



VALUING FLEXIBILITY AND INTEGRATING RISKS IN SPENT FUEL MANAGEMENT

Cécile Evans, Orano

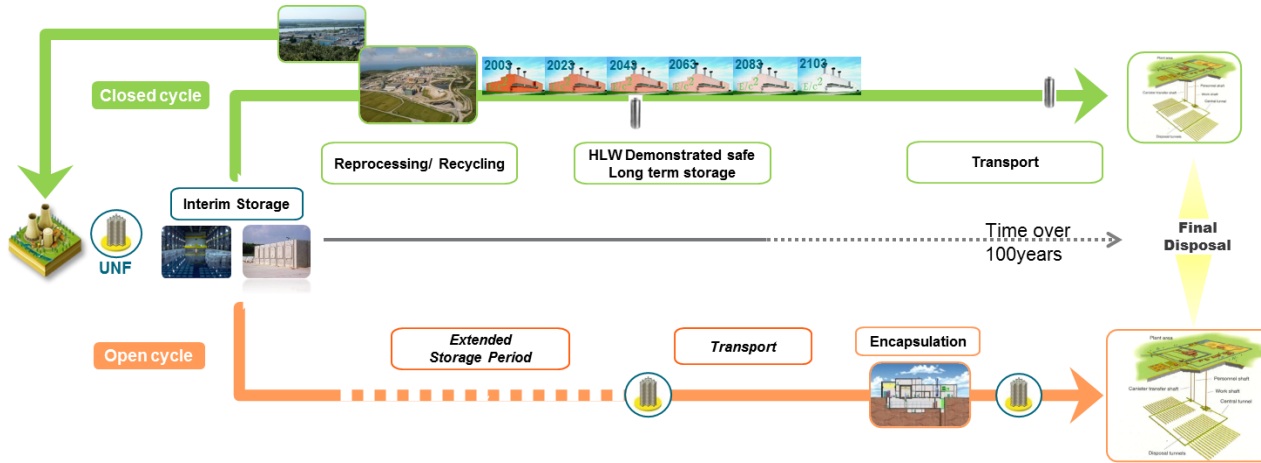
IAEA, Nuclear Back End Webinar Series
Integrated View of the Spent Fuel Management Steps for Decision Making

10th February 2021



Spent Fuel management

Two main Nuclear Fuel Cycle Options : Open or Closed



Multi-dimensional criteria

- Long term energy mix plan: Installed and future Nuclear capacity
- Nuclear Phase out
- National & International Policies
- Regulation
- Available Resources incl. financial
- Social Acceptance
- Geology
- Plant D&D planning– site remediation- asset valorization/sale

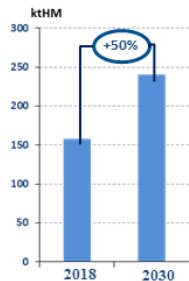
A very long-term multi-dimensional strategic approach

All stages have to be considered to assess overall technical and economical performance and value

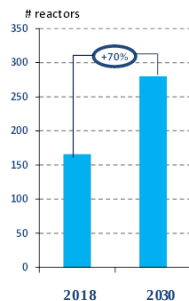
Challenges and drivers for utilities

Cost of electricity, long-term liabilities /risks, financial performance

Spent fuel inventories



Shutdown reactors



Risks & Challenges



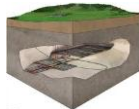
Pool Saturation



Extended interim storage period beyond design life raising uncertainties.



End of life management at shutdown reactors (including premature shutdowns, stranded sites)



GDF delayed or undecided

Environment

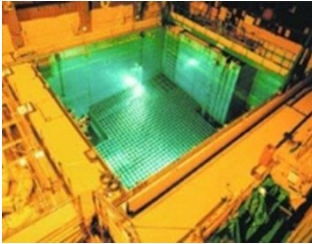
- Regulatory requirements
- Technical – economic
- Security concerns
- Public support
- Environmental impact
- Financial accountability

Spent Fuel interim Storage Solutions are needed independently of the retained option

Various solutions and services for the different systems are implemented worldwide

