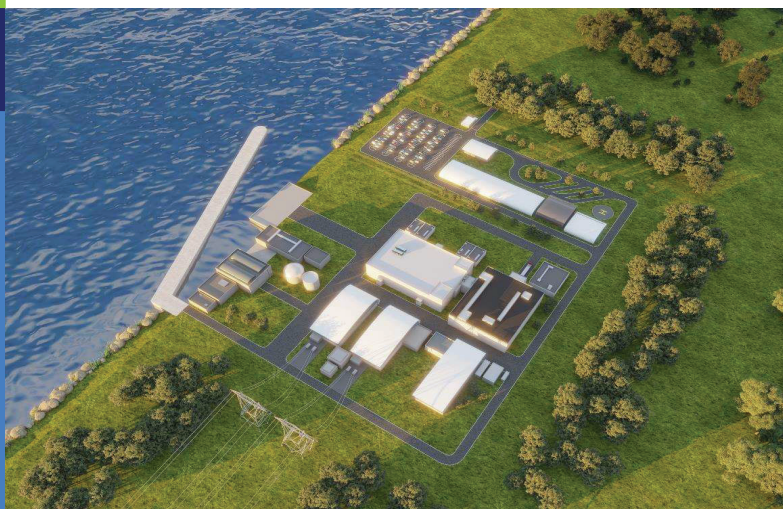
NUWARD SMR

Leading the way to a low-carbon world

Audition at the Chamber of Representatives of Belgium
Committee for Energy, Environment and Climate

30/05/2023

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NUWARD SMR: European by design, lever for a carbon-free world

■ Three main market segments:



Replacing **coal-fired power plants** in the 300-400 MWe range,
Supplying **energy-intensive industrial sites** with heat and power,
Powering grids with limited capacity for large power plants or
demanding small incremental power build-up.

■ Adapted to multipurpose uses:



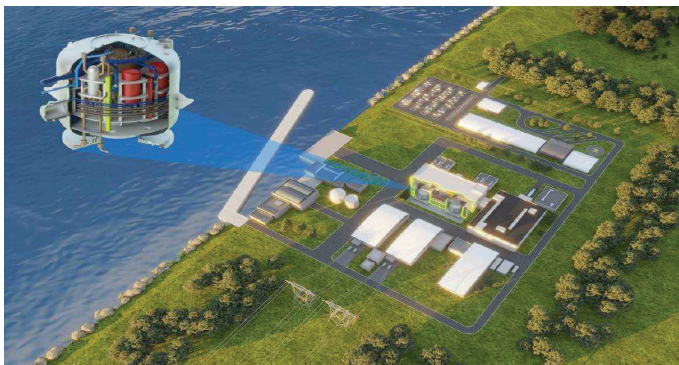
Hydrogen production, deep decarbonation of industrial processes with
heat and electricity, district heating, water desalination.



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NUWARD SMR: a Pressurized Water Reactor 340MWe power plant



A nominal power of **340 MWe** from 2
integrated reactors of 170 MWe each



>90% availability, 60 years of operation
Compatible with ENTSO-E grid requirements
Load-following capability



Safety objectives that meet the best
international standards with passive systems



Modular approach and **simple competitive**
design targeting **40-month** construction
duration for a NOAK



Improved **landscape** integration



Multipurpose by design (H2, district heating, desalination, heat & electricity cogeneration, CO2
capture): able to deliver 100-120 MWth of steam.



Designed for export, allowing adaptation to multiple markets without significant re-design



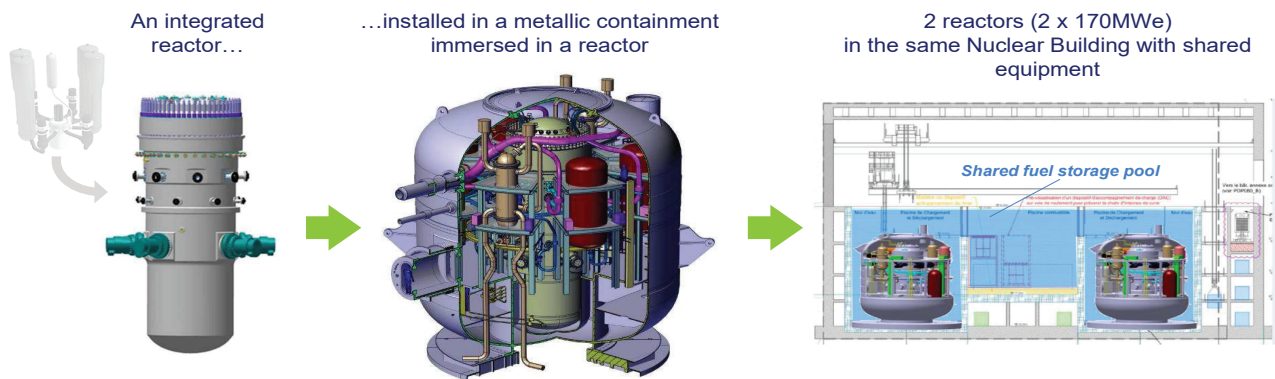
First Nuclear Concrete in France in 2030



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4

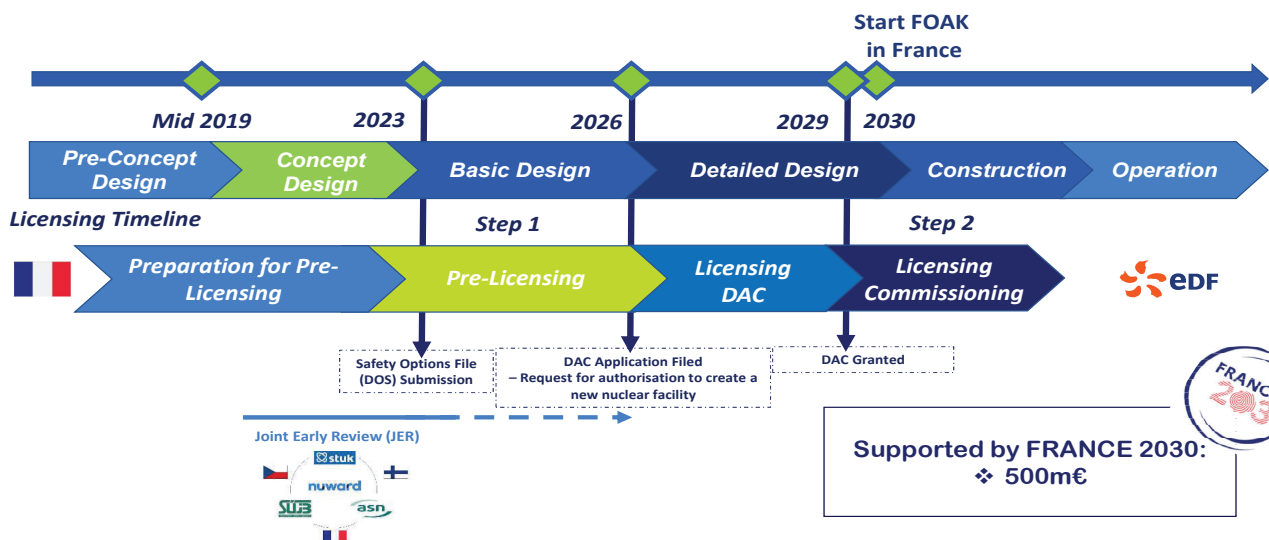
NUWARD SMR design and its two integrated reactors



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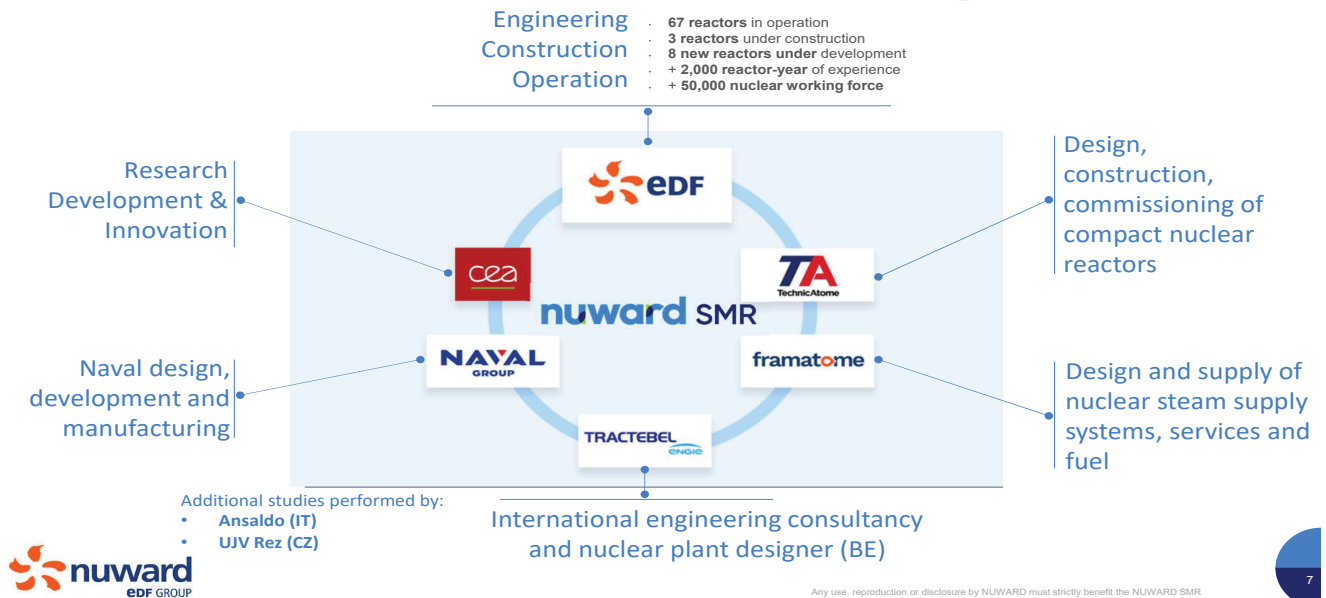
NUWARD SMR Timeline



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6

Unparalleled experience & comprehensive expertise – Made in



7

Market and product appraisal:

EU at the core of the International NUWARD Advisory Board (INAB)

Providing valuable insights and inputs to the product development to ensure NUWARD delivers what the market really needs.

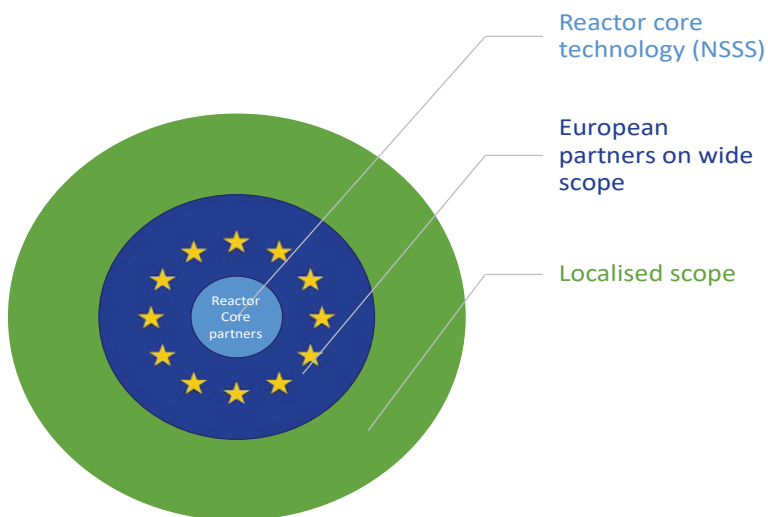


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8

Technology supply chain and partnerships approach

- ❑ Industrial capacity and capability relying in majority on the **European Nuclear Industry**
- ❑ **Development of supply chain** to incorporate European partners / suppliers / R&D to support the product industrialisation
- ❑ Industrial breakdown structure allowing **diversification of supply** and allowing targeted market's industry to support the manufacturing / construction of NUWARD



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9



Thank you



nuward SMR

EDF is deeply committed to CO₂ neutrality

Wherever the Group operates, **EDF** wants to invent a new energy model to address the climate crisis

- lower-carbon emission,
- more efficient,
- less impact on the environment and on people



More ambitious goals in 2030 to reduce our CO₂ emissions

Direct emissions ↓ 50 % compared to 2017
Indirect emissions ↓ 28 % compared to 2019

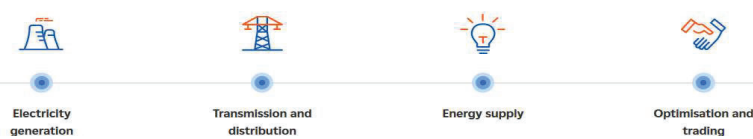
Build a net zero energy future with electricity and innovative solutions and services, to help save the planet and drive well-being and economic development.

Any use, reproduction or disclosure by NUWARD must strictly benefit the NUWARD SMR Project. Any further use, reproduction or disclosure is prohibited without the express prior approval of NUWARD.

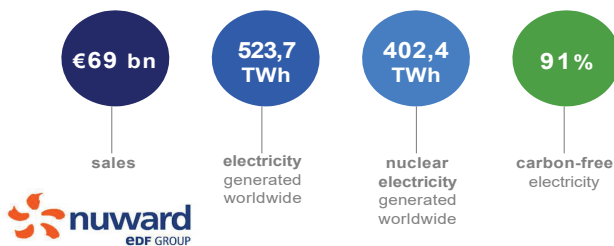
11

EDF, the world's leading electricity company

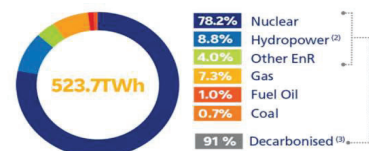
Its business covers all electricity-related activities



Key figures in 2021



Electricity generation share (TWh)



(1) Consolidated data.

(2) Hydro output including pumped storage consumption.

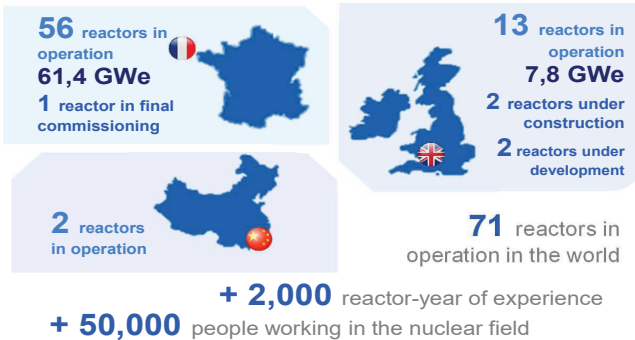
(3) Direct output-related CO₂ emissions, excluding life-cycle analysis (LCA) of fuel and production means.

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12

EDF, the largest nuclear operator in Europe and worldwide

→ EDF, the world's leading nuclear operator



→ EDF manages the entire nuclear power plant lifecycle

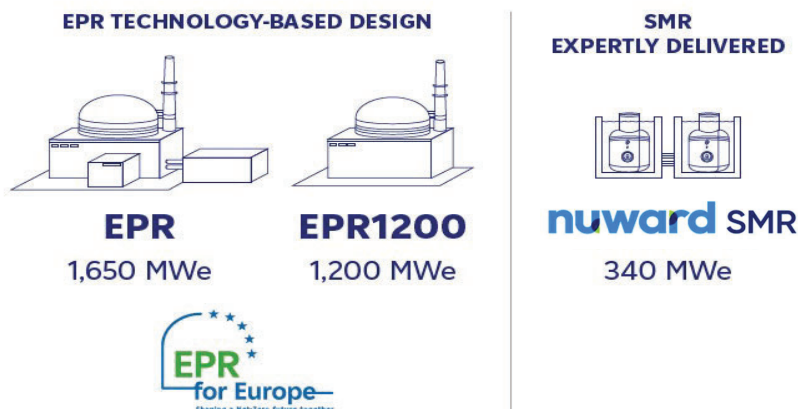
- > DESIGN
- > BUILD
- > OPERATE
- > DECOMMISSION



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13

Shaping Net-zero Future With State-of-the-art Nuclear Technologies And Services



A comprehensive portfolio of technologies to address the world's energy mix decarbonisation challenge

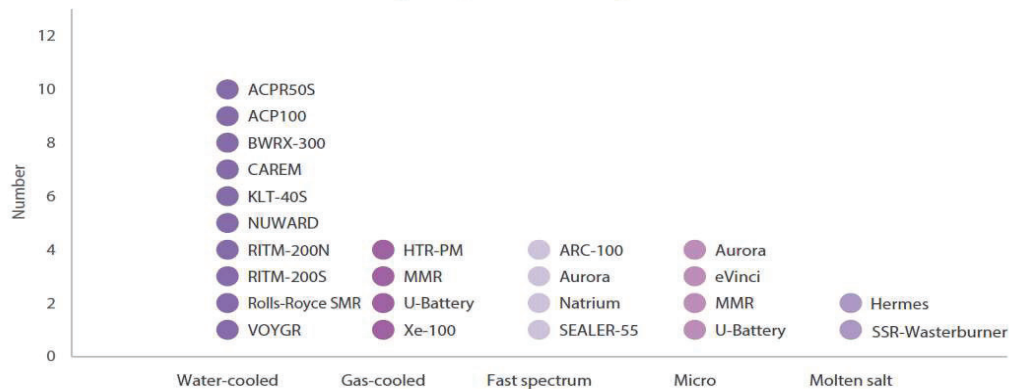


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14

A variety of technological and industrial maturities among the numerous concepts of SMR under development suggests the rise of Generation 3 SMRs in the 2030's and a longer time to market for AMRs

Figure 7. Reactor concepts



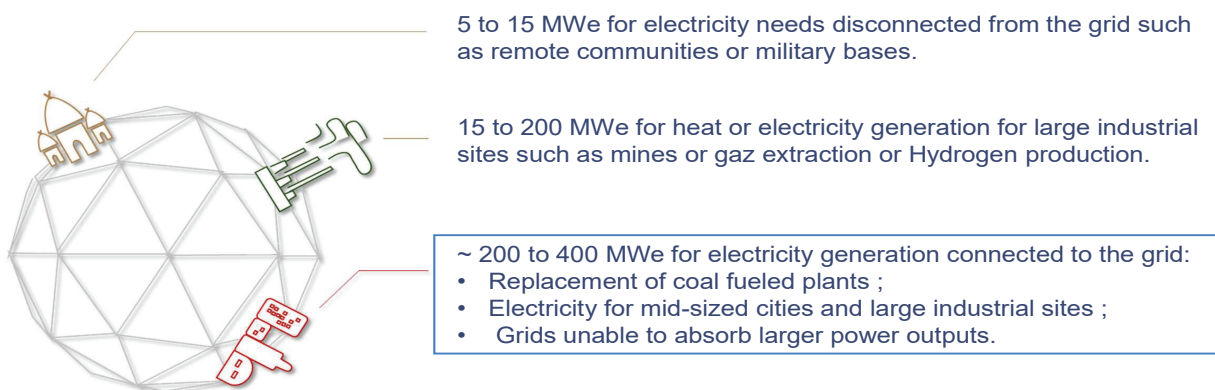
Source: The NEA Small Modular Reactor Dashboard



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15

SMR concepts can also be differentiated according to their power and their usages

