IAEA
International Atomic Energy Agency

Technical Working Group on Nuclear Fuel Cycle Options

Back End of the Fuel Cycle Considerations for Small Modular Reactors

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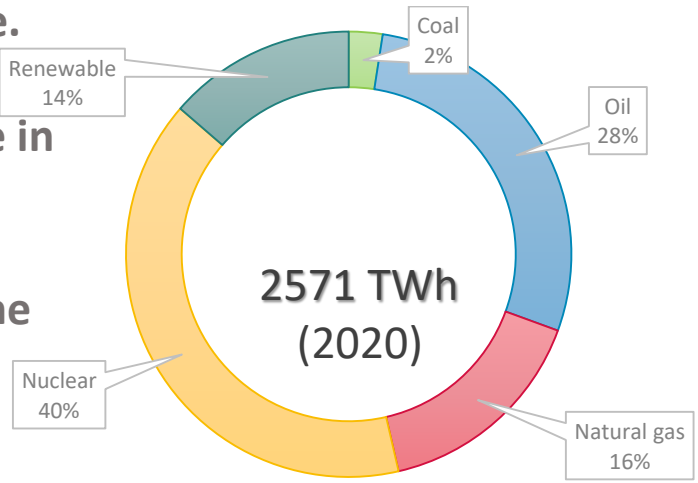
France and the Energy transition

- To reach carbon neutrality by 2050 in order to limit global warming, an energy transition has been initiated in France.
- Renewable and nuclear energies can play a significant role in a context of electrification of many uses.
- Producing carbon-free electricity is the direction for the the future energy mix while gradually reducing the fossil fuels use and very quickly the coal.
- Diversification of nuclear uses: heat, cogeneration, hydrogen production, etc.
- Nuclear energy developpment requires construction sites, financial commitments of several billion euros, societal approval and are therefore complex projects to bring out.
- Therefore, small nuclear reactors, which require lower financial commitments, with shorter construction times and with greater simplicity to operate should be part of the French energy strategy



Primary energies consumption in France (2020)
Source : www.statistiques.developpement-durable.gouv.fr/

Evolution of the French nuclear panorama

- Nuclear power is an essential tool in the race against global warming. In this fight, electricity must weigh from 20 to 40% to reduce carbon emissions.

- The French President E.Macron announces the construction of six to fourteen EPRs (6+8), life extension of the existing fleet (if possible) and support for modular reactor projects (ie. SMR).

- "France 2030" is a strategic investment plan to meet the great challenges of our time, in particular the green transition, to bring out the technological champions of tomorrow and support the transitions of our French sectors of excellence: energy, automotive, aeronautics or space.

- The first of the 10 objectives of this plan is to "bring about the emergence in France of small, innovative nuclear reactors with better waste management". EUR 1 billion will be invested by 2030 to achieve this goal.

France 2030

- **In the frame of France 2030, 500 MEur are dedicated to the development of the French SMR – Nuward**

- **Additionally, 500 MEur for call for proposals will feed new reactor concepts in the field of fission and fusion.**

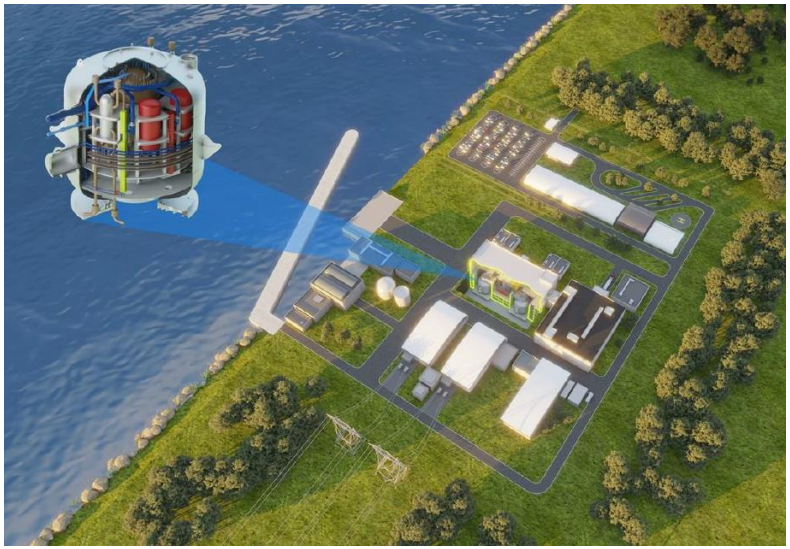
- **These reactors should promote breakthrough innovations in order to :**

  - Combine production of electricity with heat or hydrogen,
  - Promote the closing of the cycle nuclear fuel and improvement of the management of radioactive waste, by reducing its volume or activity
  - Improve the competitiveness of the energy produced, nuclear safety and security.

