

SummerSchool Introduction : Stakes and challenges of nuclear waste and industrial vitrification

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Deputy Scientific Director**

SUMGLASS 2023 – Nîmes – Septembre 25-29th 2023

CEA Mission - some key figures

For more than 75 years, the CEA has been committed, through its four divisions, to the **scientific, technological and industrial sovereignty of France and Europe** for a better controlled and more secure present and future.



Defence and security of the country



Energies nuclear and renewable



Technology research for Industry



Fundamental research



20 181

Employees

€ 5,1 Mds

Budget

> 5 045

Publications

670

Patents deposits

7 200

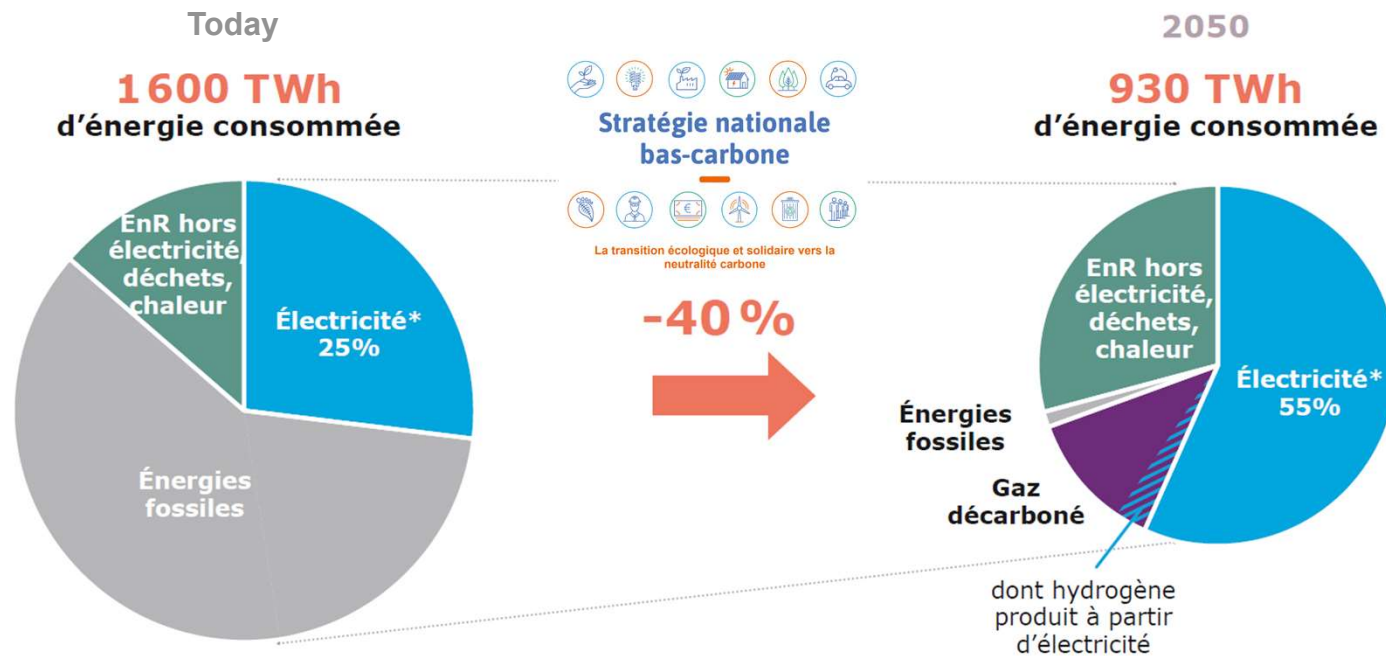
Active patents

9 Centres
5 Regional Platforms for technology transfer
4 major university clusters





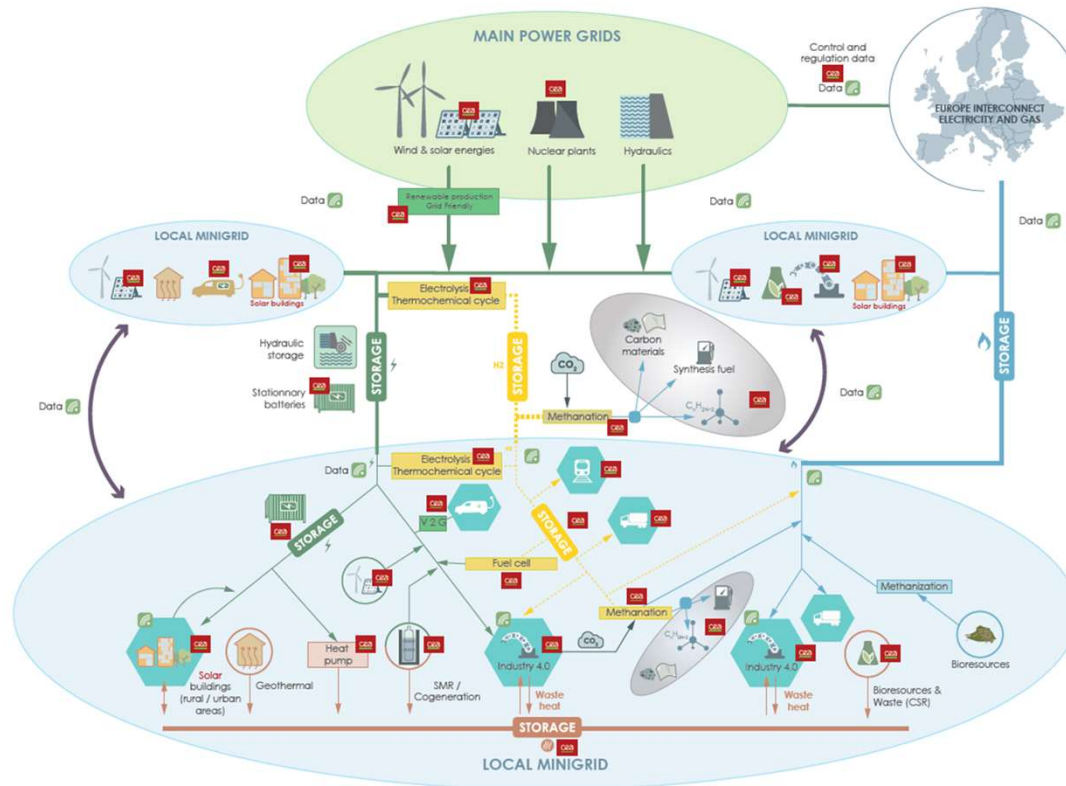
Energy transition : towards Net Zero 2050



* Consommation finale d'électricité (hors pertes, hors consommation issue du secteur de l'énergie et hors consommation pour la production d'hydrogène)
Consommation finale d'électricité dans la trajectoire de référence de RTE = 645 TWh



Vision for Net Zero by 2050



- | | |
|---|---|
| MULTI-ENERGY VECTORS:
(ELECTRICITY, HEAT, GAS
/ HYDROGEN) | CONVERGENCE OF
RENEWABLES AND
NUCLEAR |
| MULTI-SACLE & MULTI-
AGENTS | INNOVATION |