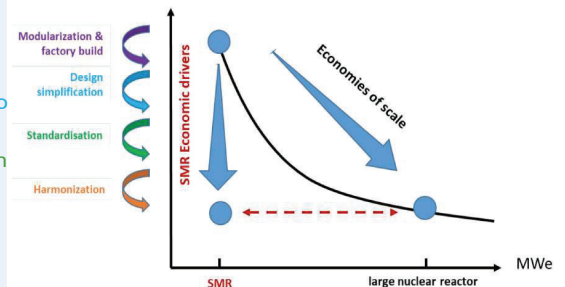


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16

Key conditions for successful deployment of SMRs

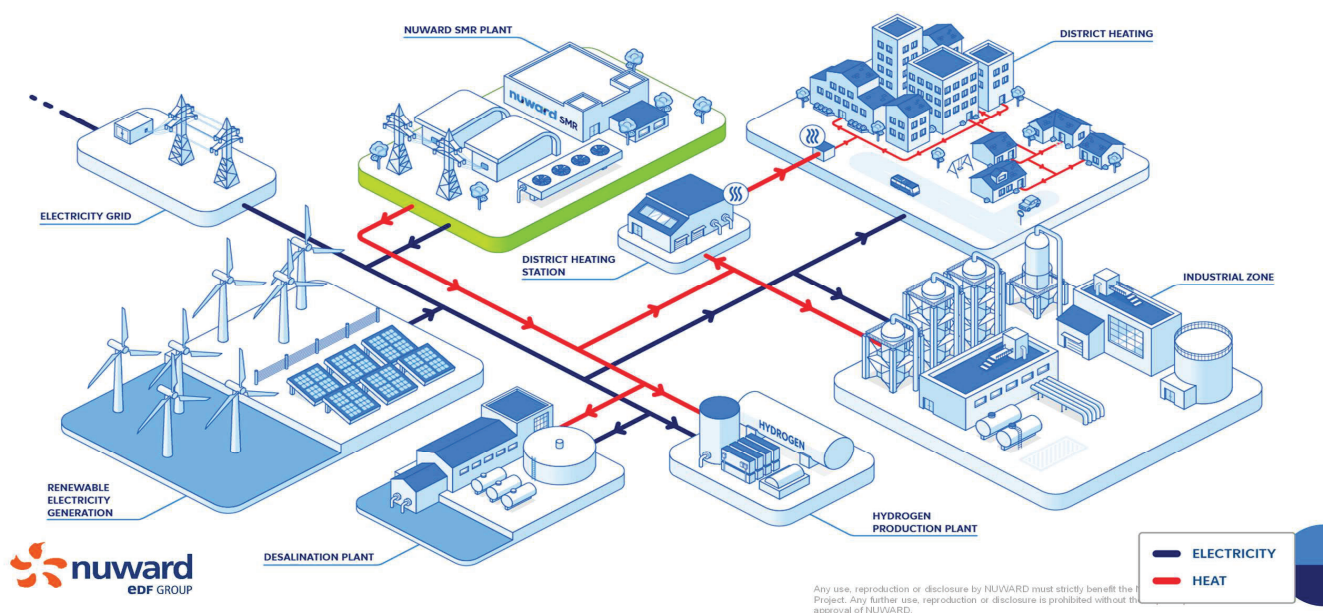
MODULARISATION & FACTORY BUILD	Modular design and manufacturing (construction cost decrease, shortened on-site construction duration)
SIMPLIFICATION	Simplification of design (architecture, components, civil structure, easy and quick to build)
STANDARDISATION & SERIES EFFECT	Standard design and series effect (production of components in series, standardisation, large new build programme, etc.)
HARMONISATION	Harmonised and adapted design for worldwide deployment: regulatory requirements, in-factory certification, passive system qualification
FINANCING	Revenue guarantee, manageable construction risk profile, adapted regulatory framework
INTERNATIONAL MARKET	Access to worldwide market



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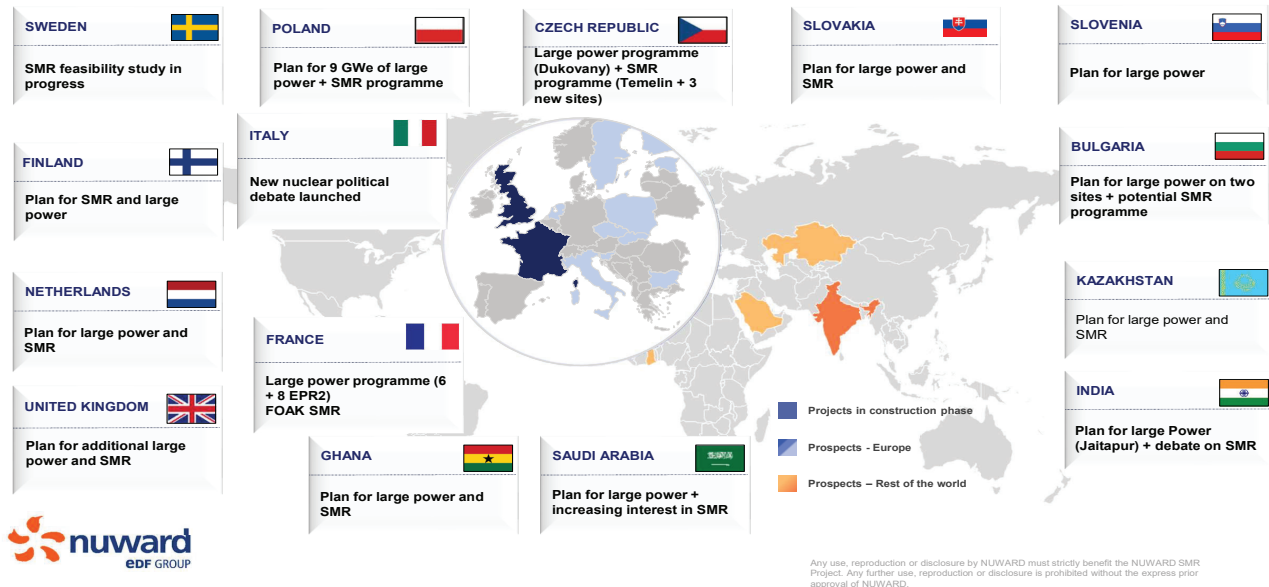
17

NUWARD SMR: Multipurpose by design

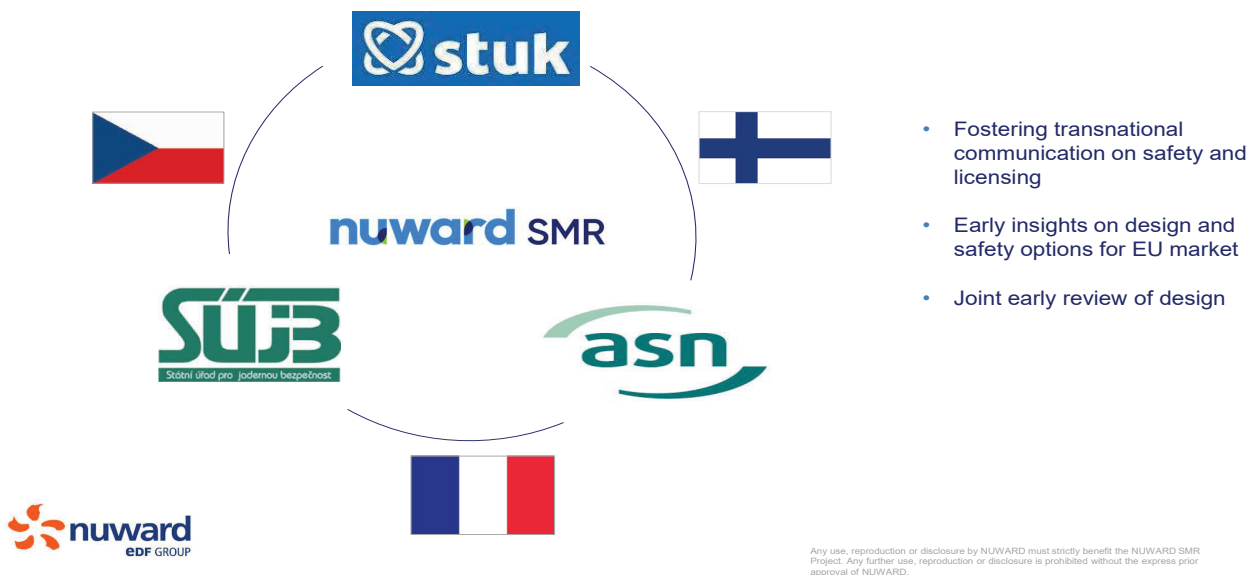


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EDF well placed to help Europe lead the nuclear programme acceleration



Encouraging collaboration on international licensing conditions





Westinghouse Advantage

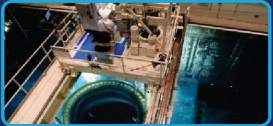
Over 70 years of experience developing & implementing new nuclear technologies that enable reliable, clean, safe and economical sources of energy for generations to come.



10,500 employees located in 19 countries



+70 global best-in-class nuclear & fuel manufacturing facilities



~50% of the world's nuclear power is generated using our technology



1ST successful deployment of Gen III+ reactor technology



Westinghouse Non-Proprietary Class 3

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Shaping Today's and Tomorrow's Energy

A Portfolio of Innovative Solutions



Our reactors can also deliver these beyond-electricity benefits:

Long-Duration Energy Storage

Hydrogen Generation and Process Heat

Radioisotope Production

Complementary Clean Energy Products
to Serve the Needs of Diverse Global Customers

Fuel Cycle Closure



AP300 SMR

The world's only SMR based on Nth of a kind operating reactors



Proven Technology

300MWe | 900MWth
single-loop PWR with
demonstrated reliability



Reduced Costs

Smaller safety related
footprint reduces
construction, operating
& maintenance costs



License Certainty

Advanced Passive Safety
based on AP1000 technology
brings licensing certainty



Trusted to Deliver

Proven pedigree throughout
lifecycle ensures deployment
& operational success



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AP300 SMR Roadmap

Leverages our AP1000 reactor design and licensing experience to achieve deployment by early 2030's

AP1000 Design & Licensing Completed
1999 - 2012



- Design Certification
- Passive Safety System Testing & Demonstration
- Deployment & operation of AP1000 reactors

AP300 Design & Licensing
2022 - 2027



- NRC design certification
- Standard plant ready to deploy

Project Preparation
2027-2030



- Site specific design & licensing
- Long lead time procurement

Ready for Construction
2030



36 months for NOAK construction



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Westinghouse LFR

Complement Advanced Passive LWRs by providing enhanced application versatility for mid-to-long term markets while aiming at a superior level of economic performance relative to any other GenIV technology.

Support **deep decarbonization** through high-temperature process heat

Enhanced sustainability and improved waste management with the capability to support **closed fuel cycles**

Enhanced site-ability to suit a wide range of customers and applications

Aim at a **step-change improvement in economics**



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Our History in Belgium

Westinghouse builds the 1st PWR in Europe, in Belgium (BR 3 in Mol) and grants a license to *the ACEC (Ateliers de Constructions Electriques de Charleroi)* for the construction of PWRs.

1957

Westinghouse installs its first European offices in Europe, in Brussels.

1971

Westinghouse Electric Belgium moves all its engineering activities in Belgium to Nivelles.

2002

A hot storage area of 3000m² for large contaminated components and equipment is inaugurated in Nivelles.

2013

Westinghouse takes over *les ACEC*.

1970

Westinghouse inaugurates its European Services Center in Nivelles and moves all its field activities to this facility

1986

The Pump & Motor Workshop is inaugurated. Its capacity is increased 3 years later to reach 3000m² today.

2010

- Westinghouse Electric Belgium contributed to the design and construction of 18 nuclear power plants in Europe, of which 5 in Belgium.
- More than **120 employees** work for Westinghouse Electric Belgium as of today, mainly highly skilled engineers and technicians.
- Westinghouse Electric Belgium's activities are dedicated to services to nuclear power plants in Europe.



**Westinghouse
Electric Belgium S.A.**
Rue de l'Industrie 43
B-1400 Nivelles (Belgium)
Tel: +32(0)67.28.81.11

Nivelles, 30 Mai 2023

*A l'attention de la Commission de l'Énergie, de l'Environnement et du Climat
Chambre des représentants de Belgique
Palais de la Nation, B-1008 Bruxelles*

Mesdames et Messieurs les Représentants,

En 2021, Westinghouse Electric Belgium a fêté ses 50 ans de présence en Belgique. La première filiale de Westinghouse créée en Europe l'a été à Bruxelles en 1971. Cette décision a été le fruit d'une collaboration bien plus ancienne. En effet, le premier Réacteur à Eau Pressurisée (REP) installé hors des Etats-Unis a été construit en collaboration avec Westinghouse à la fin des années 50 au centre d'étude de l'énergie nucléaire de Mol. Westinghouse octroie à cette occasion une licence sur sa technologie REP aux Ateliers de Constructions Electriques de Charleroi (ACEC). Ce "Belgian Reactor number 3" (BR3) a été en service de 1962 à 1987. Dans la même période fut créée la Franco-Américaine de Constructions Atomiques (Framatome) par Westinghouse, Schneider et Merlin Gérin avec pour objectif de construire des centrales nucléaires en France et d'exploiter la technologie REP sous licence Westinghouse. Cette vague de construction a débuté par la centrale de Chooz A construite par EDF en collaboration avec l'exploitant belge et mise en service en 1967. Au cours des années 70, la centrale de Tihange 1, de conception Westinghouse, construite en Belgique et détenue à 50% par EDF a préfiguré la première série des centrales françaises de 900 MWe. Ce modèle d'exploitation de licence a été similaire dans plusieurs pays (avec KWU Siemens en Allemagne par exemple, ou encore au Japon ou en Corée). Cela explique pourquoi aujourd'hui, sur les 437 réacteurs nucléaires en fonctionnement dans le monde, répartis dans 32 pays, environ la moitié repose sur une technologie Westinghouse.

Au niveau international et du nouveau nucléaire, depuis les années 1980, Westinghouse a été impliquée dans un programme de simplification de la technologie REP, visant à réduire les coûts et les temps de construction des centrales de grande puissance ainsi qu'à améliorer la sûreté intrinsèque du réacteur. Pour y répondre, Westinghouse a développé l'AP1000®, premier REP de Génération III+ ayant obtenu une licence de conception et d'exploitation par l'autorité de sûreté américaine (NRC). Réacteur à deux boucles à sûreté passive (qui repose sur des phénomènes physiques naturels, nécessitant ainsi peu d'interventions humaines et pas de puissance électrique pour fonctionner), le nombre de systèmes et d'équipements est réduit. Par ailleurs, sa construction modulaire permet d'effectuer de nombreuses opérations de construction en parallèle. La conception de l'AP1000® est compacte et optimale en termes de quantité de béton et d'acier utilisée par MWe généré. Depuis 2018, quatre AP1000® sont en opération en Chine ; deux tranches sont actuellement dans une phase avancée de construction sur le site américain de Vogtle (dont une en cours de démarrage), et plusieurs contrats de conception ou construction ont été signés dans plusieurs pays (Chine, Ukraine, Pologne).

Aujourd'hui, les défis de la filière nucléaire sont la transition énergétique et la décarbonation. Dans ce contexte, Westinghouse est actuellement engagée sur plusieurs projets de développement, tels que :

- Le microréacteur eVinci™, une batterie nucléaire portable qui peut livrer en même temps de la puissance électrique (jusqu'à 5 MWe) et de la chaleur (jusqu'à 15 MWth), fabriquée et chargée entièrement en usine et déployable dans des zones potentiellement isolées en moins de 30 jours, avec une autonomie en combustible d'au moins 8 ans et sans nécessité de stockage du combustible usé. Ce microréacteur devrait être commercialisé après 2025 en Amérique du Nord.
- Le Westinghouse SMR, un petit réacteur modulaire (300 MWe) de Génération III+, à boucle unique et basé sur la technologie AP1000®, s'appuyant sur et développant les concepts de

R.C.N. 96482 - T.V.A: BE 0449.543.728

simplicité et de sûreté entièrement passive, employés avec succès dans les réacteurs AP1000® déjà en opération. Ceci permet d'obtenir une conception à haute performance sans ajouter les risques et les défis normalement associés à un réacteur innovant (prototype). La taille du réacteur et son design simplifié permettent une empreinte ultra-compacte (avec intégration de la piscine de désactivation du combustible à l'intérieur de l'enceinte de confinement) et de limiter considérablement les besoins en eau brute (source froide). Ce SMR sera prêt à être construit en environ 36 mois à l'horizon 2030.

- Le Lead Fast Reactor (LFR), un Réacteur à Neutrons Rapides (RNR) de taille moyenne (950 MWth / 450 MWe) refroidi au plomb liquide, à sûreté passive et appartenant à la Génération IV des réacteurs nucléaires :
 - Le choix du plomb et la sûreté intrinsèque : Le choix du plomb comme caloporteur primaire du réacteur offre de nombreux avantages en termes de sûreté intrinsèque. Le plomb a un point d'ébullition extrêmement élevé qui, associé à sa conductivité thermique élevée et à un volume assurant une grande capacité calorifique, permet une évacuation plus efficace de la chaleur produite par le cœur du réacteur. De plus, en raison du fonctionnement du réacteur à pression atmosphérique, du fait que le plomb ne réagit pas de manière exothermique avec l'air ou l'eau et qu'il est lui-même une barrière naturelle contre les radiations (à la différence du sodium), le plomb liquide représente une ligne de défense inhérente.
 - La réduction des déchets et la fermeture du cycle combustible : Le LFR a la capacité de fonctionner soit avec un combustible à base d'oxydes d'uranium enrichi soit avec du MOX (combustible à base d'un mélange d'Uranium et de Plutonium issu du retraitement ou recyclage du combustible usé). Le problème des déchets est significativement réduit par rapport à la situation actuelle car la technologie des réacteurs à neutrons rapides chargés de combustible MOX permet d'économiser les ressources fissiles par une meilleure utilisation de l'uranium 238 et en multi-recyclant le plutonium (le projet vise un cycle d'opération entre deux rechargements de combustible de l'ordre de 10 ans). Ce choix permettrait d'assurer la fermeture du cycle combustible et de considérablement réduire les déchets nucléaires à vie longue.
 - Sa conception basée sur la sûreté passive permet une simplification et une compaction du système. Cette simplicité et la construction modulaire permettant de maîtriser coûts et délais.
- Ce réacteur sera commercialisé à la fin des années 2030.
- Une solution de stockage thermique à base de béton et d'huile intégrée aux réacteurs Westinghouse permet (par manipulation de divers soutirages de vapeur) de varier la puissance électrique générée d'un réacteur, tout en maintenant une puissance du cœur constante. Cette solution emploie de manière innovante des matériaux et des technologies facilement disponibles sur le marché pour offrir des solutions de stockage d'énergie économiquement de pointe, soutenant ainsi le déploiement de sources de production d'énergie non-modulables tout en gardant le haut facteur de disponibilité d'un réacteur (point fort de l'économie des centrales nucléaires) ainsi que la durabilité du système. Cette solution peut être combinée aux réacteurs décrits ci-dessus.

Je vous prie d'agréer, Mesdames et Messieurs les Représentants, l'expression de ma considération la plus distinguée.