- **And the President Macron recalled that “always improving safety while reducing costs” remained a priority.**

NUWARD, the French SMR

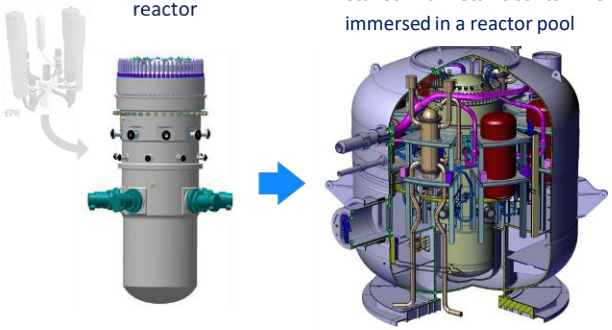
NUWARD™: safety as priority and competitive by design



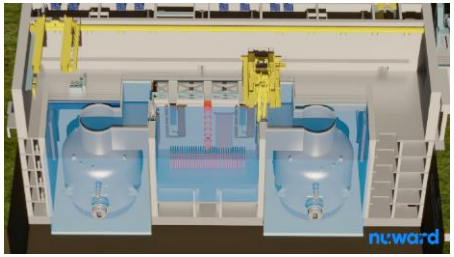
- A nominal power of **340 MWe** (2×170 MWe)
- GEN3+ meeting **post Fukushima** requirements
- International standard design to meet the requirements of multiple **safety** authorities.
- Modular & standardised design, for in-factory assembly and testing and **reduced time for construction on site**
- Outstanding **load-following** capability
- **Passive Design,** no countermeasures beyond the site boundary (EPZ at site boundary)
- **Landscape integration** and low environmental impact

An integrated reactor

… installed in a metallic containment immersed in a reactor pool



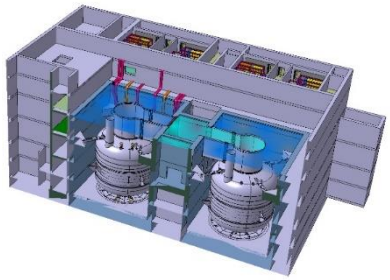
2 reactors (2 x 170MWe)
in the same Nuclear Building with shared equipment