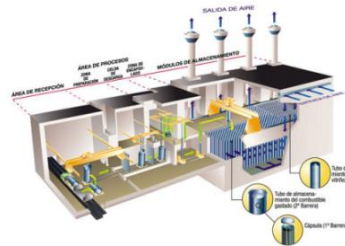
STORAGE

Wet



Centralized pool

Vault



Reinforced concrete structure with array of storage cells above or below ground

STORAGE

Canister + Overpack



Storage & transport functions separated
(2 different overpacks – same canister)

TRANSPORT

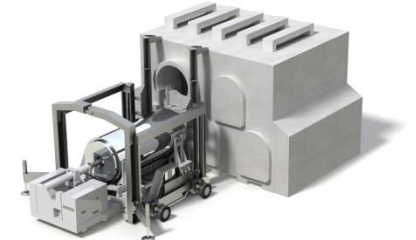
Dual Purpose



One cask providing both the storage and transport functions integrated

Long-term Interim Storage is becoming a reality

- Continued safety and security of “existing” systems (aging management programs)
- Long term performance of “new” systems



NUHOMS® Matrix

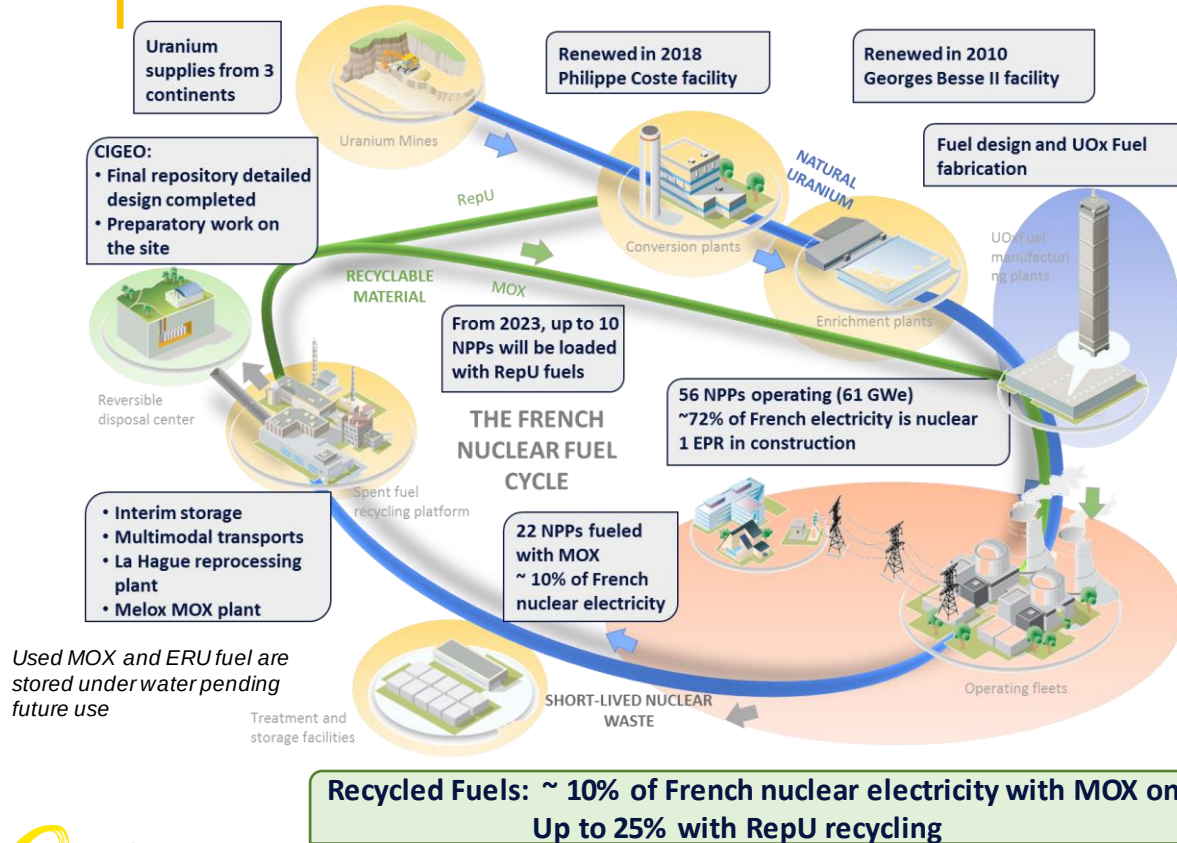
All spent fuel management schemes require a handling and transport program