| SMART -GRIDS
DIGITAL AND DEMAND
SIDE MANAGEMENT | REGULATION AND NEW
BUSINESS MODELS |
| CIRCULAR ECONOMY
(RESSOURCES AND
CO2) | SOCIETY ADHESION |



French President orientations on future energy policy

In his speech in Belfort on 10 February 2022, the President of the Republic indicated the following guidelines for energy policy, with the objective of dropping fossil fuels by 2050

- **Energy Sobriety:** reduce consumption by 40% in 2050
- Produce more decarbonised energy
 - **Massive development of renewables** (PV, offshore and onshore wind, thermal renewables)
 - **Relaunch of the nuclear industry:** target of 25 GW of new capacity by 2050
 - When possible, life extension of reactors subject to safety review: studies beyond 50 years
 - Launch of a "New Nuclear" programme with 6 EPR2 (programme of 3x pairs as proposed by EDF) and study of 8 other EPR2
 - **1 billion €** public aid programme for **small reactors:** support for the development of the French SMR industrial project (NUWARD), call for projects on innovative reactors, objective of a first prototype in 2030
 - Establishment of regulatory and financial conditions for the organisation of the sector
- The **Nuclear Policy Council** (July 2023) made decisions on the localisation of the 3rd EPR pair and **increased staff and missions of CEA to drive and reinforce the French nuclear R&D**