X.P. Pitoiset

Xavier PITOISET
Chief Engineer, Digital & Innovation
Westinghouse Electric Belgium

R.C.N. 96482 - T.V.A: BE 0449.543.728

21-06-23



Commission CLIMATE, Chambre des Représentants, Belgique

Roberto Adinolfi,
Chairman of the Board

ansaldo | energia

Ansaldo Energia Group in a Snapshot



3300
Employees



1,491 € million
2021 Revenue



4,506 € million
Backlog



3,0%
R&D spending*
*R&D spending vs 2021 Revenue



2151
Patents

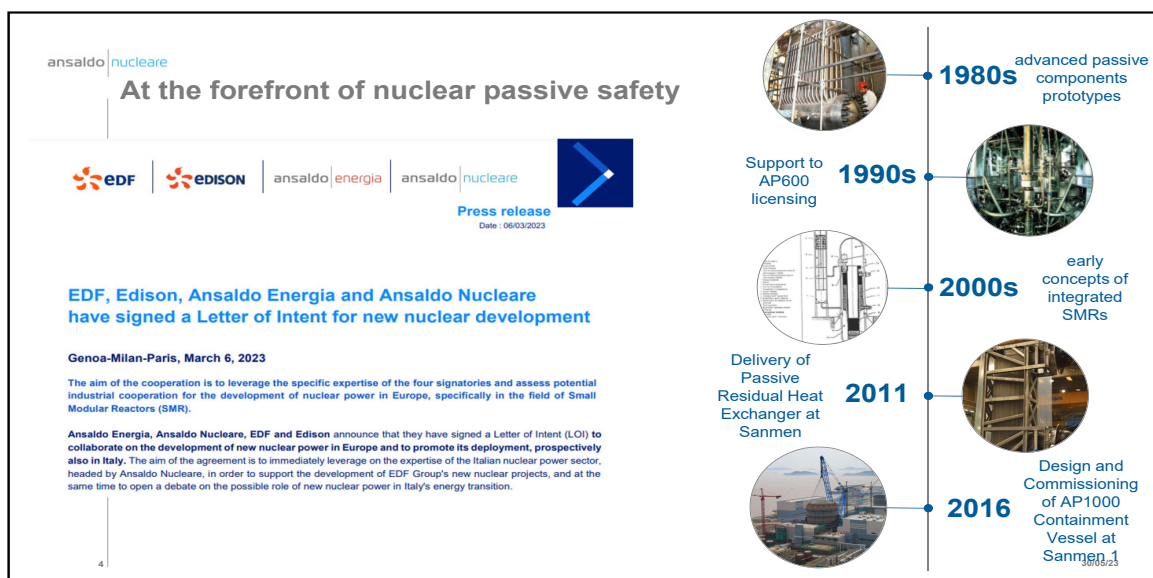
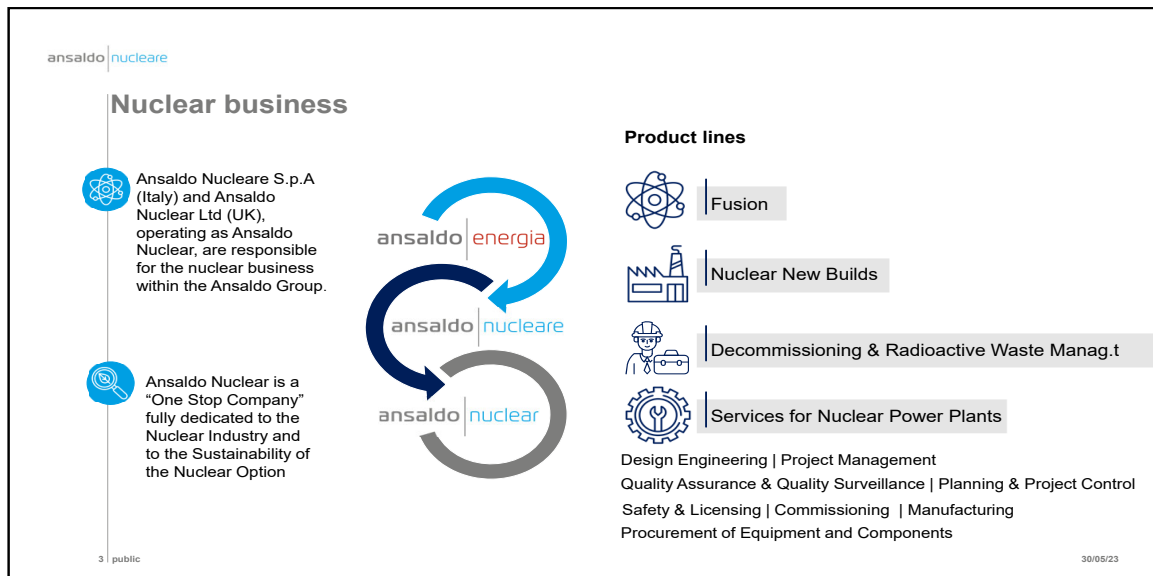


2
Repair centers

2 | public

30/05/23

21-06-23



21-06-23

ansaldo | nucleare

At the forefront of the EU LFR development

Westinghouse Develops Next-Generation Nuclear Plant with Ansaldo Nucleare

October 3, 2022 by [Westinghouse Electric Company](#)

Companies Sign Agreement to Continue Long-Standing Collaboration to Deploy Lead-cooled Fast Reactor

Under this new agreement, the two companies will advance a common design to maximize synergies, combine experience in design, testing and licensing, and align respective partner and supply chain organizations. The agreement builds upon development activities already underway in the United Kingdom, United States, Italy, and Romania, where more than ten state-of-the-art, lead-based test facilities are being installed.

The LFR technology combines the use of liquid lead as a coolant, high-temperature operation, and fast neutron spectrum with engineering solutions promoting design simplicity and robustness. The objective is step change performance improvement relative to traditional nuclear technology, including enhanced economics, market versatility beyond electricity and improved sustainability.



5 | public

30/05/23

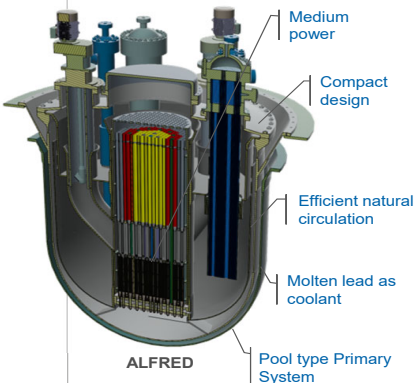
Timeline of LFR Development:

- 1980s**: Codevelopment of Superphenix (LMFBR)
- 1990s**: Early studies on Energy Amplifier by Nobel prize C. Rubbia
- 2000s**: Long-lasting collaboration with SCK-CEN for the design of MYRRHA
- 2010s**: 10+ EURATOM projects for the development of Gen-IV LFR technology
- 2020s**: Experimental facilities to support LFR technology

ESNII
European Sustainable Nuclear Industrial Initiative

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LFR technology development in Romania



ALFRED

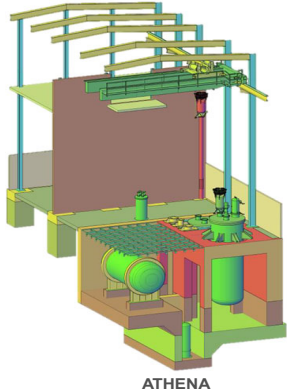
- Medium power
- Compact design
- Efficient natural circulation
- Molten lead as coolant
- Pool type Primary System

FALCON: a long-lasting endeavour, in collaboration with Italian research centers, academia and supply chain, to promote the Gen-IV LFR technology at EU level and beyond.

ALFRED: an international programme to support the development of a **technology park** in Romania, aimed at accelerating the LFR deployment.

Romanian Government **commitment** to support the initiative by investing more than 120 m€ in the construction and operation of **experimental facility** as a strategic asset for the country.

ATHENA: most powerful in Europe and unique **pure-lead pool-type facility** worldwide for **performance test** and **licensing support** on LFR technology (worth 20 m€ investment).



ATHENA

6 | public

30/05/23

21-06-23

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Fusion Technology

Two **short-term** programs:

- **ITER**, Cadarache: world's largest tokamak, supported by an International Consortium (IO).
- **DTT**, Frascati: domestic opportunity, by an Italian consortium (ENEA, ENI, CREATE).

Medium-term opportunities

- STEP by UKAEA in UK
- DEMO as part of the EUROFUSION roadmap

Fusion

Consolidated role gained in ITER program
Positioning throughout the value chain
Participation to Italian Project coordinated by ENEA (DTT)

- **ITER** (France)
Tokamak Assembly – TAC2
- **ITER** (France)
Steady state electrical network – TB13
- **ITER** (France)
Engineering Remote Handling / Tokamak Cooling System
- **DTT** (Italy)
Engineering (plant, systems, components)



7 | public

30/05/23

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Our Vision

Nuclear needs a brand new positioning in the European scenario towards Energy Transition

- Nuclear energy shall contribute to the 3 main pillars of a sustainable energy system:
 - *Lowest environmental impact*
 - *High resiliency (i.e. availability of energy sources)*
 - *Lowest system costs*
- In the European scenario, we believe that a new positioning for nuclear should be pursued acting along 3 main lines:
 - **Simplification**
 - **Social acceptability**
 - **Transnational synergies**

8

30/05/23

21-06-23

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Our drivers for a New Nuclear

Simplification

- Financing of large NPPs is very different from other power plants, because of the size of the investment and the long construction schedule, with associated risks. This is even more true for First-of-a-Kind new reactor designs
- Simplification is crucial towards reduction of construction costs and timing, then making the financing less cumbersome

Social acceptability

- When looking to Europe as an integrated market, a high level of safety shall be granted and perceived. Innovation based on passive safety features looks the best way to be pursued
- Similarly, waste minimization is an issue to address, when looking for an increasing nuclear production. New plants able to close the fuel cycle. i.e. Generation IV designs, will have a place in the future markets

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Our drivers for a New Nuclear (cont.)

Transnational Synergies

- New Nuclear needs to be standardized, particularly in Europe where the national markets are usually too small to allow for series effect benefits
- Development of New Nuclear requires significant financial and human resources: cooperation is the key to accelerate
- The European Supply chain has been suffering the lack of New Builds in the past decades: while capability and quality seem largely retained, investments are needed to increase capacity, if nuclear shall effectively contribute to the European Energy transition
- Cooperation among national supply chains can allow for less investment costs, while ensuring larger and more stable markets to everybody

**The SMR business model looks to us
the most appropriate approach to develop and deploy
a New Nuclear in Europe**

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21-06-23

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Our goals

1. To contribute to the first SMRs which will be built in Europe by 2030

- These will be based on LWR technology, as the most mature
- They will pave the way towards cooperation schemes among national authorities, and then towards transnational design approval process
- They will favour new aggregations of the European Supply Chains, then influencing single supplier's investment plans

Towards such a goal, we have entered into a cooperation with Nuward, as supplier of services and components, as well as partner in exploiting the possible contributions of the Italian supply chain

11 | public 30/05/23

ansaldo | nucleare

Our goals

2. To accelerate the development and the deployment of Lead Fast Reactors

- This is the most mature Gen-IV technology able to minimize wastes and close the fuel cycle
- Adequate to cope with industrial heat needs up to 400-500 °C
- Can rely on extensive EU knowledge, mainly accrued in Belgium and Italy, and on testing facilities under construction in Romania and UK
- Licensing is the critical factor for such a schedule: a demonstrator is needed to support it, before going commercial
- First-Of-A-Kind reactor can be deployed by 2035, to catch the market opportunities linked to closure of most European power plants

Towards such a goal, we aim to combine the best competences towards a successful industrialization of the technology: in this respect we are associating with Westinghouse to merge technical competences and Vendor expertise

Our ambition is to expand the cooperation to other technology champions in EU

12 | public 30/05/23

21-06-23

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Our goals

3. *To be at the forefront of fusion technology industry*

- Our experience at ITER is giving us significant return in terms of advanced technology processes
- The step from ITER up to a commercially viable fusion plant is huge and will require further technology breakthroughs in various areas, but...

**We do know that innovation in nuclear requires
longranging view and
collaborative approach**

13 | public

30/05/23

Commission CLIMATE, Chambre des Représentants, Belgique

Public Hearing on SMR, Bruxelles, May 30, 2023

Contribution of Ansaldo Energia Group

Speaker: R. Adinolfi, Chairman of the Board, Ansaldo Nucleare spa

The Ansaldo Energia Group is one of the largest European suppliers in the Power Generation sector. The Group is owned by Cassa Depositi e Prestiti, the financial Branch of the Italian Ministry of Treasury: the minority participation of Shanghai Electric Corporation, already reduced to 12,5%, is going to further dilute to less than 1%, due to the decision of CDP to increase the social capital of the Group in the month of June.

Ansaldo Energia presence in the nuclear sector dates to the 70ies: after the Chernobyl accident and the following decision to close all the Italian Nuclear Power Plants, the Group decided to maintain a strategic presence in this sector, operating abroad, mainly in Europe.

As of today, the nuclear business is managed by the fully owned subsidiary Ansaldo Energia spa, which in turn fully controls the UK based subsidiary, Ansaldo Nuclear Ltd. The two companies, managed as a single entity, are active in four main fields: New NPPs, Fusion, Decommissioning & Waste Management, Service to the operating reactors. Our competences range from engineering to project management, procurement and installation, with manufacturing capability of bespoke components in our UK factory.

Ansaldo Nucleare has been a nuclear innovation pioneer in Europe: since the 90ies we have been at the forefront of the R&D on passive safety features, as a new feature to increase the safety of Generation III reactors. We designed, built and tested the prototype passive cooling components both for BWR and for PWR, and we also actively developed integrated primary systems. More recently, we have been supplying critical nuclear components for the first AP1000 deployed in China, including the innovative Metal Containment Vessel.

Furthermore, we actively pursue the development of Lead cooled Fast Reactors, which we consider one of the most promising GEN IV technologies. Our experience with fast reactors started in the 80ies when we contributed as minority partner (40%) to the Superphenix project. In early 90ies, looking after the Accelerator Driven System proposed by Nobel Prize Carlo Rubbia, we appreciated the advantages offered

by lead as an alternate coolant to sodium. Since then, we have been leading more than 10 Eu projects on this technology, most of them together with SCK CEN. We also provided an extensive and fruitful contribution to the Myrrha Project in the Front End Engineering& Design. But our main focus on LFR has been in Romania, where we have created a consortium together with ENEA and RATEN, the national R&D agency, to promote ALFRED, a technology demonstration program which attracted, up to now, financing for 120 M€.

Finally, our Group is also active on Fusion technology, mainly at ITER, where we supply nuclear components like the Vacuum Vessel sectors, but also engineering and support systems.

As these references testify, ANSALDO vision is centered on a **brand-new positioning of nuclear** in the European scenario towards Energy transition. Nuclear can provide a substantial contribution to reduce the environmental impact of energy generation. Thanks to the good availability of uranium sources, it can ensure higher resilience to the energy system. And thanks to its complementarity with intermittent RES it can even reduce the overall system costs.

Hence, how to reach this brand-new position in the European scenario? According to us, there are three development lines to pursue. The first one being **Simplification**.

Complex NPP designs often resulted, particularly in Europe, in long construction schedules, which further increased the financing cost of the project, already suffering from the size of the investment, the long-term return and the perceived uncertainty risk. Future nuclear power plants should pursue a simplified design, in terms of overall equipment and structures, as well as of limited bespoke components

When looking at Europe as an integrated market, a further key feature of the New Nuclear shall be the **Social Acceptability**: if our products shall serve markets like Belgium or Italy, an elevated level of safety shall be granted, and even more perceived. Passive safety features will help achieving broader confidence and at the same time will help to simplify the design. Similarly, waste minimization shall be taken into account: new plants able to close the fuel cycle, i.e. Generation IV designs, will have a place in the future markets.

Last but not the least, we firmly believe that New Nuclear shall be based on **Transnational Synergies**. European national markets are rarely large enough to develop a full fleet of a new design and to benefit from the consequent series effect. Furthermore, development of New Nuclear requires significant financial and human resources, cooperation among several parties is the key to accelerate. The European supply chain has suffered the lack of new projects in the past decades: while we

believe there is still an adequate capability in Europe to deliver high quality components and services, we recognize that investments are needed, in the supply chain, to increase capacity at the level expected to effectively contribute to the energy transition. Cooperation among national supply chains can help reducing the overall investment needs and will also ensure to the industrial investors a more stable and broader market.

Based on the above consideration, Ansaldo considers that the **Small Modular Reactors** look the most appropriate approach to develop and then deploy New Nuclear in Europe.

In line with such a vision, we have assigned to ourselves two main goals:

1. ***To contribute to the first SMRs which will be built in Europe by 2030:*** these will likely be the ones based on Light Water Reactor technology, as the most mature.

Anyhow, such projects will pave the way towards transnational synergies, both in the licensing arena and in the supply chain. So, for us is important to be involved, to properly shape our short-term investments. As recently announced in the press, towards such a goal we entered in a cooperation with NUWARD-EdF.

2. ***To accelerate the development and the deployment of LFRs:*** we do believe that designs able to minimize waste production are needed to respond to the issue of Social Acceptability, and we consider the LFR technology as the most mature among the GEN IV technologies able to close the fuel cycle. Furthermore, it can also serve the industrial heat needs up to 500 °C and contribute to clean hydrogen production, in line with the trends of the energy transition in Europe.

Competences existing mainly in Belgium and Italy, together with the numerous test facilities available in these countries and in Romania, can allow for the desired acceleration. Licensing will anyhow be the critical factor in the schedule, as a demonstrator is needed to support it. Our expectation is to deploy a first industrial plant by 2035, to catch the market opportunities linked to the end of life of most existing NPPs.

We already entered a cooperation with Westinghouse, aiming to combine best technical competences and Vendor expertise in order to achieve a successful industrialization of LFRs in the shortest time. Our ambition is to further expand such cooperation to other technology champions in EU.

Finally, we intend also to continue our support to Fusion, to keep our current positioning at the forefront of the technology: even if the path to a commercially viable fusion plant is huge, we do know that innovation in nuclear requires long ranging view.

This is what we have been doing since the 90ies and what we are going to do, always looking for collaboration as the key to success.

Energie Nucléaire et SMR

Yves Bréchet

Qui suis-je?

- Professeur des Universités (Grenoble, McMaster (Canada), Monash(Australie)
- Spécialiste de Science des matériaux
- Membre de l'Académie des Sciences
- Auteur de nombreux livres et articles scientifiques dans le domaine des matériaux, et en particulier des matériaux en relation avec l'énergie
- Ancien Haut Commissaire à l'énergie atomique (conseiller gouvernemental en France pour les questions énergétiques) 2012-18
- Directeur scientifique de Saint Gobain
- Président du conseil scientifique de Framatome

Pourquoi l'énergie nucléaire aujourd'hui?