Transportation is mandatory to

- Intermediate consolidated storage and/or
 - Centralized storage of recycling infrastructure and/or
 - Centralized storage for future conditioning prior to emplacement in Geological repository
-
- Industry safety records are high in countries actively shipping spent fuel (France, UK, Japan, Sweden,...)
 - In other countries, transportation will occur after many years of interim storage, transportability is a must and needs to be planned
 - Countries that need to develop transport programs may face political and public acceptance challenges
 - There is a growing need to continue dialogue with the public and main stakeholders



The French fuel cycle: an integrated industrial system



French management plan for radioactive waste and materials:

- Defines the orientations for the management of radioactive waste and materials in France using a system analysis of existing installations, futures evolutions given the energy policy in force, inventories, storage capacities...
- Identifies the needed studies, new management system and new infrastructures
- Plan prepared by the Ecological Transition Ministry and the Safety Authority
- Includes participation of all stakeholders of which NGOs



Orano recycling platform: a strategic asset with 40 years of experience, shared worldwide

- Operational experience and excellence

Safe transport by train, truck & ship



7,500 French used fuel shipments to La Hague

2,500 coming from abroad

La Hague reprocessing plants



Modular design of storage capacity up to 25,000 vitrified HLW vitrified canisters using natural air circulation

~27 000 tHM reprocessed for France

10 500 tHM reprocessed for 6 other countries outside France

Melox fabrication plant

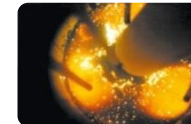


2 700 tHM MOX fuel produced, loaded in 43 reactors worldwide

5,200 MOX fuel assemblies loaded in French reactors

- Continuous enlarging industrial scope and capacities through innovation and R&D

- Wide range of LWR fuel including high Burn up, RTR, RNR, MOX fuels and specific types
- Cold Crucible induction melting to enlarge products' range and further reduce waste
- Research centers to enhance the robustness of Melox Fuel Fabrication Plant
- Beaumont (La Hague) test facility: development & qualification in inactive operating conditions



Recycling is a key asset allowing to reduce risks, increase flexibility and financial predictability

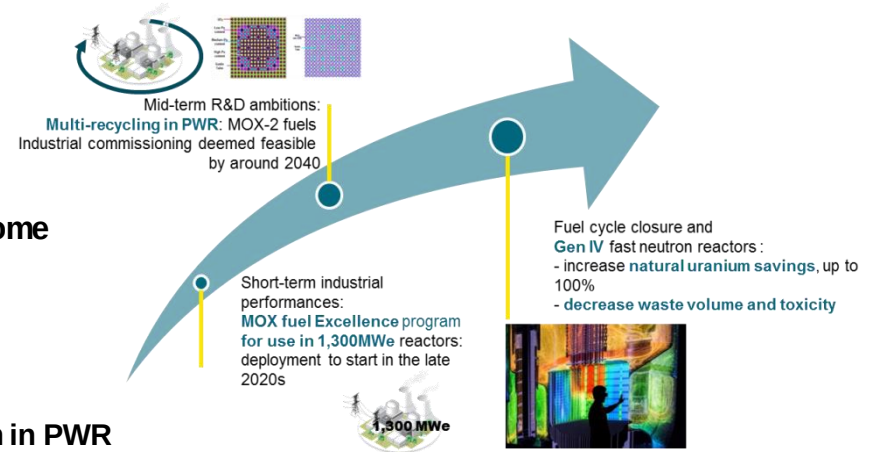
French Multiannual Energy Program orientation adaptation of the strategic industrial and R&D roadmap for closure of the fuel cycle