 **Strong involvement of CEA in PV and hydrogen technologies**

 **R&D with EDF on nuclear reactors lifetime**

 **Strong involvement of CEA in the NUWARD SMR project and innovation in nuclear production systems**



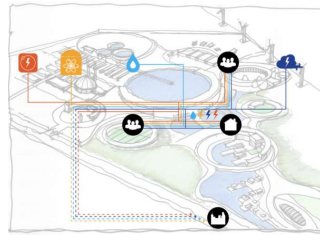
Nuclear R&D activities roadmap at CEA



Reinventing nuclear power with SMR



Source : Third way, NICE Initiative

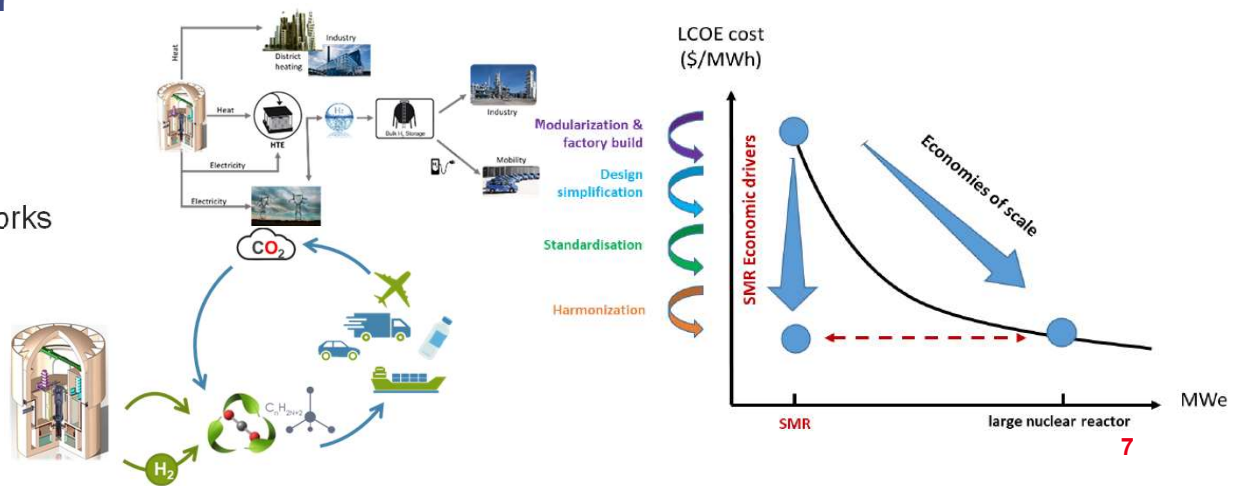


New approach to nuclear reactor design

- Simplicity
- Passive safety and absence/reduction of off-site countermeasures
- Prefabrication – modularity
- Production in series

New use cases for nuclear power

- Network integration and balancing
- Energy hub and remote sites
- Replacement of coal plants
- Heating and industrial heating networks
- Hydrogen & e-fuel
- Desalinization