Des atouts longtemps sous évalués

Une double urgence: le réchauffement climatique, l'usage parcimonieux des ressources

- Nécessité de décarboner nos économies pour lutter contre le réchauffement climatique
 - Transport
 - Batiment
 - Industrie
- Nécessité de le faire vite...après des années de procrastination
- Nécessité décarboner l'électricité avec des technologies disponibles économes en matière, en espace, en énergie

Le problème est mondial et nécessite une action coordonnée des grands groupes de pays (en particulier l'Europe) pour la définition des objectifs de décarbonation de nos économies

Les solutions sont locales et nécessitent de prendre en compte la situation de départ: aucun pays n'a légitimité à imposer au groupe une solution plutôt qu'une autre . Il est dangereux de confondre les objectifs et les moyens

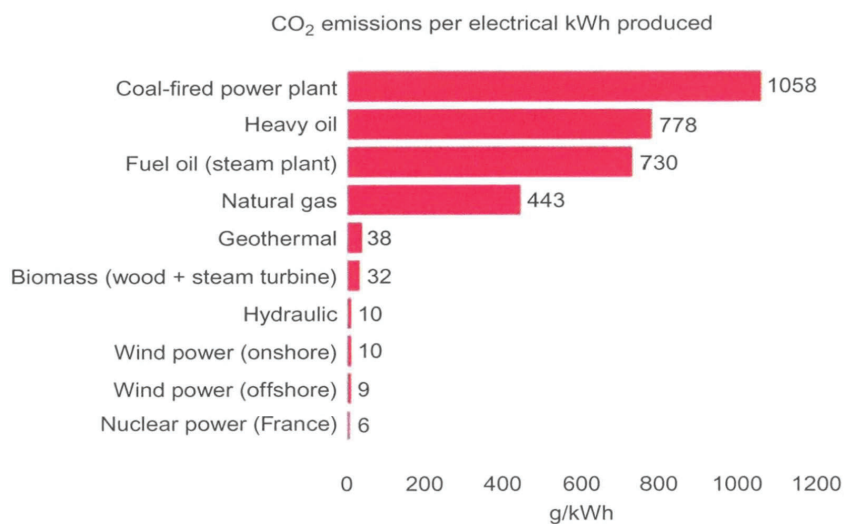
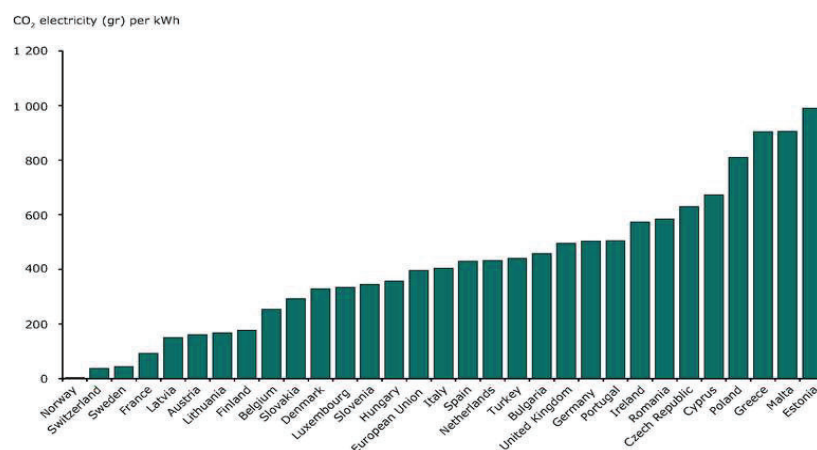
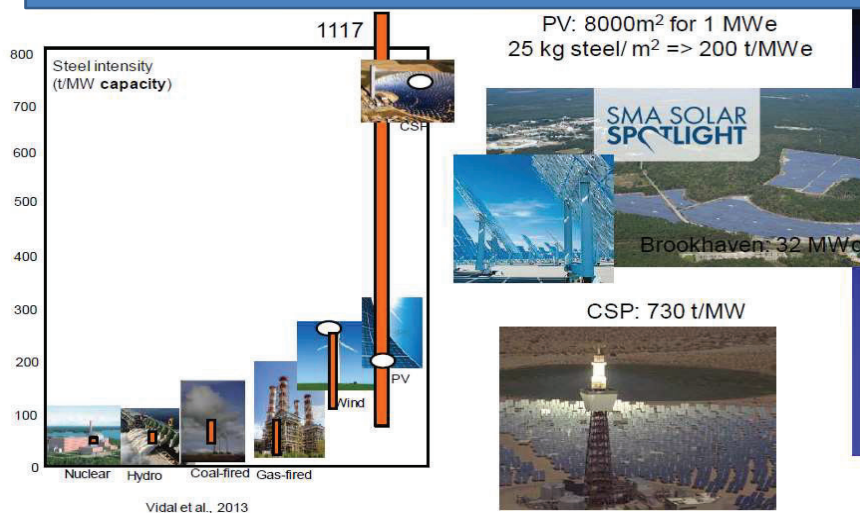


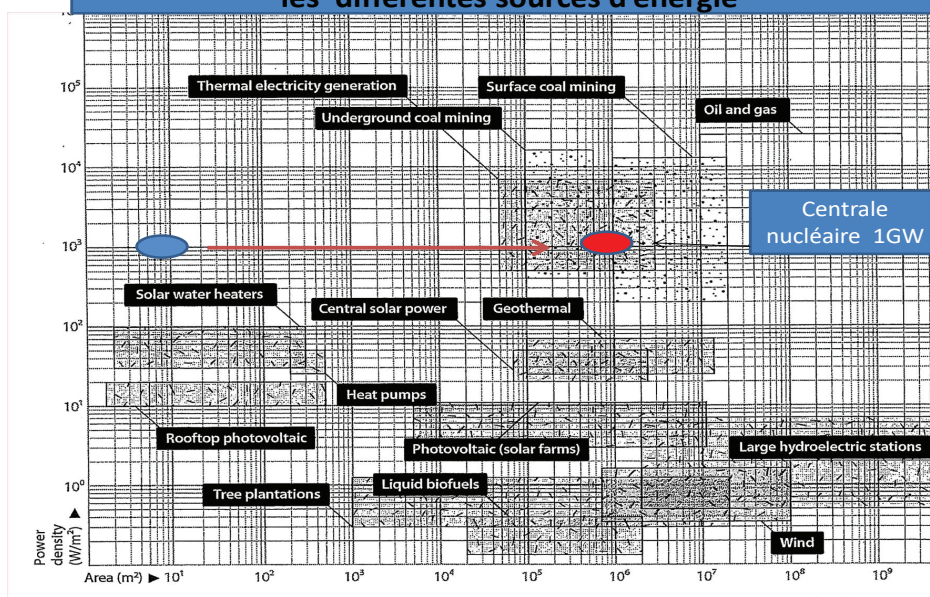
FIG. 9

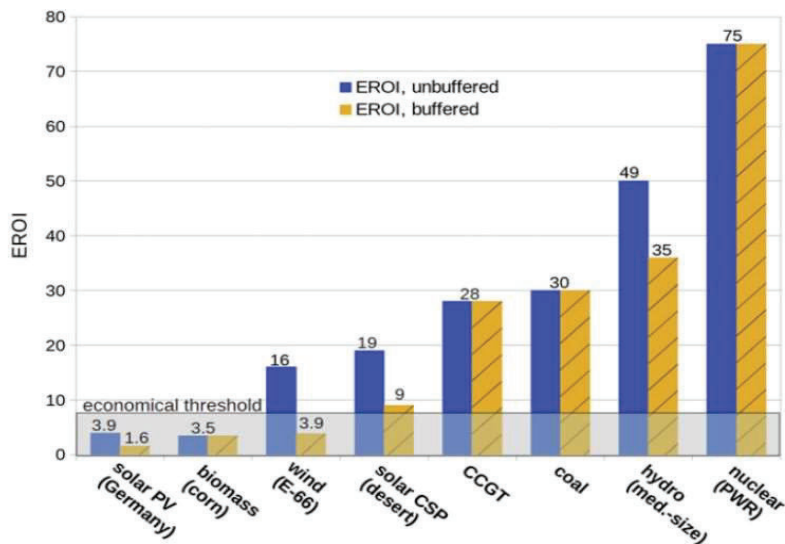
CO₂ emissions in g/kWh for the different types of energy.

UNE ENERGIE ECONOMIQUE EN MATIERES

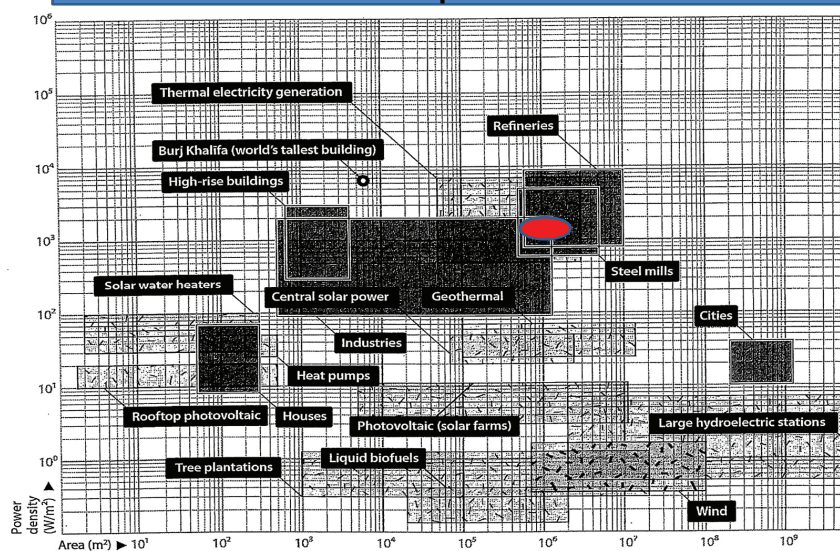


Usage de l'espace au sol pour les différentes sources d'énergie





Adéquation production consommation: nécessité de transport et de réseaux...

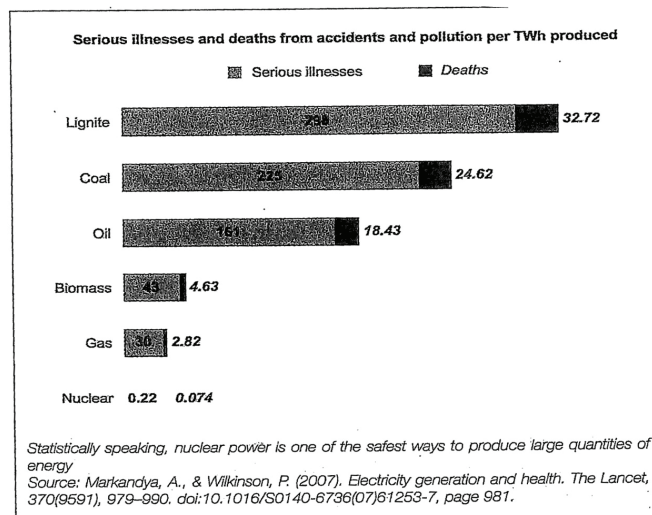


Des craintes constamment entretenues... les 4D

dangers
demantèlement
déchets
dépendance

Quatre accidents majeurs

- **Windscale (UK):** 0 morts + 0
- **Three mile Island (USA):** 0 morts + 0
- **Tchernobyl (R) :** 4000 morts
- **Fukushima (J):** 0 morts + ?



Les opérations de démantèlement dans le monde

149 réacteurs en arrêt définitif dans le monde fin 2013
119 dont le **démantèlement est en cours**
6 réacteurs dont le **démantèlement est terminé**
(tous aux États-Unis)



Yankee Rowe, USA



Après



Avant

Winfrith, UK

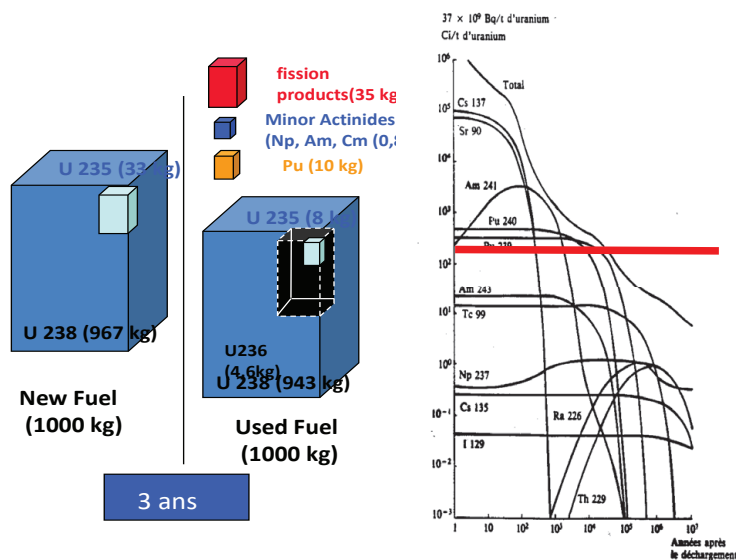
Après



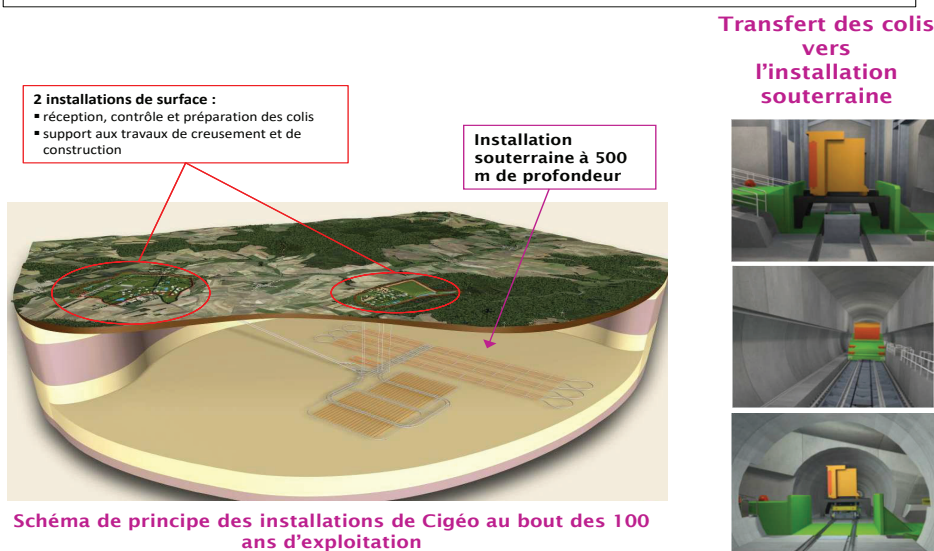
Académie des sciences - Colloque démantèlement des installations nucléaires, 8-9/10/2014

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Les déchets nucléaires

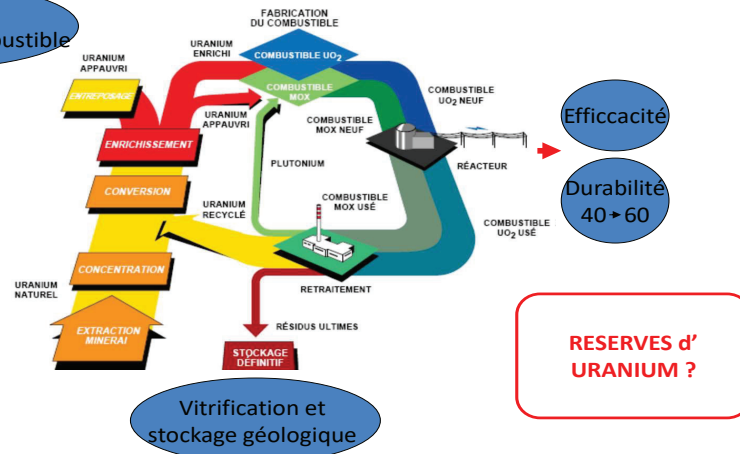


Stockage géologique profond

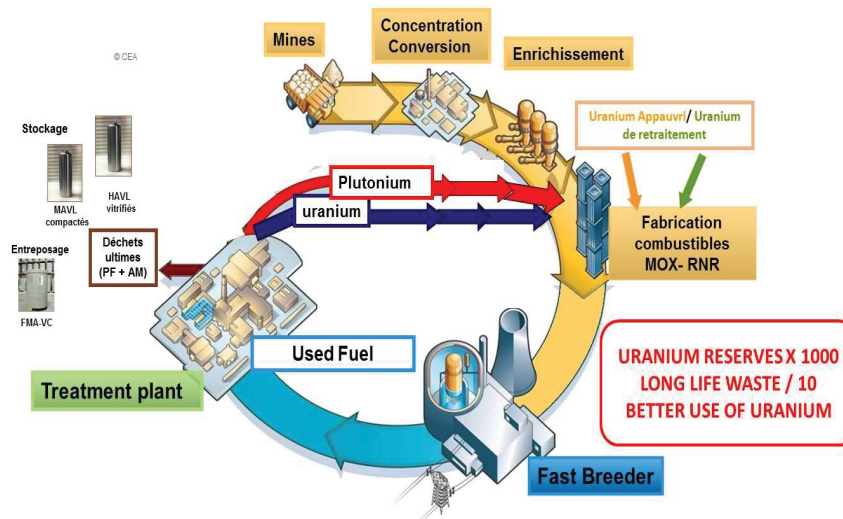


Le cycle du combustible en France en mode REP

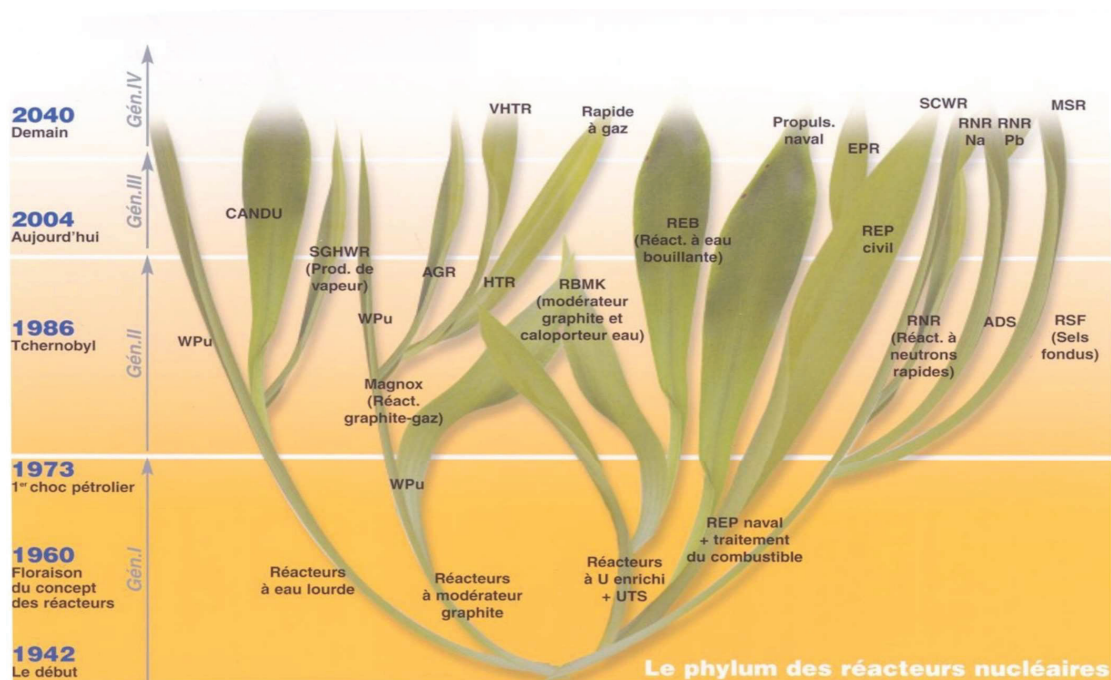
Processing and
Reprocessing du combustible

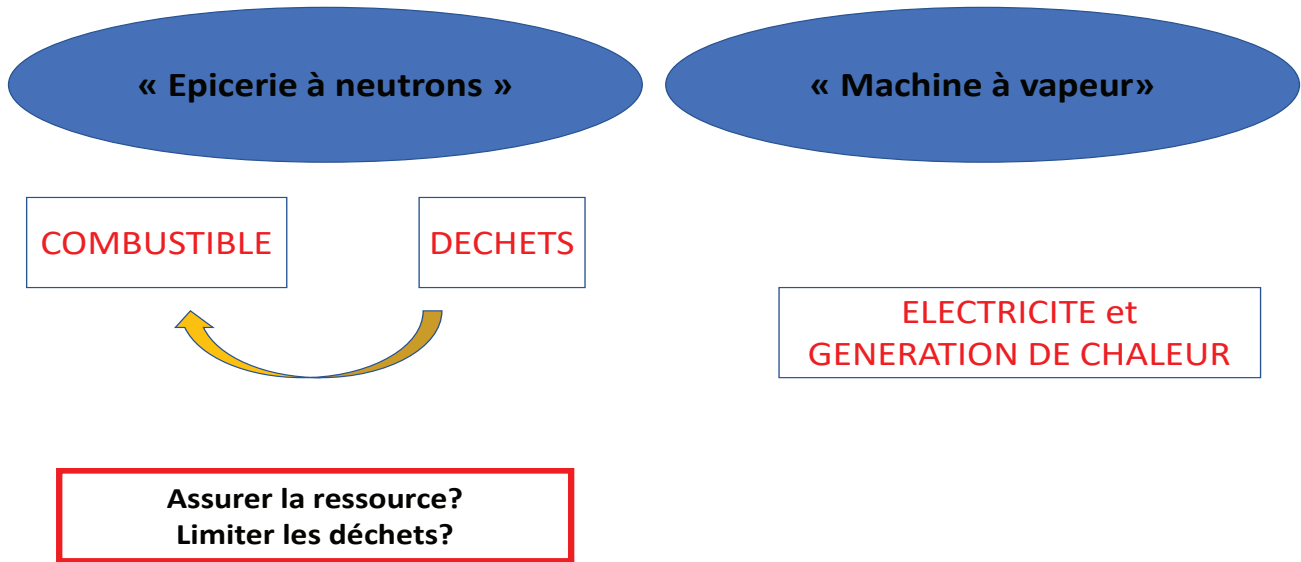


Le cycle fermé et les réacteurs à neutrons rapides

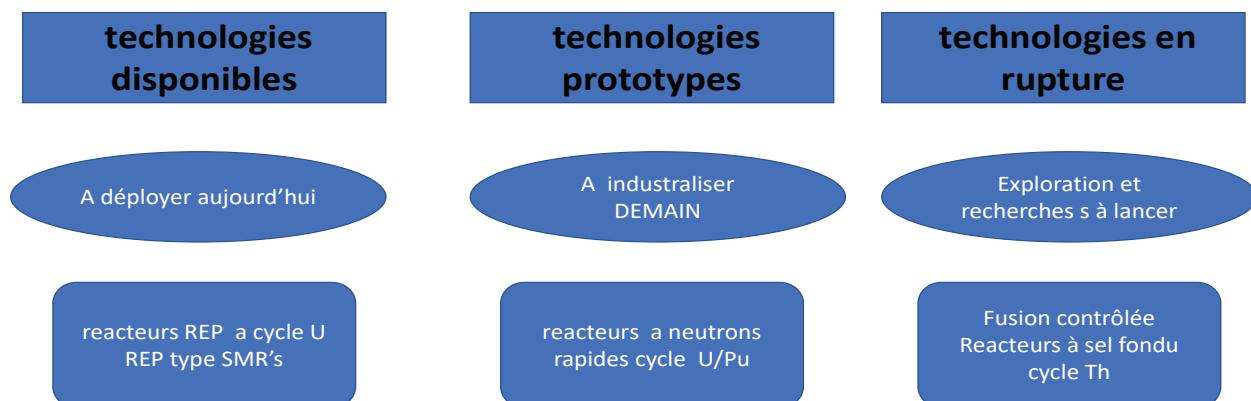


Quels réacteurs?