- Diversification of the energy mix with the raise of renewable, up to 14 reactors shut down by 2035 to reach 50 % of nuclear energy in power generation, depending on electricity prices, the mix of neighboring countries, the electric system margins

- Mono-recycling back-end strategy to continue until 2040
Industrial mastery of reprocessing and recycling technologies: the enabler to move to advanced fuel cycle

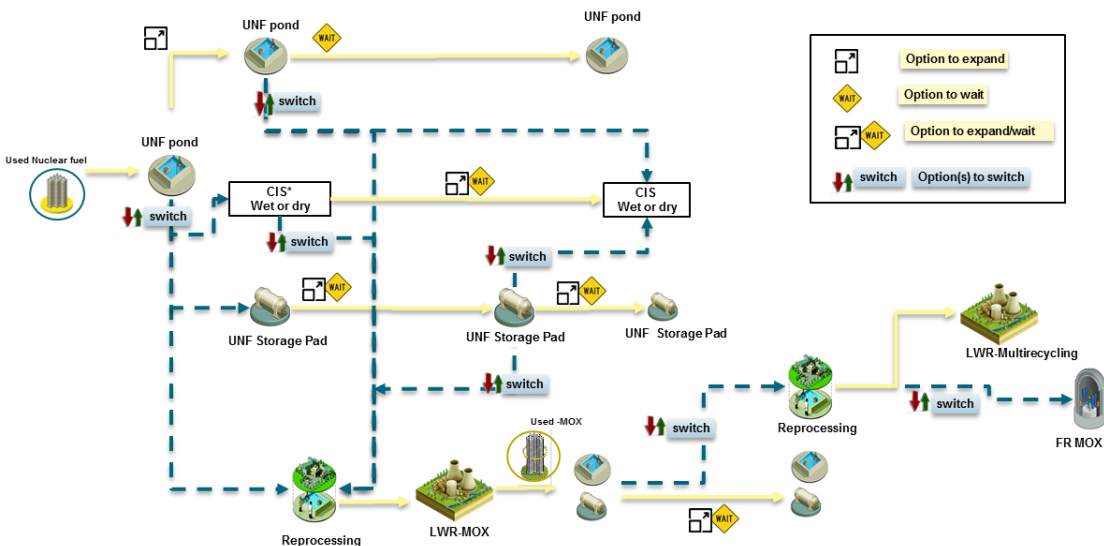
- Development of R&D program between CEA, EDF, Framatome and Orano to support closure of the nuclear fuel cycle:

- Maintaining the perspective of a Fuel cycle closure and GenIV fast neutron reactors
- Focusing in the middle term on Multi-recycling of plutonium in PWR



Plutonium Multi-recycling in LWR prepares the perspective of a potential industrial deployment of a fleet of Fast Reactors in the second half of the 21st century considering natural uranium availability

Having Flexibility in back-end options offers mitigation for known/unknown risks and uncertainties



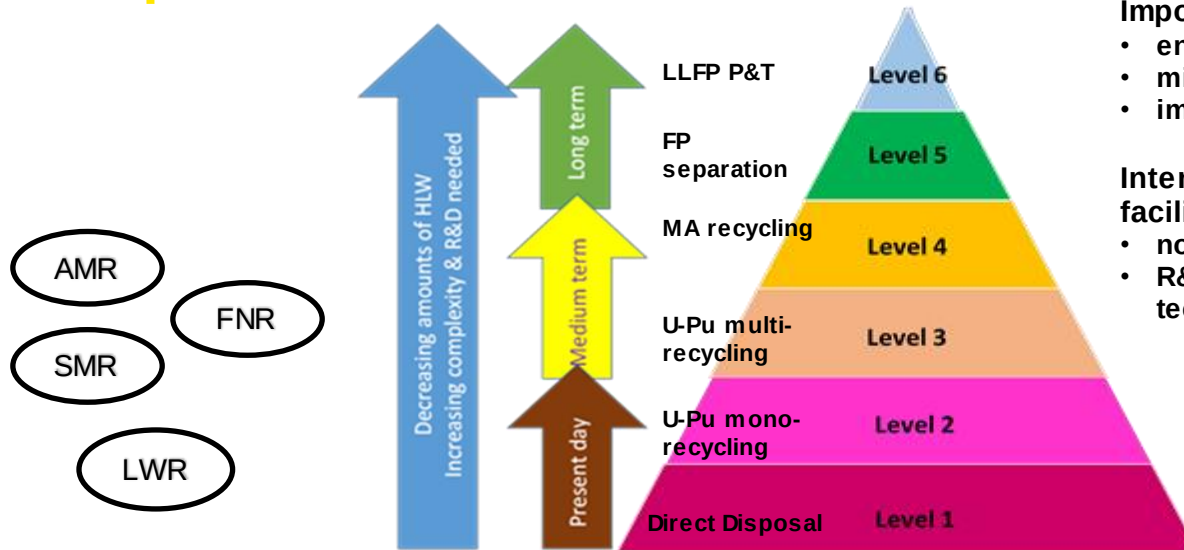
Uncertainties impacting the overall Spent fuel management path :