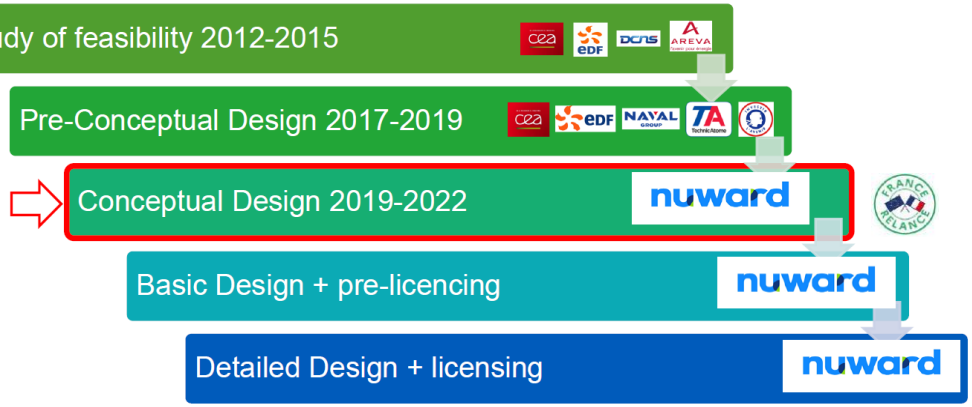


Source : NUWARD™

NUWARD, the French SMR

❖ **NUWARD™ a 340 MWe Pressurized Water SMR plant with 2 reactors (2x170 MWe)**





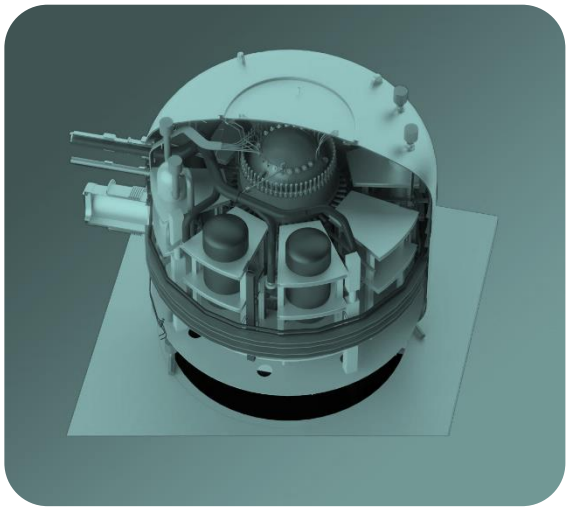
- **September 2020: 50M€ budget** has been allocated to NUWARD™ as part of the **French Recovery Plan**,
- **October 2021:** French President Macron announced an investment of **one billion euros in nuclear energy in the "France 2030" plan**, to "develop innovative small-scale nuclear reactors in France by 2030 with better waste management".
- **February 2022:** French President Macron announced grating of **€500 million for NUWARD™ as part of the €1 billion call for projects supported by France 2030**. This will support the whole design development phase (including innovation, testing and full licensing of the plant) until 2030. The **French President also announced that construction of a reference plant in France will be launched by 2030**.

NUWARD, the French SMR

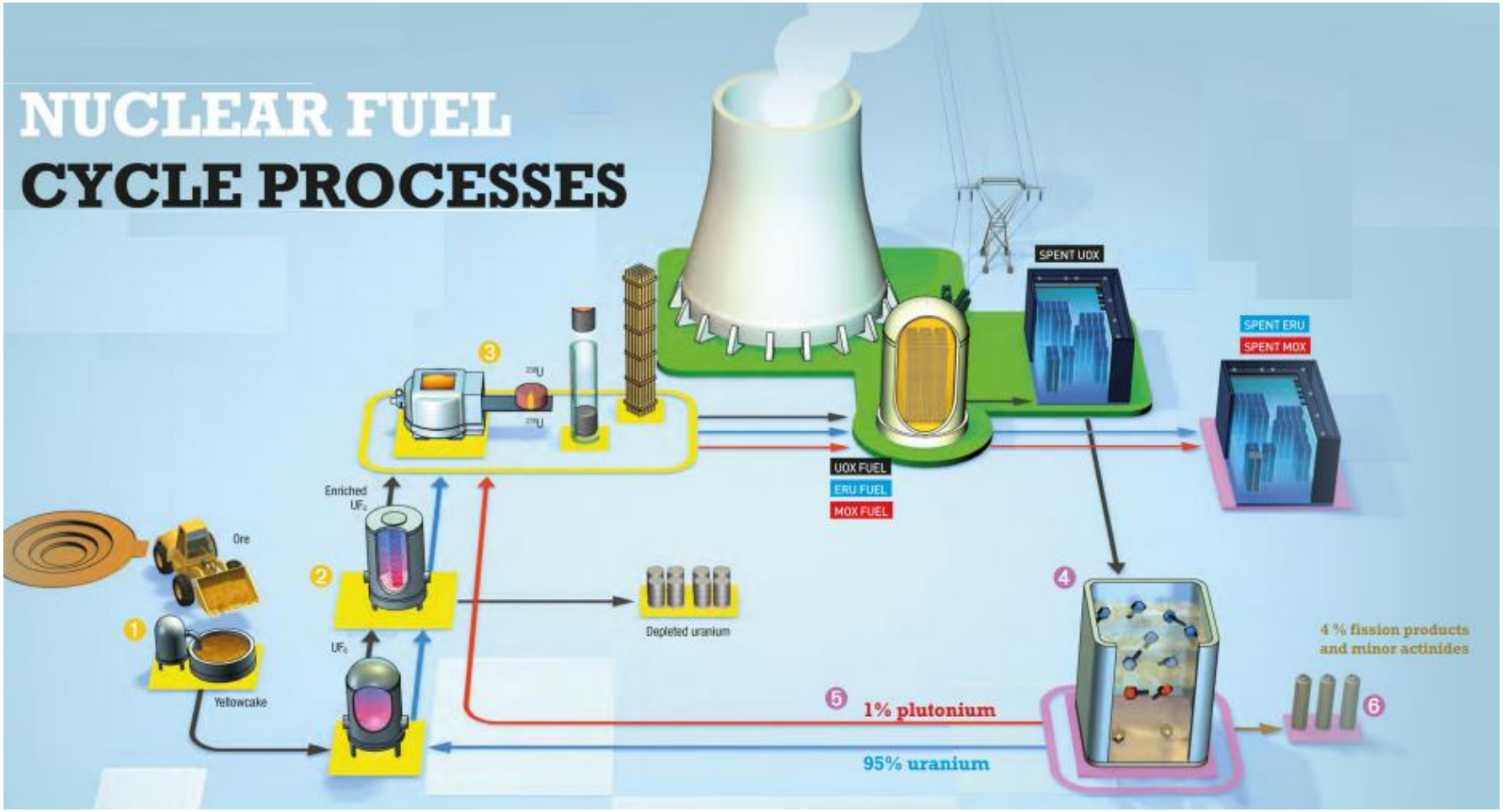
- In collaboration with the Finnish and Czech safety authorities, ASN (French nuclear authority) is undertaking a first of a kind joint preliminary review of the NUWARD™ reactor project :