TRL (Technological Readiness level) et stratégies de décision





H.G. RICKOVER, Admiral, US Atomic Energy Commission (1953)

An academic reactor or reactor plant almost always has the following basic characteristics: (1) It is simple. (2) It is small. (3) It is cheap. (4) It is light. (5) It can be built very quickly. (6) It is very flexible in purpose ("omnibus reactor"). (7) Very little development is required. It will use mostly "off-the-shelf" components. (8) The reactor is in the study phase. It is not being built now.

On the other hand, a practical reactor plant can be distinguished by the following characteristics: (1) It is being built now. (2) It is behind schedule. (3) It is requiring an immense amount of development on apparently trivial items. Corrosion, in particular, is a problem. (4) It is very expensive. (5) It takes a long time to build because of the engineering development problems. (6) It is large. (7) It is heavy. (8) It is complicated.

LES SMR?

Ce qu'on aime ... et ce qu'on aime moins dans les SMR

- | | |
|--|--|
| • Nouveaux usages ... | • Nouveaux besoins? |
| • Possibilité de sécurité passive | • Validation par les autorités de sûreté |
| • Possibilité de construction « off site » | • Entretien délocalisé |
| • Investissement initial plus faible | • Investissement cumulé? |
| • Nouveaux marchés à l'export | • Risque de prolifération |
| • Adaptabilité à l'intermittence | • Vieillesse accélérée |
| • Modularité des puissances | • Garantie de disponibilité |

Il ne faudrait pas que les atouts des SMR se limitent à leur capital de « sympathie politique »

- « small is beautiful » : la mystique de la start up licorne...
- Rapidement construit (?) et donc rapidement inaugurable (!): un outil de communication politique...

Le questionnaire minimal pour les SMR

- Pourquoi un SMR plutôt qu'un réacteur « classique »?
- Commencer par expliquer « comment ça marche » : quel est le principe du réacteur, son intégration dans le cycle combustible existant.
- Dire quelles sont les applications visées. Dire en quoi le projet est complémentaire de l'existant, que cela soit en termes de réacteur électrogène ou en termes d'autres applications
- Présenter le concept, les idées de conception (en thermohydraulique, en neutronique, en thermodynamique, la question du volume/puissance...)
- Les aspects structurants : « quels combustibles ? Quels caloporteurs ? Quels dispositifs de sûreté ? »
- Les aspects nécessaires pour réaliser : « quels matériaux ? corrosion et fluage ? », « Quels procédés de fabrication ? »
- Une discussion sur les « points qui font mal » : fabrication, sûreté, contrôle non destructifs, etc.
- Les questions géopolitiques, en particulier en termes de prolifération, en termes de ressources en combustible
- Il est essentiel de ne pas perdre vue les aspects « système », c'est-à-dire le cycle du combustible, amont (extraction et fabrication) et aval (recyclage et déchets).

Les SMR peuvent réintroduire dans le nucléaire un potentiel d'innovation qui lui fait aujourd'hui souvent défaut. Choisir un SMR plutôt qu'un autre nécessite une véritable évaluation scientifique et ne peut se faire « au sentiment ».

CONCLUSIONS

Conclusion (1)

- **L'énergie Nucléaire fournit une électricité essentiellement décarbonée**, et c'est une technologie disponible
- Elle répond aux besoins d'énergie pour des secteurs industriels nécessitant des **ressources énergétiques denses et stables**
- C'est une forme d'énergie **peu consommatrice de ressources** de matière, d'espace et d'énergie grise pour sa production
- La **fermeture du cycle** dans les filières à neutrons rapides permet d'assurer un nucléaire durable par l'utilisation optimale des ressources et la minimisation des déchets

Conclusion (2)

- En tant que telle, **l'énergie Nucléaire peut jouer un rôle majeur dans la décarbonation de nos économies industrielles**
- Son importance dans un mix électrique dépend de la situation de chaque pays et **doit être laissée à chaque pays** comme une composante essentielle à sa souveraineté industrielle. Aucune instance supranationale n'a légitimité à imposer ce choix
- L'expérience passée en France a montré **qu'une volonté politique forte peut permettre de développer un parc électronucléaire important** (58 réacteurs en 20 ans), et que l'exploitation d'un parc ne maintient pas les compétences nécessaires à son renouvellement
- Elle a aussi montré qu'une **politique à long terme (30 a 60 ans) est nécessaire** et est plus efficace que l'émiettement d'une politique en tranches de 3 a 5 ans

Conclusion (3)

- Dans des pays déjà fortement nucléarisés, **il est déraisonnable de se priver de moyens de production** décarbonés, pilotables, surs, amortis. La priorité doit être donnée à la prolongation du parc dans les conditions de sûreté garanties. Les fermetures anticipées sont un gaspillage du patrimoine commun
- **Le renouvellement du parc doit se faire en priorité avec des réacteurs de puissance moyenne** (1000 a 1500MW)
- **La fermeture du cycle par des réacteurs à neutrons rapides est une condition nécessaire pour un nucléaire durable**
- **Les SMR sont des solutions potentiellement intéressantes**, de par leur capacité à stimuler l'innovation, à attirer de nouveaux talents. Ils peuvent correspondre à des besoins bien spécifiques (réacteurs calo-gènes, réacteurs prototypes, dessalination, production d'hydrogène) mais ils ne sont pas un substitut à un parc de grands réacteurs avec un réseau électrique bien structuré
- **Ils ne doivent pas être source de dispersion des moyens à des fins politiciennes d'affichage**
- **Le choix entre les multiples propositions doit se faire après une instruction scientifique et technique** des dossiers devant une commission d'examen compétente. Il ne peut être le fait du prince.

De complexe inpasbaarheid van een nieuwe kerncentrale in de energietransitie

Bernard ter Haar, juni 2023

Dit memo is op persoonlijke titel geschreven ten behoeve van de hoorzitting van de Belgische Kamer van volksvertegenwoordigers over kleine kernreactoren op 20 juni 2023

Inleiding

Het afgelopen jaar heeft een multidisciplinair samengesteld team van experts in opdracht van het Nederlandse kabinet onderzocht hoe het energiesysteem van de toekomst past in een klimaatneutraal Nederland in 2050 en wat de belangrijkste ontwikkelpaden zijn om in zo'n klimaatneutraal energiesysteem te komen. De auteur van dit memo was voorzitter van dit Expertteam. Het eindrapport van het expertteam is te vinden op de website www.etes2050.nl

Relevante bevindingen van het expertteam

Elektriciteit vormt de ruggengraat van het klimaatneutrale energiesysteem. De overgrote meerderheid van de energievraag en het -aanbod heeft de vorm van elektriciteit, in tegenstelling tot in het huidige energiesysteem, waar vraag en aanbod in overgrote meerderheid de vorm van fossiele brandstoffen heeft.

Een klimaatneutraal Nederland in 2050 is realiseerbaar als het energiesysteem tussen 2040 en 2045 fossielvrij is geworden, en het elektriciteitssysteem al in 2035 CO₂- neutraal is. Die deadline van 2035 zal voor België niet heel anders zijn. In Nederland zal de gebruikte elektriciteit voornamelijk geproduceerd worden met zon en wind, op land en op de Noordzee. Vooral Wind op zee zal een hoog vermogen gaan leveren. Omdat de deadlines zo krap zijn, en omdat de verbouwing van het energiesysteem moet plaatsvinden in een tijd van schaarste aan vakmanschap, ruimte en materialen, is een robuuste en realistische planning van de gehele transitie essentieel.

Nederland heeft op dit moment één operationele kerncentrale (in Borssele), met een vermogen van iets minder dan 500 MW. Het Nederlands kabinet heeft een principebesluit genomen om twee nieuwe kerncentrales te bouwen, elk met een vermogen van (ruim) meer dan 1000 MW. Het expertteam heeft ernstige zorg over de inpasbaarheid van kerncentrales in het Nederlandse energiesysteem, zoals hieronder wordt beargumenteerd.

Enkele ervaringen omtrent kernenergie

Voorstanders van kernenergie wuiven potentiële nadelen van kernenergie graag weg en wijzen op grote mogelijkheden van nieuwe innovaties, zoals de SMR's: kleine, compacte kerncentrales. De feiten laten vooralsnog een ander beeld zien. De ervaringen wereldwijd laten zien dat de bouw van een kerncentrale vaak (veel) langer duurt dan gepland, en ook (veel) duurder is dan gepland. Er wordt op veel plaatsen in de wereld gewerkt aan het ontwerpen van SMR's, maar operationeel zijn ze nog niet, en beloftevolle innovaties op het gebied van kernsplijting en -fusie kosten steeds veel meer tijd dan oorspronkelijk werd gedacht (dat geldt bijvoorbeeld ook voor de thorium-reactor). Het is daarom niet realistisch om de operationaliteit van een nieuwe kerncentrale (groot of klein) in te plannen vóór 2040. Daarbij is ook relevant dat nu reeds, hoewel SMR's nog niet operationeel zijn, de schattingen van de kosten (van bouw en ontmanteling) al aanzienlijk aan het oplopen zijn. Kerncentrales zijn relatief veilig, maar de impact van de veiligheidsrisico's zijn groot. Dit beperkt ook de

locatiemogelijkheden. Daarnaast speelt de potentiële gevoeligheid voor droogte, overstromingen of oorlogshandelingen. Ook de veilige (voor duizenden jaren) opslag van kernafval is nog een uitstaand vraagstuk.

De inpasbaarheid van een (grote of kleine) kerncentrale na 2035

Zoals gesteld moet het elektriciteitssysteem in 2035 al CO₂ neutraal zijn. Dat zal grotendeels geleverd worden door de goedkope energiebronnen zon en wind, aangevuld met bestaande kerncentrales, en waarschijnlijk nog enige inzet van fossiele brandstoffen of biomassa, met zoveel mogelijk afvang en opslag van CO₂. Omdat wind en zonne-energie met pieken en dalen komt, is opslag (en de productie van waterstof) een belangrijke component van het nieuwe systeem. Ook dat moet in 2035 volledig operationeel kunnen zijn. Met veel zon- en windenergie is maar een beperkt deel van de tijd regelbaar vermogen van een energiecentrale nodig.

(N.B. Één windmolen op zee zal een vermogen van meer dan 10 MW hebben. Voor SMR's wordt uitgegaan van vermogens tussen de 10 en 300 MW)

Ergens na 2035 zou een nieuwe kerncentrale aan dit systeem kunnen worden toegevoegd. Omdat dit een aanvullende energiebron betreft, wordt de robuustheid van het aanbod hiermee groter. De onzekerheid over het moment dat op deze energiebron gerekend mag worden tast de robuustheid echter juist aan. De bouw van een kerncentrale gaat zeker niet vanzelf in de markt tot stand komen, en ook de locatiekeuze zal nog een grote uitdaging zijn, niet alleen de keuze zelf, maar ook het verkrijgen van alle vergunningen voor die locatie. Er is nog nergens een kerncentrale gebouwd zonder grote bemoeienis en royale financiering van een overheid. Het is een miljardeninvestering waarvan het rendement vanwege de langdurige bouwphase heel lang op zich laat wachten. Niet alleen zal een aanzienlijke investeringsbijdrage van de overheid worden gevraagd, maar ook een garantie op prijs en omzet van de geleverde elektriciteit als de centrale gaat functioneren. Die prijs- en omzetgarantie is nodig omdat de marginale kosten van de kerncentrale hoger liggen dan die voor zon- en windparken. Zoals reeds is opgemerkt is maar een beperkte hoeveelheid tijd regelbaar vermogen nodig, maar elektriciteit van een kerncentrale wordt wel heel duur als de centrale alleen maar die beperkte tijd mag produceren. Die door de overheid gegarandeerde omzet wordt dan met een aanzienlijke prijssubsidie in het systeem gebracht tegenover het aanbod van de (veel) goedkopere elektriciteit van de particuliere wind- en zon-sector. Die sector zou dan een deel van de tijd de productie moeten terugbrengen met aanzienlijke financiële gevolgen.

Al met al is de potentiële versterking van de robuustheid van het elektriciteitssysteem dus beperkt door de grote onzekerheid over het tijdstip waarop een centrale in functie zal zijn. De locatiekeuze is ook complex en tijdrovend. Dat geldt wellicht minder voor een SMR, maar ervaring daarmee is er nog niet. Onzekerheid verstoort de robuustheid van de energietransitie. Een nieuwe centrale zal bovendien marktversturend werken in de fossielvrije elektriciteitsmarkt. De bouw van nieuwe kerncentrales heeft daarmee een hoge prijs vergeleken met andere fossielvrije bronnen. Het lijkt daarom geen aantrekkelijk perspectief voor de besteding van overheidsgeld in een nieuw energiesysteem waar sowieso al veel geld in geïnvesteerd zal moeten worden.

-0-



Nuclear power technologies in IEA scenarios

Brent Wanner, Head of Power Sector Unit, IEA

Belgium Committee on Energy, Environment and Climate

20 June 2023

Page 1

IEA World Energy Outlook scenarios

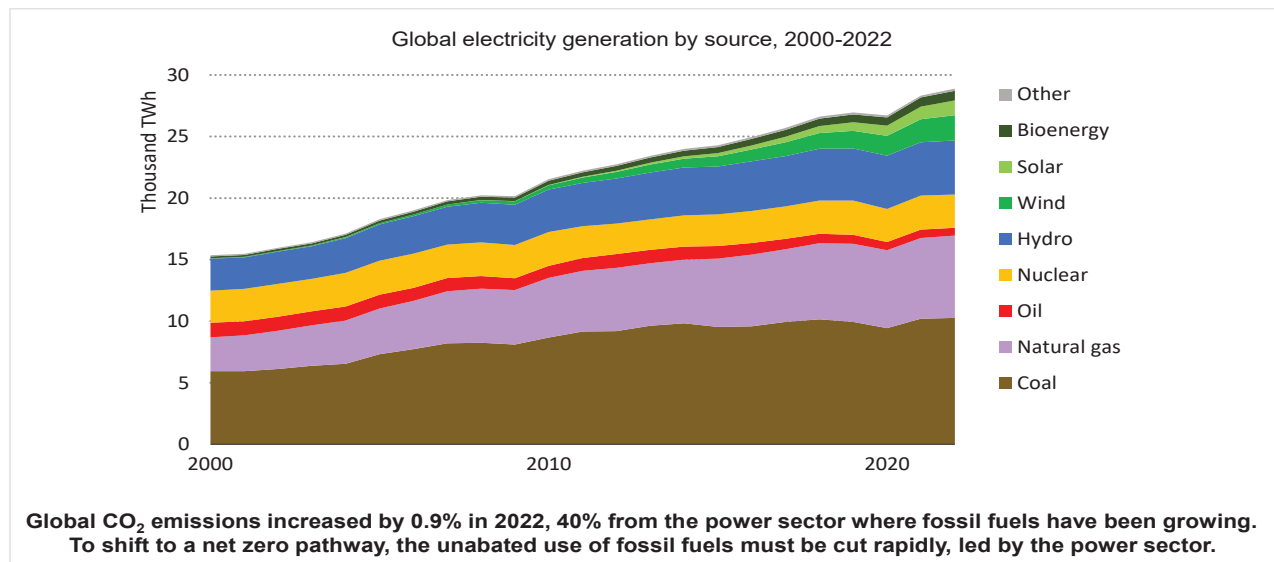


- The *World Energy Outlook 2022* considers multiple pathways, influenced heavily by policy:
 - **Stated Policies** (STEPS) reflects today's policy settings, including all laws and regulations in place across all energy sectors
 - **Announced Pledges** (APS) indicates the paths if country net zero and other pledges are met in full, including all announcements and pledges including those without implementation plans
 - **Net Zero Emissions by 2050** (NZE) provides an updated roadmap to reach net zero emissions in the energy sector by 2050 with a total emissions pathway consistent with the Paris Agreement that limits global average temperature rise to 1.5°C

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Page 2

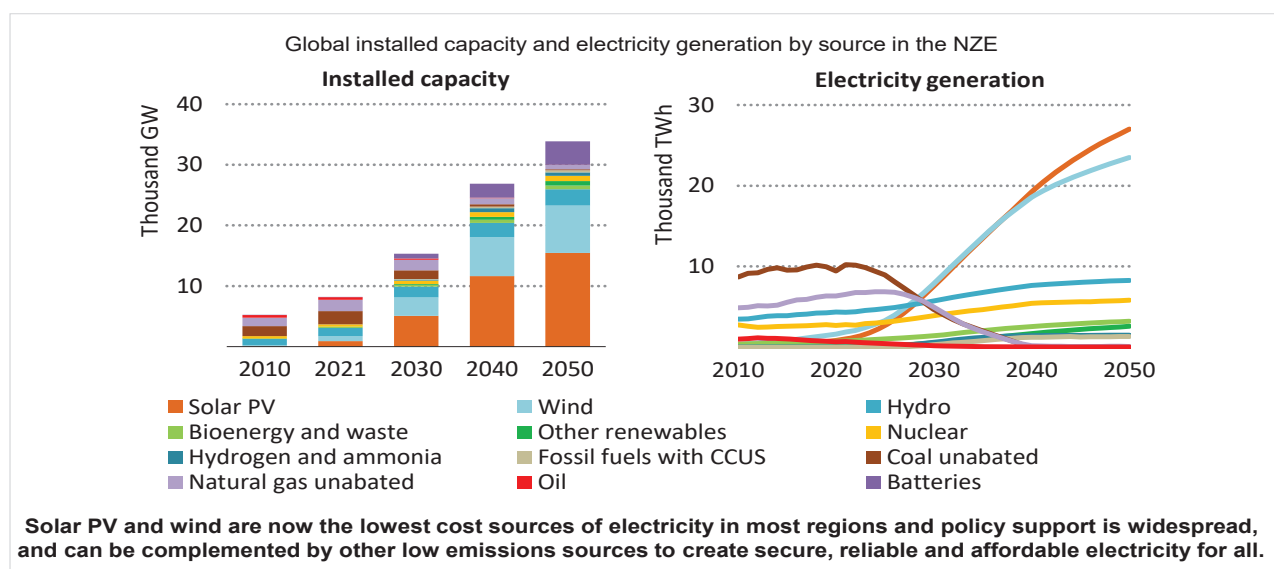
To fulfil the Paris Agreement calls for changing course