- **Environmental impact**
- **Technical-economic**
 - Evolution of SNF-management service costs
 - Timing of industrial maturity of SNF-management options: encapsulation and GDF, FR technology, advanced systems
 - Integrity of both spent fuel and storage systems with extended storage period
 - Transportability of SNF following extended storage period
 - Evolution of Nat U-price
- **Financial**
 - Discounting policies for the different SNF-management activities
 - Impact on NPP-operator competitiveness
- **Socio-political**
 - Security of SNF-management options
 - Regulatory changes impacting SNF-management options
 - Societal acceptance of SNF-management options

Spent fuel management system, very long term, involve multiple decisions

- Uncertain factors conditioning the decisional options in future times
- No fixed scenario: alternatives arise as the market conditions of options evolve and/or driven by socio-political considerations

Requirements for nuclear energy sustainability



IAEA waste burden minimisation

Importance to continue R&D efforts:

- enhance safety, reduce environmental impacts
- minimise waste burden
- improving resource-use efficiency

International collaboration should be accelerated in facilitating shared infrastructure:

- not only for disposal but also for reprocessing ,
- R&D centres necessary to develop advanced nuclear technologies

BASIS

Safe, secure, economical/affordable and publically acceptable nuclear energy with security of supply

ENDPOINT

Safe disposal of all nuclear waste ensuring some retrievability not to limit future generation's options



IAEA Nuclear Back End Webinar Series,
Integrated View of the Spent Fuel Management Steps for Decision Making, 10th February, 2021 10

Flexible and Sustainable Back End solutions

Potential issues

Approach recognizing benefit of limited early cash out but underestimating uncertainties or future risks

Wait & See approach without regular assessment of the options yet left open

Over simplified approach using static Model of idealized options

Challenges

Avoid Spent Fuel Pool saturation and safely and timely manage interim storage

Safe and optimal DGR development

Minimize environmental impact & footprint

Ensure Robustness of retained Funding

Public acceptance

Drivers

Preserve natural resources

Increase energy independence

Contribute to security of supply

Minimize waste generated for disposal

Optimize cost of safe and secure Spent Fuel management

- Spent Fuel interim Storage Solutions are needed independently of the retained management option
- All spent fuel management schemes require a handling and transport program
- All spent fuel management schemes require implementation or access to geological disposal capacity
- Recycling is a key asset to reduce risks, increase flexibility and financial predictability: Adaptable schemes providing flexibility and a road to future multi-Recycling in LWR and FR
- Nuclear's competitiveness in changing markets requires continuous innovations in fuel cycle services
- Assessment of the overall costs and associated uncertainties are essential to size liabilities
- Beyond classical NPV/DCF, the use of innovative assessment methodologies integrating Cost, Risks, Time and Options is key to develop optimal Spent Fuel management implementation program
 - To match the uncertain socio-political-economic environment
 - To minimize deployment costs and risks through phased development, valuing flexibility to accommodate future development
 - To value longer-term objectives in shorter-term decisions
 - To consider sharing infrastructures that would especially benefit countries with smaller nuclear programs



orano

Giving nuclear energy its full value