- On June 10, 2022, the French (ASN), Finnish (STUK) and Czech (SUJB) safety authorities began, with their respective technical support, the preliminary examination of the main safety options for the small modular reactor project NUWARD™ powered by EDF.

AUTORITÉ DE SÛRETÉ NUCLÉAIRE



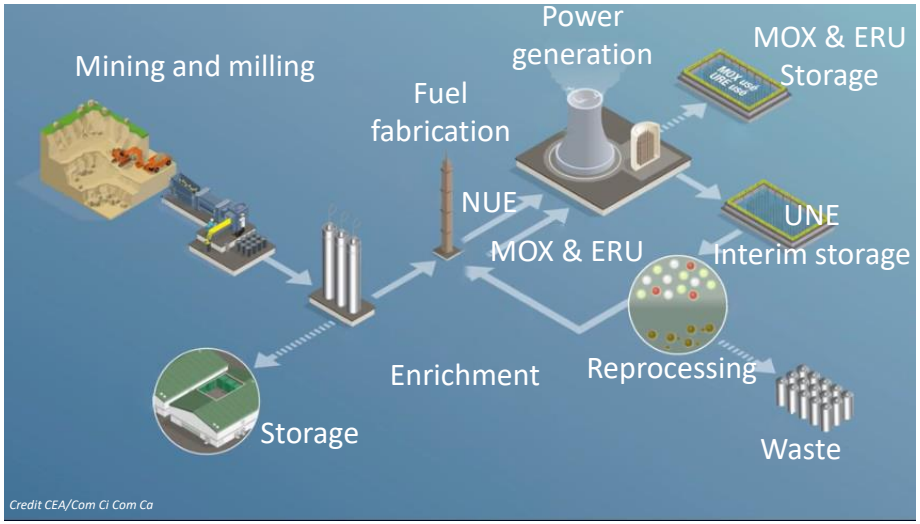
An industrial and consolidated fuel cycle for the recycling of oxide spent fuels



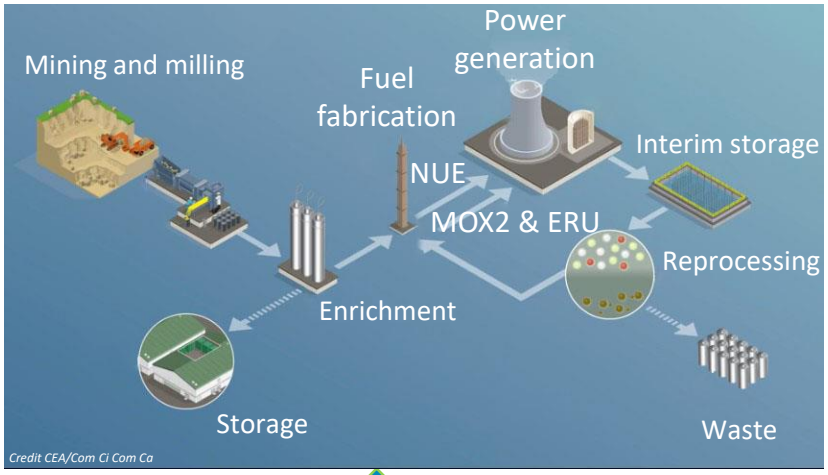
- Over 38000tHM of fuel were reprocessed at LH platform at the end of 2021
- ~2900tHM tons of fresh Mox fuel manufactured at Melox at the end of 2020