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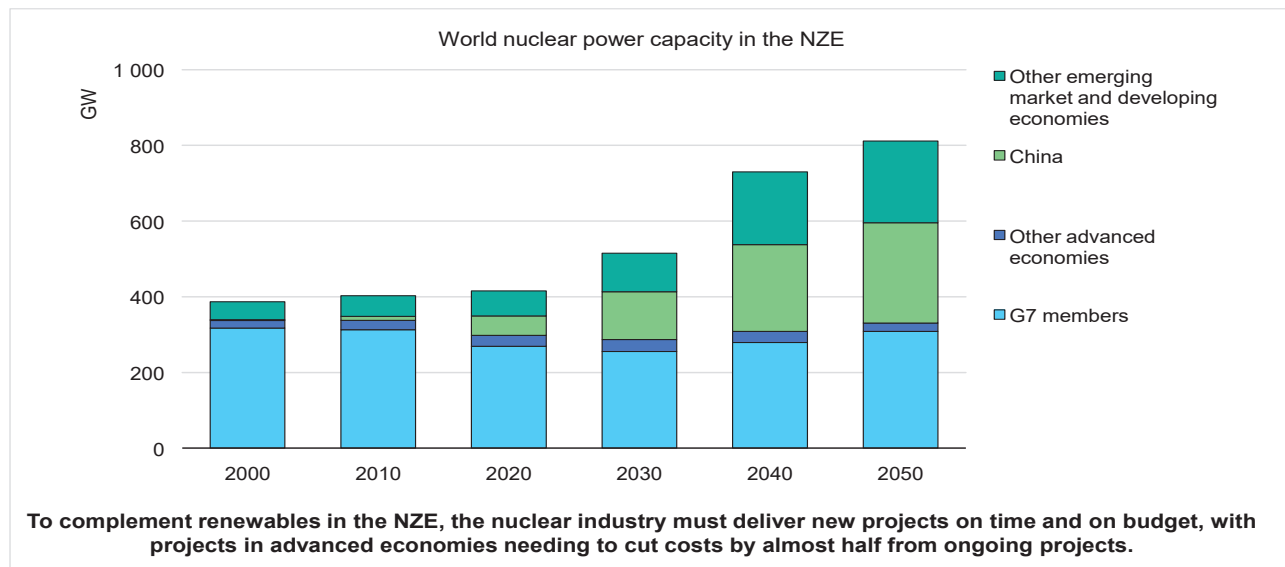
Renewables lead the way to Net Zero Emissions by 2050



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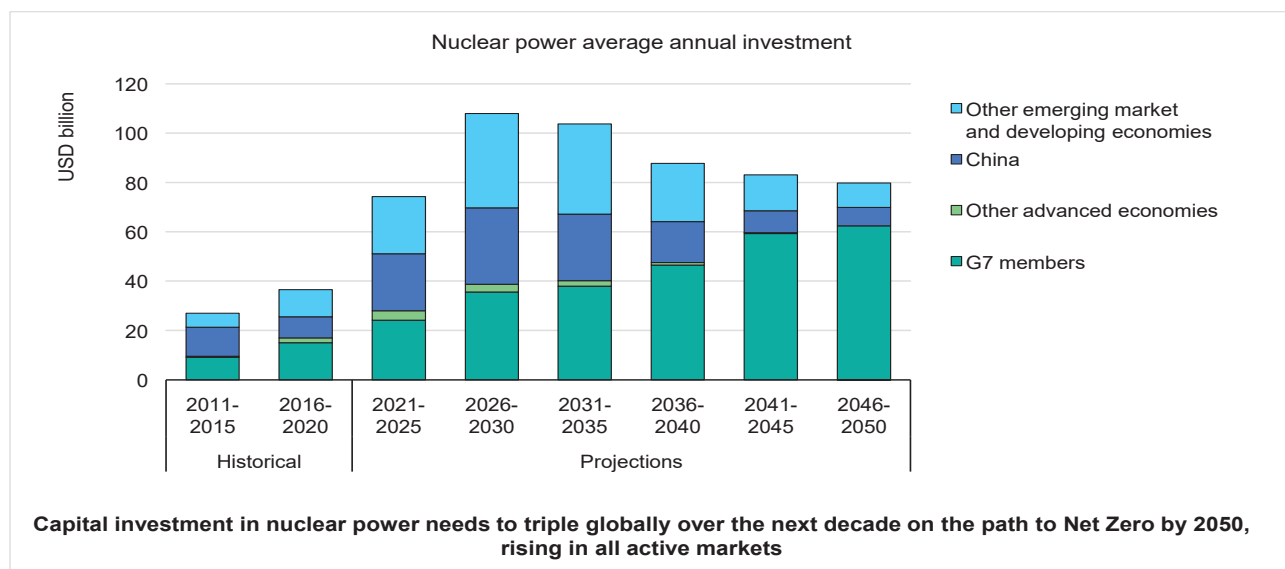
Nuclear capacity doubles to 2050 on the path to Net Zero



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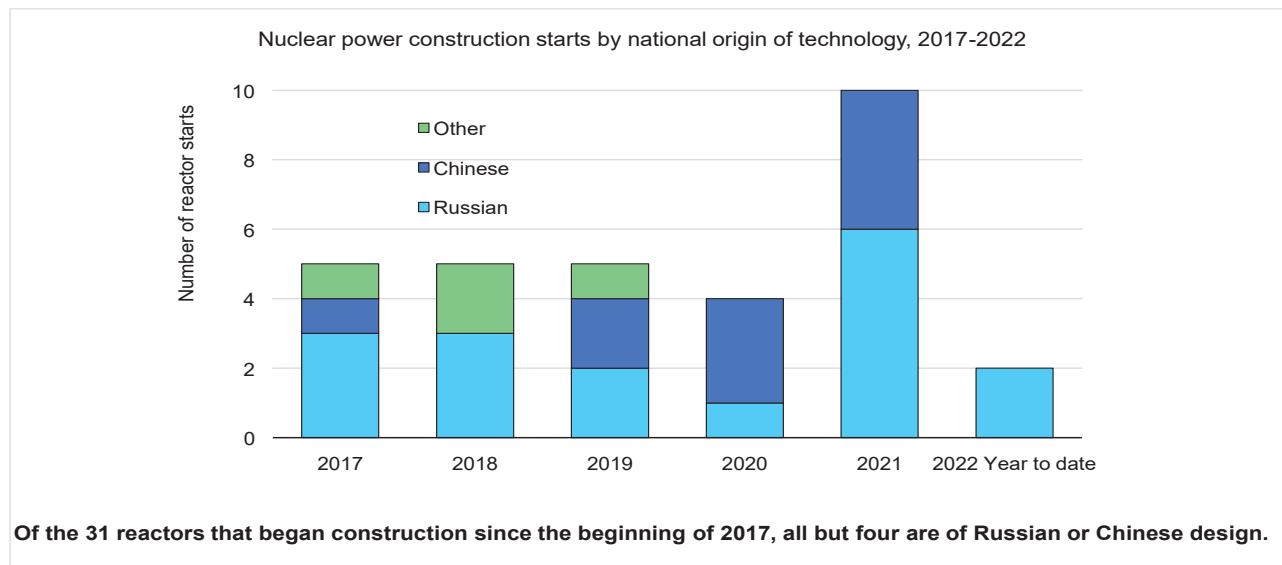
Investment in nuclear power must step up



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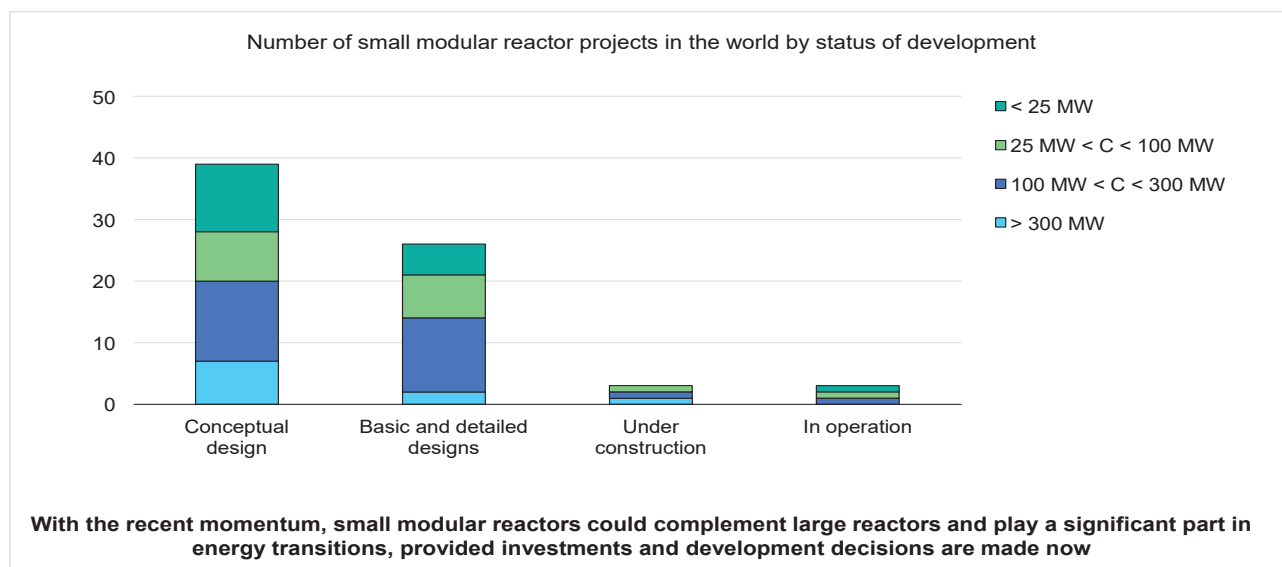
Nuclear market leadership shifting from advanced economies



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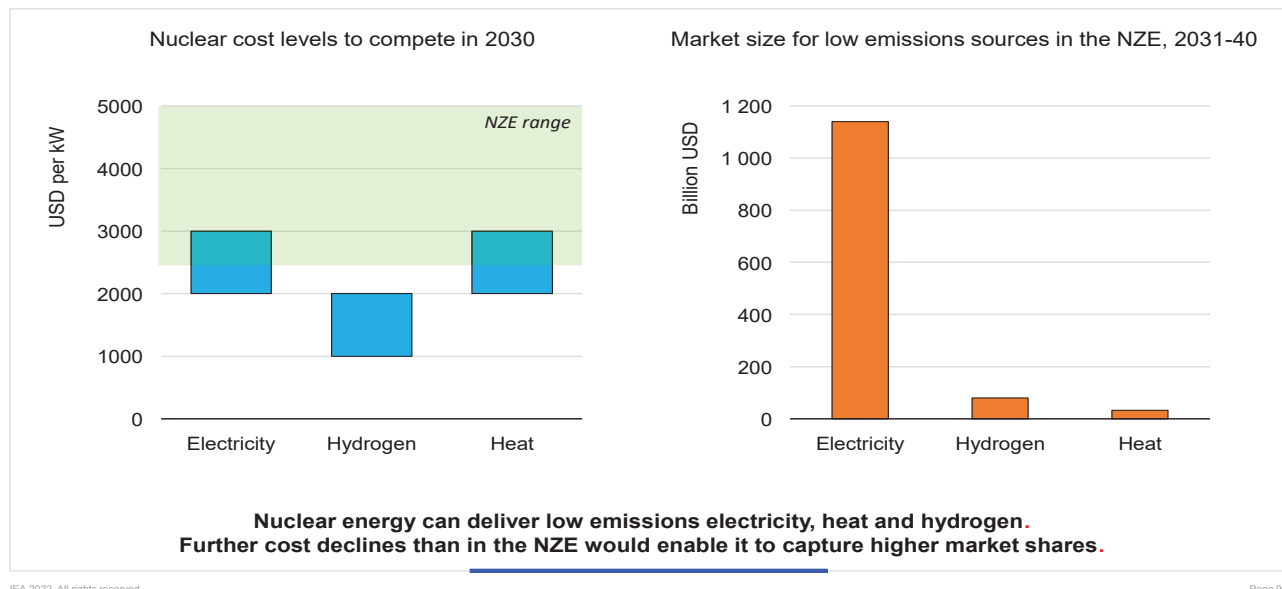
The net zero challenge has stimulated a burst of activity on SMRs



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Page 8

A larger role can open up with lower nuclear costs



Conclusions



- To fulfil the Paris Agreement, energy transitions must accelerate.
- In countries where it is accepted, nuclear energy could play an important role in ensuring rapid and secure energy transitions.
- Investments in nuclear must step up fast, both to extend operations at existing sites and to build new reactors.
- The nuclear industry has to deliver new projects on time and on budget.
- Net zero would require innovation in many areas. Small modular reactors are a promising technology.
- The IEA continues to support the security, affordability and sustainability of energy through an all fuels and all technologies approach.

WNISR2022+

World Nuclear Industry Status Report 2022+ (WNISR2022+) With particular emphasis on Small Modular Reactors (SMRs)

www.WorldNuclearReport.org

Mykle Schneider

Independent Energy and Nuclear Policy Analyst, Paris, France
WNISR Coordinator and Publisher

Audition Chambre des représentants de Belgique

Brussels, 20 June 2023

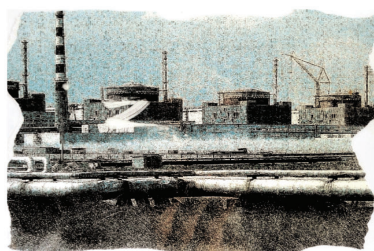
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WNISR2022+

International, Interdisciplinary Team for a Multi-Indicator Analysis

The World Nuclear Industry Status Report 2022



MacArthur Foundation | HENRIK BÖLL STIFTUNG | IWS | IAEA

World Nuclear Industry Status Report | 2022

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The World Nuclear Industry Status Report 2022

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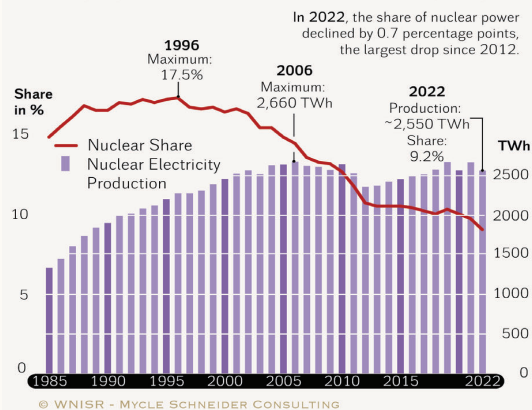
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WNISR2022+ GLOBAL OVERVIEW – ROLE OF NUCLEAR POWER (PROVISIONAL DATA)

Nuclear Electricity Production 1985–2022 in the World...

in TWh (net) and Share in Electricity Generation (gross)



...and in China and the Rest of the World in TWh (net)

In 2022, global generation decreased by 4% and dropped to the level of 2020. China increased output by 3%.



Sources: IAEA & EMBER, 2023; BP 2022

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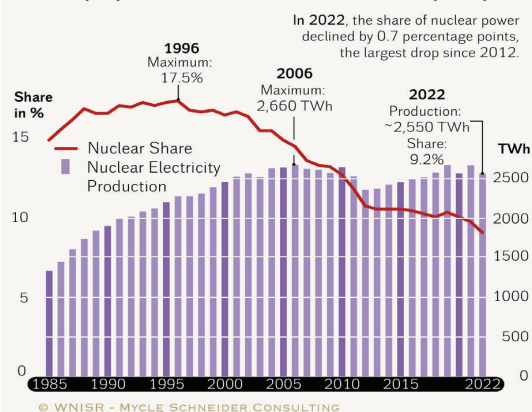
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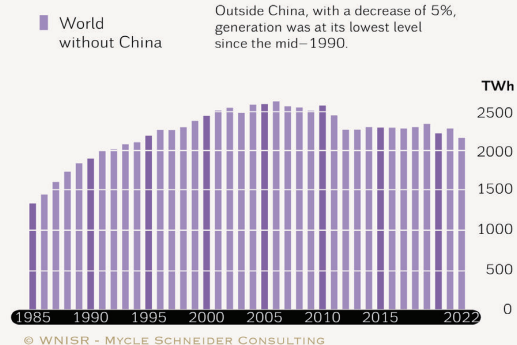
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...and in China and the Rest of the World in TWh (net)

In 2022, global generation decreased by 4% and dropped to the level of 2020. China increased output by 3%. Outside China, with a decrease of 5%, generation was at its lowest level since the mid-1990s.



Sources: IAEA & EMBER, 2023; BP 2022

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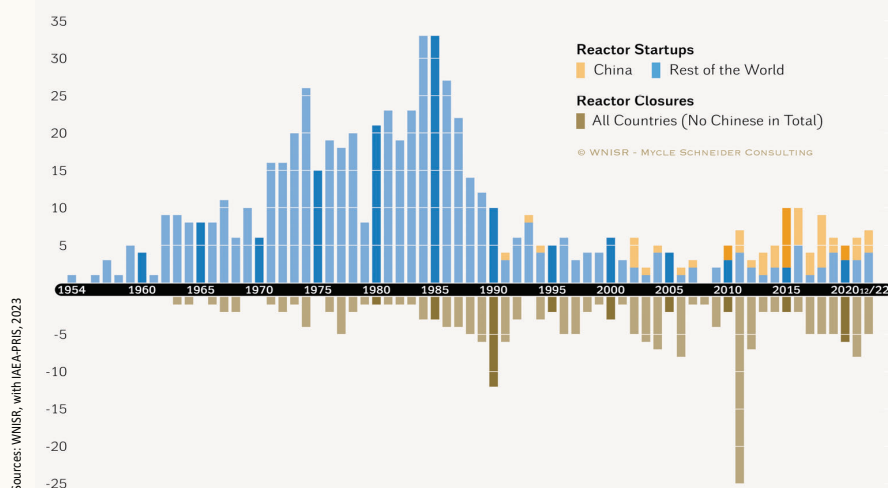
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WNISR2022+

GLOBAL OVERVIEW – STARTUPS AND CLOSURES WORLD AND CHINA

Reactor Startups and Closures in the World

in Units, from 1954 to 31 December 2022



2003–2022

World

- 99 Startups,
- 105 Closures

China

- 49 Startups
- No Closure

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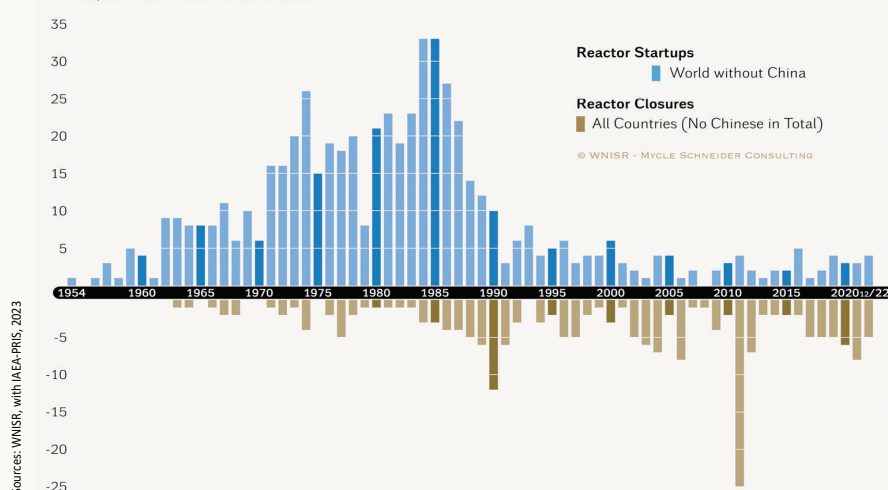
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GLOBAL OVERVIEW – STARTUPS AND CLOSURES WORLD AND CHINA

Reactor Startups and Closures in the World

in Units, from 1954 to 31 December 2022



2003–2022

World

- 99 Startups,
- 105 Closures

China

- 49 Startups
- No Closure

World Outside China

- 50 Startups
- 105 Closures

Net Balance -55

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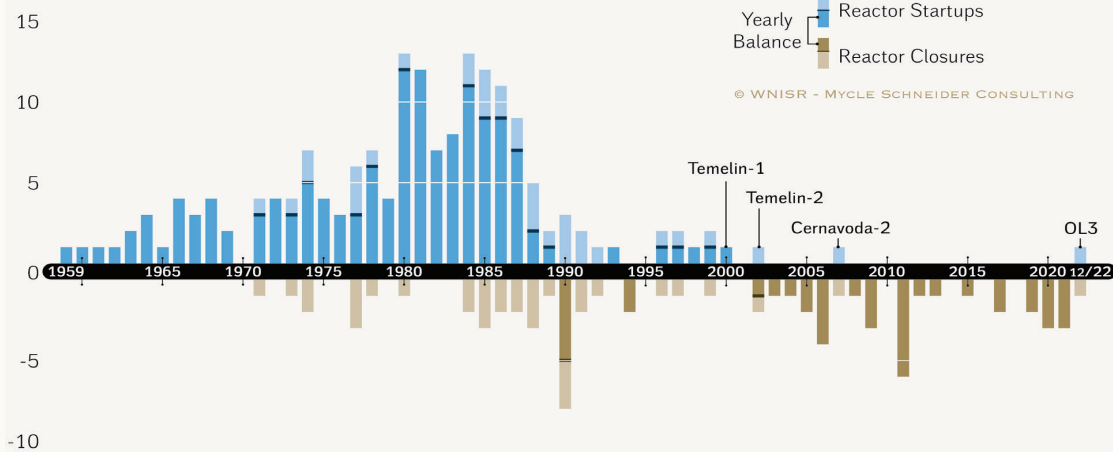
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WNISR2022+ EU27 – STARTUPS AND CLOSURES: ORGANIC, UNDECLARED PHASEOUT

Reactor Startups and Closures in the EU27

in Units, from 1959 to 1 January 2023



2003–2022

EU27

- 2 Startups,
- 33 Closures

Net Balance -31

Sources: WNISR, with IAEA-PRIS, 2023

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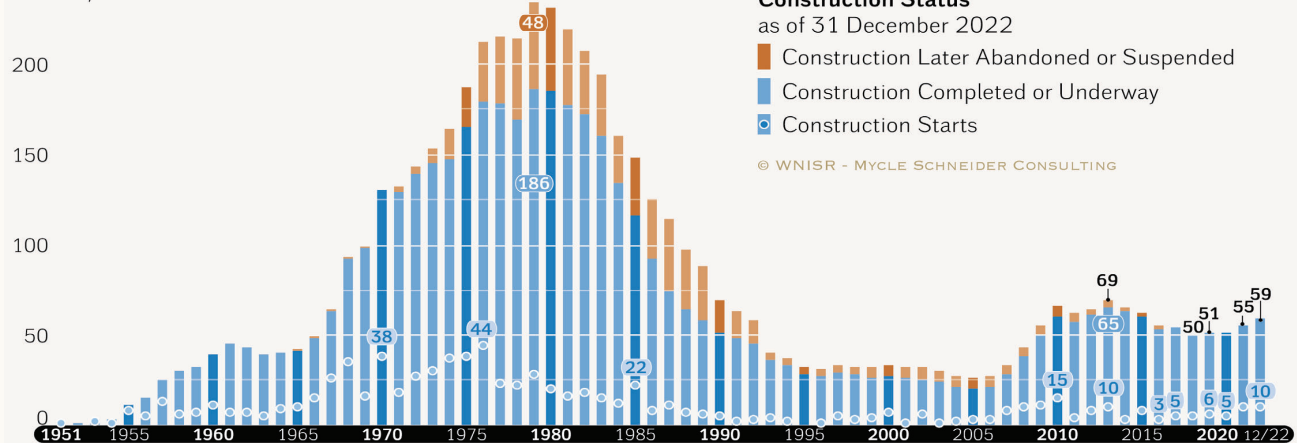
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WNISR2022+ GENERAL OVERVIEW — CONSTRUCTIONS

Reactors Under Construction in the World

in Units, from 1951 to 31 December 2022



Sources: WNISR, with IAEA-PRIS, 2023

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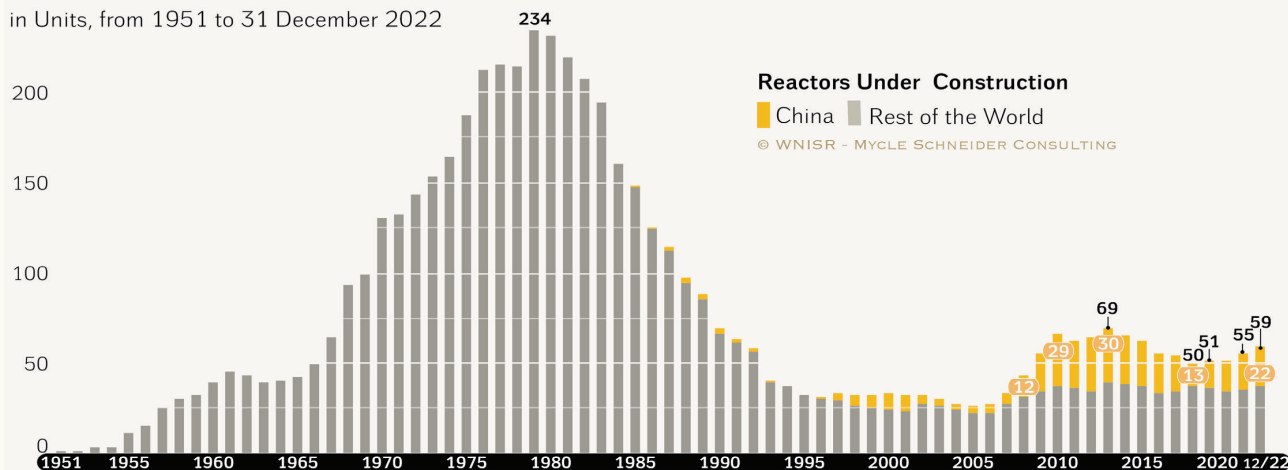
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WNISR2022+ GENERAL OVERVIEW — CONSTRUCTIONS

Reactors Under Construction in the World

in Units, from 1951 to 31 December 2022



Sources: WNISR, with IAEA-PRIS, 2023

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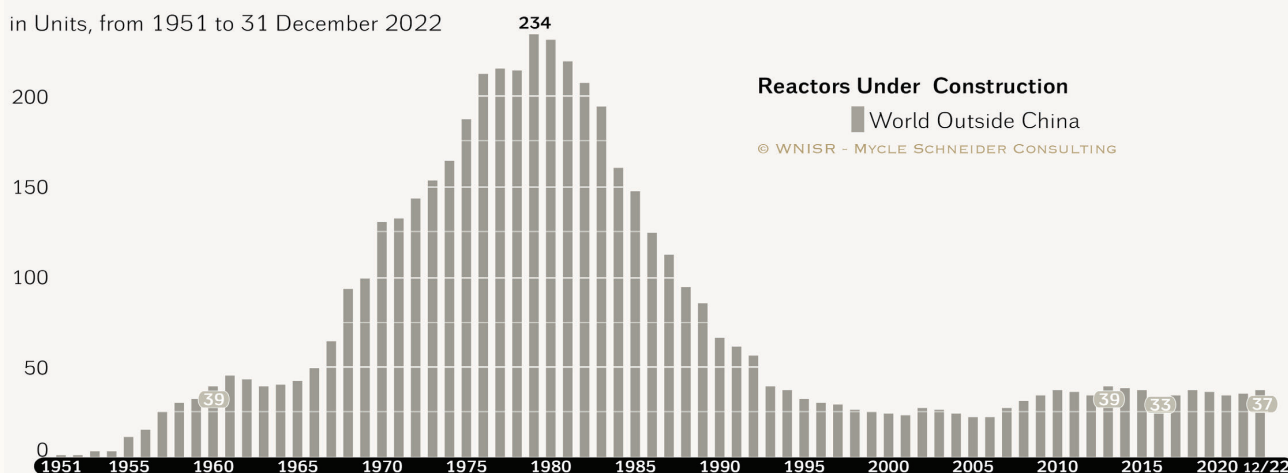
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WNISR2022+ GENERAL OVERVIEW — CONSTRUCTIONS

Reactors Under Construction in the World

in Units, from 1951 to 31 December 2022



Sources: WNISR, with IAEA-PRIS, 2023

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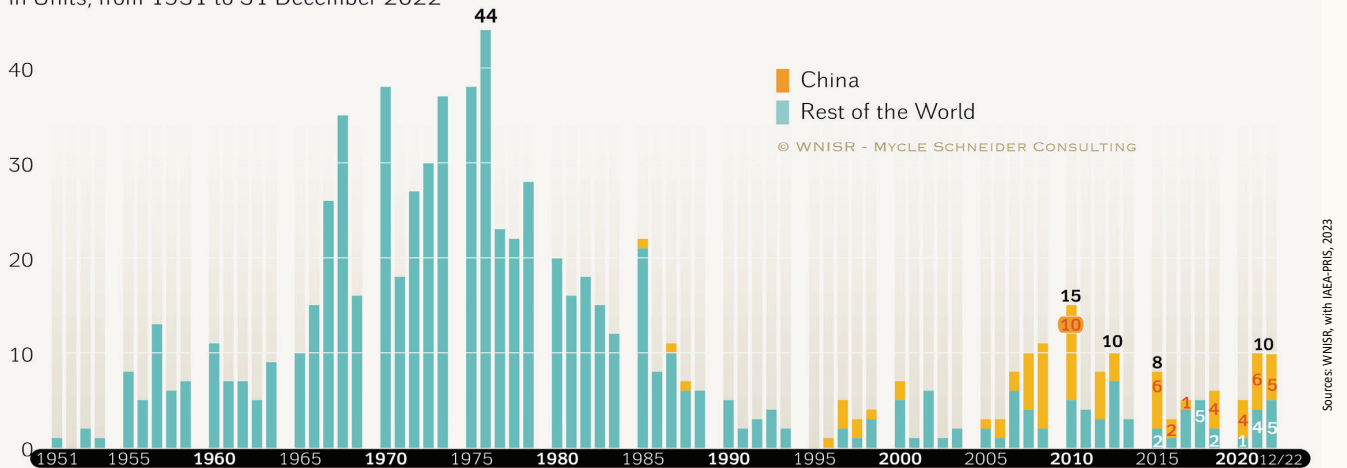
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WNISR2022+ GENERAL OVERVIEW — CONSTRUCTION STARTS WORLD OUTSIDE CHINA

Construction Starts of Nuclear Reactors in the World

in Units, from 1951 to 31 December 2022



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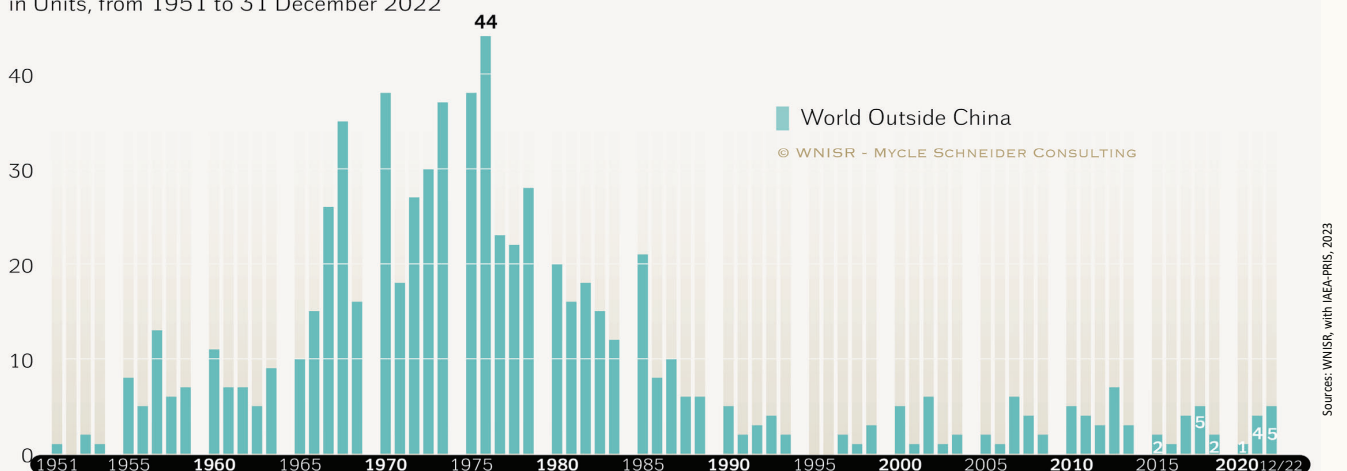
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WNISR2022+ GENERAL OVERVIEW — CONSTRUCTION STARTS WORLD OUTSIDE CHINA

Construction Starts of Nuclear Reactors in the World

in Units, from 1951 to 31 December 2022



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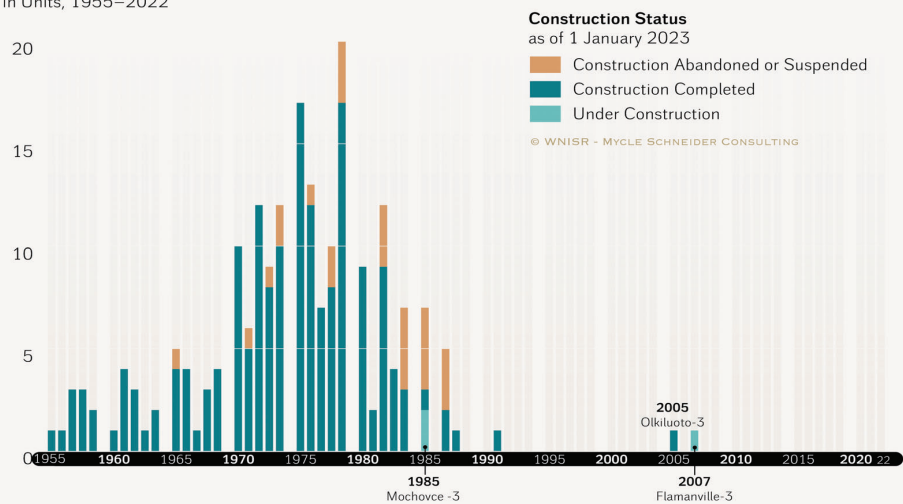
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WNISR2022+ EUROPEAN UNION (EU27) – CONSTRUCTIONS

Construction Starts of Nuclear Reactors in the EU27

in Units, 1955–2022



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WNISR2022+ SMRs – Miracle Solution to the Industry in Crisis?

Global SMR Status (provisional)

West

East

In Operation:	0	4 modules (Russia 2, China 2)
Under Construction:	1 (<i>Carem25, AR</i>)	4 modules* (Russia 2, China 1)
Certified Designs Marketed:	0	5 (Russia 3?, China 2?)
Certified Designs not Marketed:	1 (<i>NuScale 50 MW, US</i>)	1 (<i>SMART, South Korea</i>)
Design Certification Application Accepted:	0	?
Design Certification Application Submitted:	1 (<i>NuScale 77 MW, US</i>)	?
Pre-Licensing Design Reviews	9 in Canada, <i>Neward</i> in France, Finland, Czech Republic, <i>BWRX-300</i> in US, others?	?
Power Point Reactor Designs	Dozens	?

*Note: Construction started in China on behalf of Russia on a barge to carry two RITM-2005 modules, which was licensed *à posteriori*.

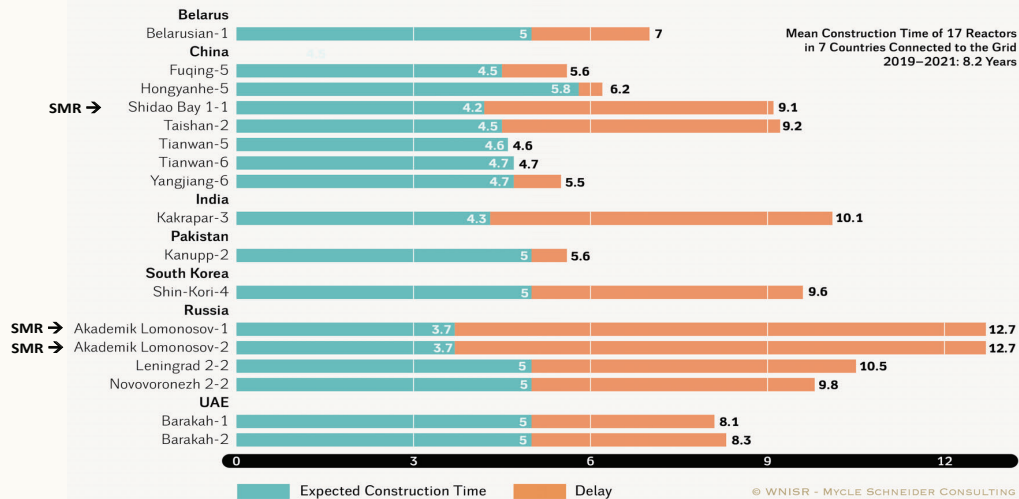
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WNISR2022+ Nuclear Construction Projects – Planning vs. Reality

Expected vs. Real Duration from Construction Start to Grid Connection for Startups 2019–2021
in Years



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WNISR2022+ Case Study EPR – 1987–2024, a 37-Year History of Delays

1987: MoU Framatome/Siemens-KWU on cooperation on development and commercialization of PWRs.

April 1989: Cooperation agreement between Framatome and Siemens, creation Nuclear Power International (NPI).

January 1992: First “Steering Committee” Meeting → project is renamed “European Pressurized Water Reactor” or EPR.

October 1997: transmission of first detailed “Basic Design Report” to the French and German Nuclear Safety Authorities.

NPI/PreussenElektra/EDF/1997 → first concrete: 1999 → commercial operation “could take place around the year 2005”.

May 2002: ratification by Finnish Parliament of construction of a new reactor.

In 2004, Framatome ANP states: “Construction time from pouring of the first concrete not exceeding **48-months**. (...)”

“In France, the **EPR design is obviously meant to replace the current fleet in the 10 years to come.**”

June 2005: French Parliament approves the Energy Planning Law including the construction of an EPR.

August 2005: Construction start OL3 → startup planned for early 2009.

December 2007: Construction start FL3 → startup planned for 2012.

2016: AREVA goes bankrupt and is broken up.

June 2018: Grid connection Taishan-1, with a **5-year delay** since construction start.

June 2019: Grid connection Taishan-2, with a **5-year delay** since construction start.

March 2022: Grid connection OL3 with a **13-year delay** since construction start.

2024: Grid connection FL3 with a **12-year delay** since construction start?

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WNISR2022+ Case Study AP1000 – 1986–2023, a 37-Year History of Delays

According to the US-NRC, “the AP1000 retains the AP600 licensing” as it is “based closely on the AP600 design”, which was under development since 1986, was certified in January 2000, but never found a customer.

- June 2000: start of AP1000 **Pre-Application Review**.
- March 2002: design application with US-NRC.
- January 2006: design certification by US-NRC.

Summer 2006: Westinghouse claims that “by using modular construction methods, Westinghouse and its project partners will be able to build the AP1000 in 36 months”.

- April 2009–June 2010: construction starts at Haiyang-1 and -2, and at Sanmen-1 and -2, China.
- March–November 2013: construction starts at V.C. Summer-2 and -3, and at Vogtle-3 and -4, USA.

July 2014: Westinghouse still claims “The AP1000 design saves money and time with an accelerated construction time period of approximately 36 months, from the pouring of first concrete to the loading of fuel.”

- March 2016: Westinghouse goes bankrupt and is taken over by a Canadian holding.
- July 2017: Construction at V.C. Summer-2 and -3 abandoned after spending >US\$9 billion and nine rate increases.
- June–October 2018: Grid connection of Haiyang-1 and -2, and at Sanmen-1 and -2, China, with **4–5-year delays**.

August 2021: Former Westinghouse Senior Vice-President, who had been leading “efforts to meet existing new plant customer needs and further develop new plant opportunities”, was charged “in a federal indictment with sixteen felony counts including conspiracy, wire fraud, securities fraud, and causing a publicly-traded company to keep a false record.”

- April 2023: Grid connection of Vogtle-3 with a **7-year delay** since construction start.
- End of 2023: Grid connection of Vogtle-4 with a **7-year delay** since construction start?