Possible evolutions of the nuclear cycle

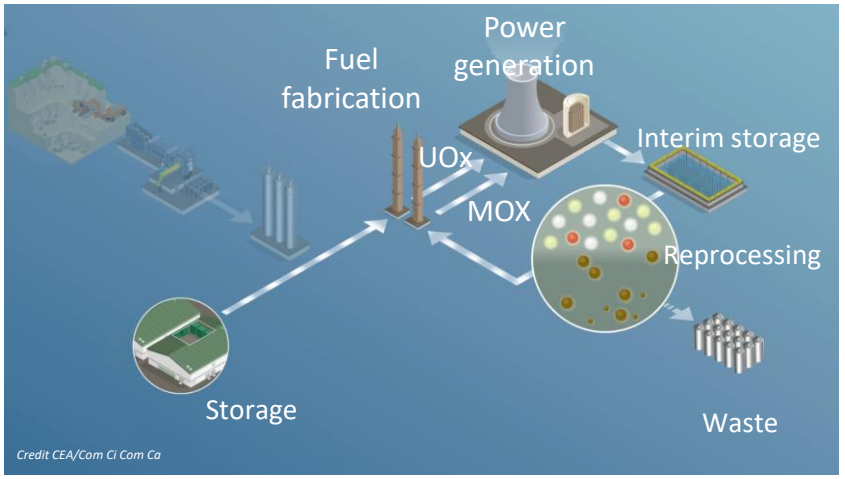
▶ **Mono recycling**



▶ **MOX multi recycling option (100%)**

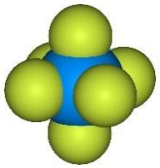


Intermediate configuration



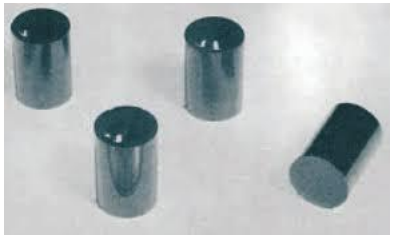
▶ **Fast reactors option (100%)**

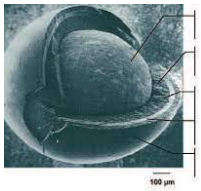
Examples of evolution and adaptions that could be required for a SMR cycle



Standard enrichment ☑
HALEU ☐

Oxide ☑
Nitrate ☑
Halide ☐
Metal ☐





Pellet ☑
Salt ☐
Triso ☐

Enrichment facility

Transportation

Conversion facility

Oxide

Molten salt

Triso

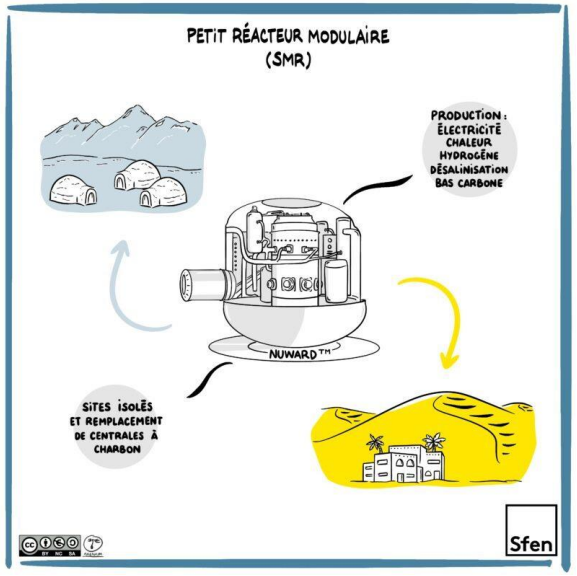
...

Reprocessing facility

Fuel fabrication facility

Hydro ☑
Pyro ?
Partial treatment ?

SUMMARY



- **SMR could drive innovations and create a new and dynamic ecosystem.**

- **Beyond large scale reators, SMR could address specific issues/solutions**

  - Isolated sites
  - Electrical network balance
  - Diversification of uses

- **France has the main facilities for the spent fuel cycl. Evolutions could be needed.**

BUT

- **From the start we need to have a global vision of the cycle : starting materials and natural ressources, life cycle, economy, storage, transportation, wastes management.**