WNISR2022+ Case Study NuScale 2000–2023, a 23-Year History of Delays

- 2000–2003: NuScale design originally developed under US-DOE funded program with co-sponsors.
- June 2007: NuScale Power Inc. formed.
- 2008: start of **pre-application design reviews** with US-NRC.

Design certification expected in 2010, grid connection in 2015–2016.

- March 2011 (one week prior to the Fukushima disaster): NuScale claims that “Nuscale Changed the Game” as it “was the first to offer the market a commercially viable modular, scalable nuclear power design”.
- 2015: launch of the “Carbon Free Power Project” with Utah Associated Municipal Power Systems (UAMPS).
- December 2016: NuScale submits a “Standard Plant Design Certification Application” to US-NRC.
- September 2020: US-NRC grants a conditional “Standard Design Approval” (SDA) based on a 12 x 50 MW plant.
- January 2023: NuScale submits a modified design application to the US-NRC based on a 6 x 77 MW plant.

Construction start scheduled for 2026, operation 1st module in December 2029, all modules in service November 2030, a **14-year delay** prior to construction start.

- March 2023: US-NRC refuses to docket the new NuScale application arguing that “there are now many areas where the level of detail in the SDA application is not sufficient to provide the bases for NuScale’s stated conclusions”.
- May 2023: Subscriptions (entitlement shares) stand at only one quarter of the nameplate capacity of 462 MW.

WNISR2022+ SMRs – High Costs of Construction

Diseconomies of Scale

Design	Cost Estimate (US\$/kW)
CAREM (Argentina)	US\$17,000/kW
Micro Modular Reactor (Canada)	US\$15,000–30,000/kW
ACP 100 (China) & HTR-PM	US\$6,000/kW (twice estimate for Hualong-One)
SMART (South Korea)	US\$10,000/kW (never sold)
NuScale (6x77 MWe, USA)	US\$20,000/kW (twice estimate for Flamanville-3)

Sources: Various, compiled by M.V. Ramana/Mycle Schneider

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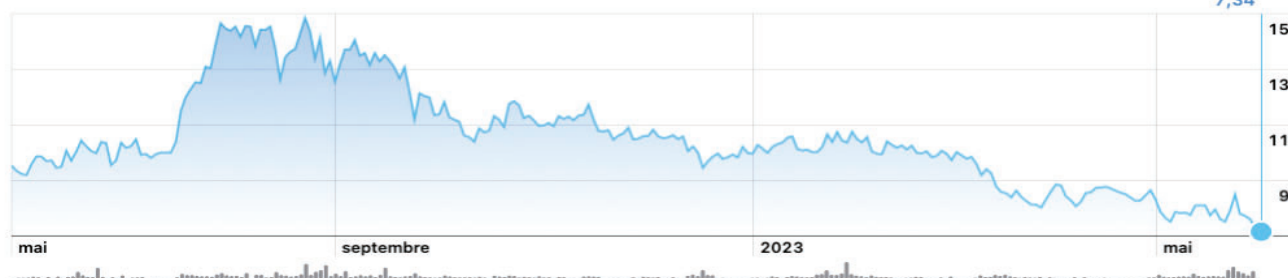
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WNISR2022+ SMRs – Investor Confidence Fading Quickly – NuScale Loses Half of Stock Value

SMR NuScale Power Corporation
NYSE · USD

7,34 -2,13 %

31 mai 2023



Ouverture	7,50	Vol.	372,3 k	Max./52s	15,85	Rendement	–
Max.	7,58	PER	–	Min./52s	7,31	Bêta	0,88
Min.	7,31	Cap. bours.	517,0 M	Vol. moyen	683,1 k	BPA	-0,51

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WNISR2022+ SMR LICENSING IN BELGIUM? – NO ACTIVITY IN BELGIUM



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WNISR2022+ CONCLUSIONS

- The global nuclear industry has been on a downward trend for decades. The current building rate is insufficient to make up for closures and thus to guarantee its survival. There are no signs of any change.
- All 28 reactor construction-starts between January 2020 and June 2023 were either in China (17) or implemented by Russia (11) in various countries.
- Past SMR projects have failed to keep their promises. They are difficult—thus long—to build, extremely expensive, and the few (four modules) that were completed in China and Russia underperform on the grid.
- NuScale, the most advanced development in the west, is years behind schedule, and
 - the US Regulator has refused to docket the modified design certification application due to lacking documentation;
 - the cost estimate is now at US\$9.3 billion for a 6-module plant, US\$20,000/kW, at least twice the estimated cost of European EPRs;
 - investors loose confidence as NuScale shares loose half of their value over the past year.
- Many SMR designs under development are in formal or informal pre-licensing talks with regulators. Compared to the EPR timeline, that corresponds to the status in the mid-1990s with the first unit coming online in the EU in 2022.
- There is no evidence that the current SMR promoters will do any better than previous reactor developers and builders.
- The Belgian Regulator FANC/AFCN has no documented activities on SMRs, nor does it cover the issue on its website.
- The increasingly widening gap between perception by the public and decision-makers and industrial reality of the nuclear sector is worrying, since, as a result, focus, human and financial resources are diverted from essential, available options.

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BRUSSELS, 20 JUNE 2023

WNISR2022+ Mycle Schneider, Paris mycle@worldnuclearreport.fr - www.WorldNuclearReport.org



Mycle Schneider works as independent international consultant on energy and nuclear policy. He is the initiator, coordinator and publisher of the [World Nuclear Industry Status Reports](http://www.WorldNuclearReport.org). He is a Founding Board Member and the Spokesperson for the International Energy Advisory Council ([IEAC](http://www.IEAC.org)). He is a Founding Member of the International Nuclear Risk Assessment Group (INRAG) and a member of the International Nuclear Security Forum ([INSF](http://www.INSF.org)), based at the Stimson Center, USA. He is a member of the International Panel on Fissile Materials (IPFM), based at Princeton University, USA. Between 2004 and 2009, he has been in charge of the Environment and Energy Strategies Lecture of the International Master of Science for Project Management for Environmental and Energy Engineering at the *Ecole des Mines* in Nantes, France.

From 2000 to 2010, he was an occasional advisor to the German Environment Ministry. 1998–2003, he was an advisor to the French Environment Minister's Office and to the Belgian Minister for Energy and Sustainable Development. Mycle Schneider has given evidence or held briefings at national Parliaments in 16 countries and at the European Parliament. He has advised Members of the European Parliament from four different groups over the past 30+ years. He has given lectures or had teaching appointments at over 20 universities and engineering schools in 10+ countries.

WNISR2022+ ANNEX-1/1

APRIL 2023



With support from  Roland Berger

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ANNEX-1/2

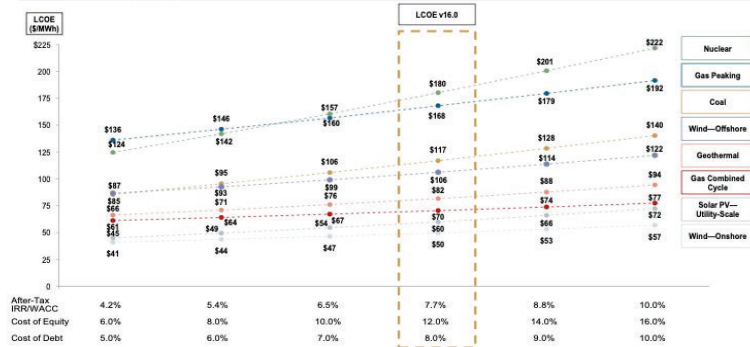
LCOE

LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 16.0

Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital

A key consideration in determining the LCOE values for utility-scale generation technologies is the cost, and availability, of capital⁽¹⁾; this dynamic is particularly significant for renewable energy generation technologies

Midpoint of Unsubsidized LCOE⁽²⁾



LAZARD

Source: Lazard and Robert Deger estimates and publicly available information.
 (1) Financing costs reflect the additional capacity needed to supplement the net capacity of the renewable resource (intermittent capacity) ("ELCC") and the net cost of new entry (cost "COE") of a new firm resource (capital and operating costs, less expected market revenues). Net COE is assumed and published by grid operators for each regional market. Grid operators use a natural gas CT as the assumed new resource in MISO, PJM, NYISO, and SPP. In CAISO, the assumed new resource is a 4-hour lithium-ion battery storage system (\$15-\$20/MWh). For the PV + Storage cases in CAISO and PJM, assumed storage configuration is 10% of PV MW and 4-hour duration.
 (2) ELCC is an indicator of the reliability contribution of different resources to the electricity grid. The ELCC of a generation resource is based on its contribution to meeting peak electricity demand. For example, a 1 MW wind resource with a 1% ELCC provides 10 MW of capacity contribution and would need to be supplemented with 1 MW of additional firm capacity in order to represent the addition of 1 MW of firm system capacity.
 (3) LCOE values represent the midpoint of Lazard's LCOE v16.0 cost ranges for each technology adjusted for a regional capacity factor to demonstrate the regional differences in both input and firming costs.
 (4) For PV + Storage cases, the effective ELCC value is represented. CAISO and PJM assess ELCC values separately for the PV and storage components of a system. Storage ELCC value is provided only for the capacity that can be charged directly by the accompanying resource up to the energy required for a 4-hour discharge during peak load. Any capacity available in excess of the 4-hour maximum discharge is attributed to the system at the same ELCC. ELCC values for storage range from 90%–95% for CAISO and PJM.
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ANNEX-1/3

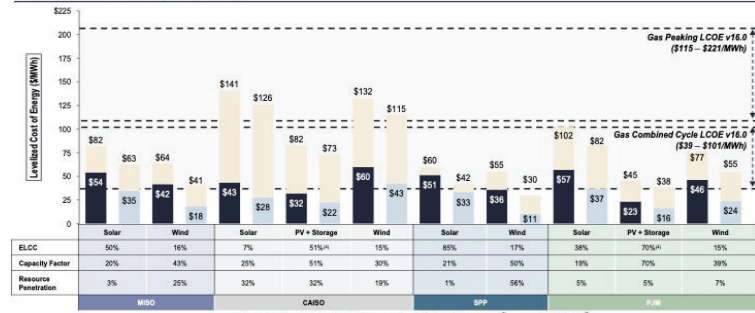
LCOE

LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 16.0

Levelized Cost of Energy Comparison—Cost of Firming Intermittency

The incremental cost to firm⁽¹⁾ intermittent resources varies regionally, depending on the current effective load carrying capability ("ELCC")⁽²⁾ values and the current cost of adding new firming resources—carbon pricing, not considered below, would have an impact on this analysis

LCOE v16.0 Levelized Firming Cost (\$/MWh)⁽³⁾



LAZARD

Source: Lazard and Robert Deger estimates and publicly available information.
 (1) Firming costs reflect the additional capacity needed to supplement the net capacity of the renewable resource (intermittent capacity) ("ELCC") and the net cost of new entry (cost "COE") of a new firm resource (capital and operating costs, less expected market revenues). Net COE is assumed and published by grid operators for each regional market. Grid operators use a natural gas CT as the assumed new resource in MISO, PJM, NYISO, and SPP. In CAISO, the assumed new resource is a 4-hour lithium-ion battery storage system (\$15-\$20/MWh). For the PV + Storage cases in CAISO and PJM, assumed storage configuration is 10% of PV MW and 4-hour duration.
 (2) ELCC is an indicator of the reliability contribution of different resources to the electricity grid. The ELCC of a generation resource is based on its contribution to meeting peak electricity demand. For example, a 1 MW wind resource with a 1% ELCC provides 10 MW of capacity contribution and would need to be supplemented with 1 MW of additional firm capacity in order to represent the addition of 1 MW of firm system capacity.
 (3) LCOE values represent the midpoint of Lazard's LCOE v16.0 cost ranges for each technology adjusted for a regional capacity factor to demonstrate the regional differences in both input and firming costs.
 (4) For PV + Storage cases, the effective ELCC value is represented. CAISO and PJM assess ELCC values separately for the PV and storage components of a system. Storage ELCC value is provided only for the capacity that can be charged directly by the accompanying resource up to the energy required for a 4-hour discharge during peak load. Any capacity available in excess of the 4-hour maximum discharge is attributed to the system at the same ELCC. ELCC values for storage range from 90%–95% for CAISO and PJM.
 This study has been prepared by Lazard for general informational purposes only, and it is not intended to be, and should not be construed as, financial or other advice. No part of this material may be copied, photocopied or duplicated in any form by any means or redistributed without the prior consent of Lazard.

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MYCLE SCHNEIDER CONSULTING

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BRUSSELS, 20 JUNE 2023



RETHINKING NUCLEAR

20 June 2023
Navid Samandari, CEO & co-founder

SeaSalt in a nutshell



Founded in 2014	HQ in Copenhagen , Denmark
Privately held and privately funded	Business offices in South Korea & Singapore
120+ employees 26 nationalities 30+ Ph.D.s in nuclear, chemistry and materials	Developing a 4 th generation safe and affordable nuclear solution called the CMSR Power Barge First deployment before 2030



We will only reach our goals for **decarbonisation** if the alternative is **cheap** enough and scales **fast**.

VISION

Transform energy markets and **out-compete fossil fuels** to create a bright future with abundant clean energy for everyone.

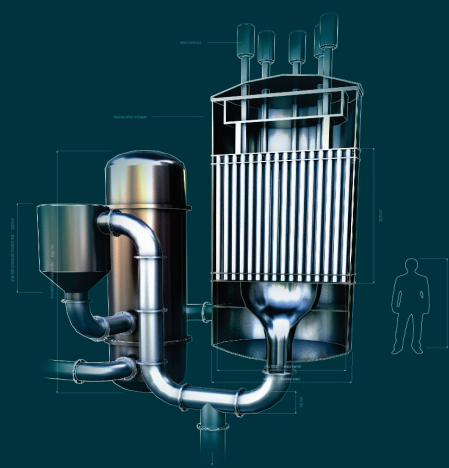
UNPRECEDENTED OPPORTUNITY

Executing a rapid **world-wide deployment** of the Compact Molten Salt Reactor via **shipyard serial production** of Power Barges.



Seaborg's Unique Offering

- 1** **Proprietary Technology** – The CMSR cannot melt down or explode
- 2** **Shipyard** construction & Modular fabrication ensures economical attractiveness
- 3** **Licensing Approach** allows for fast international deployment
- 4** **Co-development and project financing** with Seaborg's participation throughout the project

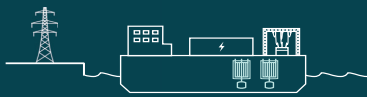


SEABORG

The CMSR Power Barge Life Cycle

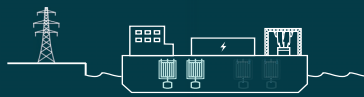
1

Two CMSRs for the
first 12-year fuel cycle
Commissioned and
tested **in shipyard**



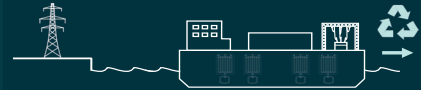
2

Two CMSRs for the
second 12-year fuel cycle
Commissioned and
tested **on-site**



3

Green site recovery
Decommissioning
at **central facility**



SEABORG

Commercial Consortium Agreement in place with key partners in the industry



Nuclear energy technology
company developing a safe
nuclear compact molten salt
reactor to be deployed on
power barges on a global
scale



SAMSUNG HEAVY INDUSTRIES

One of the **Big Three Shipbuilders**
in the world.
SHI has 48 years of experiences in
engineering, manufacturing,
commissioning for vessels,
including floating power plants.



**Worlds 3rd largest
nuclear power operator**
(≈25 NPPs¹ worldwide).
Responsible for 32.6% of
South Korea's electric
power supply.

Note: 1) Nuclear Power Plant

SEABORG

Conventional Nuclear and Molten Salt Reactors

Conventional Nuclear: Light Water Reactors (LWRs)



Fuel:
Uranium Pellets



Reactor core:
Solid fuel rods



Cooling:
Water

LWR features

- High pressure
- Gaseous fission products contained
- Many and complex safety systems
- Economic at large scale

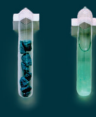
Molten Salt Reactors (MSRs)



Fuel:
Fluoride salt with
uranium



Reactor core:
Molten salt loops

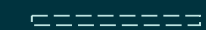


Cooling:
Molten Salt

MSR features

- Low pressure
- Fission products chemically bound
- Fewer safety systems due to inherent safety characteristics
- Economic at much smaller scale

SEABORG



Site footprint/
exclusion zone

100 m



Emergency
planning zone

750 m



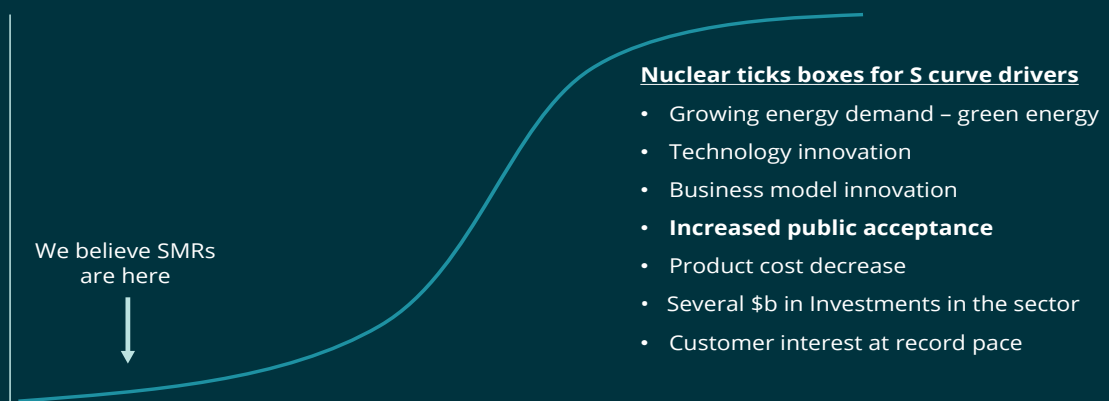
SMR Projects in EU



SEABORG

Starting a nuclear S curve

Seaborg does not believe nuclear has hit the S-curve – yet!



SEABORG



Seasalt Group

Covering two cornerstones of the energy spectrum



4th generation **nuclear energy** technology company developing an inherently safe nuclear Compact Molten Salt Reactor to be deployed on barges on a global scale.

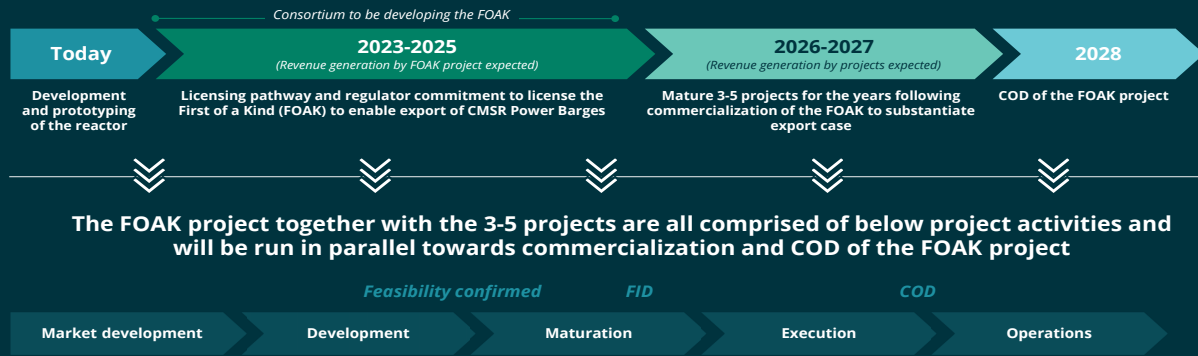


Energy storage technology company set to deploy hydroxide salts as an inexpensive, grid scale energy storage system to complement renewable energy production, enabled by Seaborg's patented chemistry control technology.

Significant synergy potential between the two entities in relation to molten salt research and innovation, IP co-operation and commercial opportunities

SEABORG

Seaborg targets commercialization of first-of-a-kind project in 2028



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