Energy transition : CEA R&D programmes

Vitrification R&D programs

Current and future nuclear industry



Common programmes



New energy technologies



Cross-cutting programmes



Basic research



Closure of carbon cycle



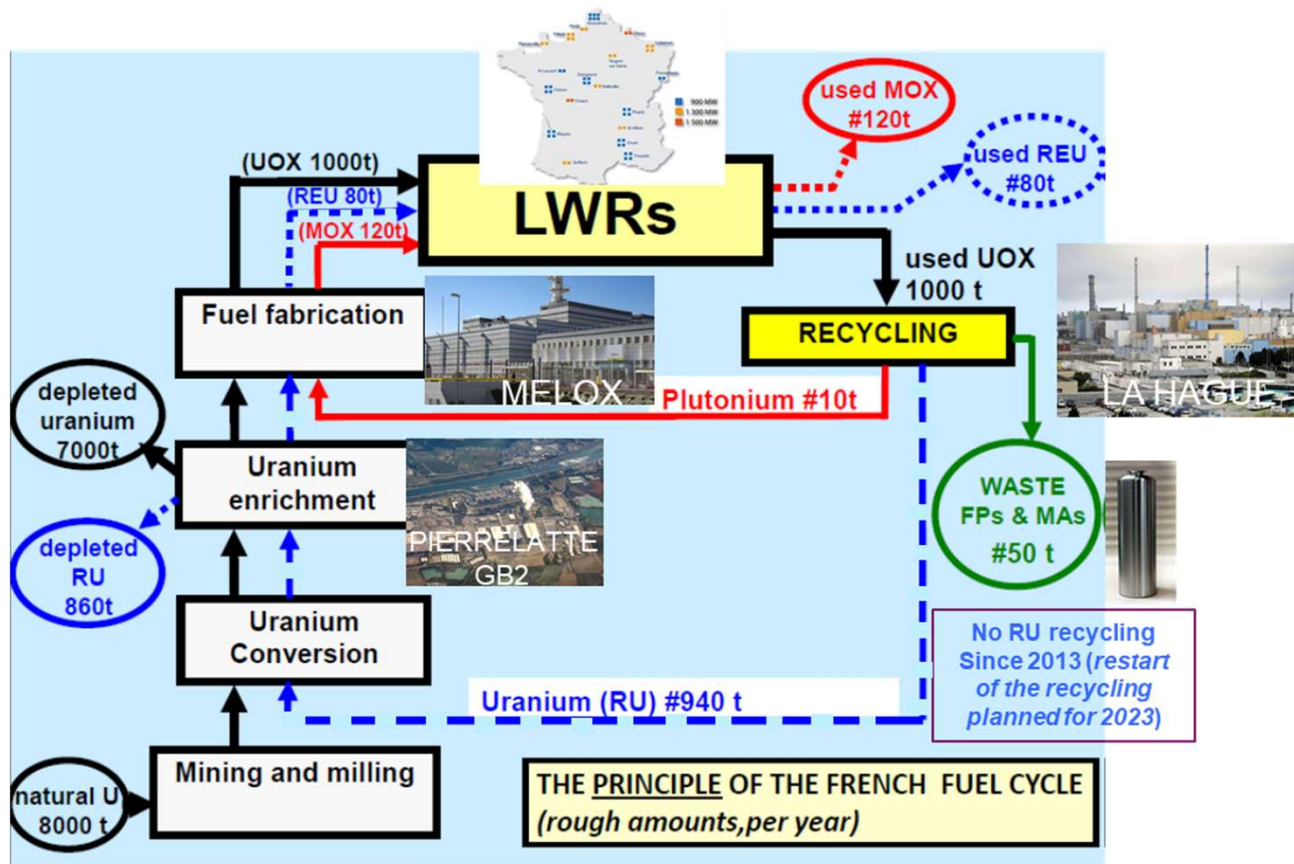
Tech-Economy



R&D for Clean up and Dismantling



Current french nuclear fuel cycle





A strategic & industrial roadmap for closure of the fuel cycle



Mid-term R&D stakes :

- Investigation of **fuel multirecycling in PWR** using **MOX2 fuels**
(e.g. assemblies with mixed Pu and natural or enriched uranium recycling rods)



Long term R&D stakes :

- R&D program for **Generation IV reactors** and **closure of the fuel cycle**, including sodium FNR reactors and cycle plants
- a **simulation program**, using new digital know-how (e.g. **digital twin**)
- an **experimental program**

Short term industrial stakes :

- Produce MOX fuel to **supply the existing nuclear fleet**
- Prepare for use of **MOX fuel in existing reactors** (1300 MWe reactors fleet)



Strong impacts on vitrification (Fission products, PGM, minor actinides...)



Managing the past to prepare and enable the future :

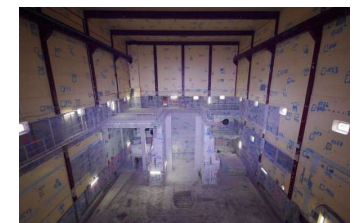
Our missions in Cleaning-up & Dismantling, waste recovery and waste management

▪ CEA/DES missions in the field of Cleaning up and Dismantling on civil centers:

- Operations on the shut-down facilities
- Management of waste, materials, fuels and sources
- Operation of nuclear service facilities
- **Perform R&D on every steps including waste management, cementation and vitrification**

▪ The challenges for our activities :

- Operating our facilities safely and securely, and ensuring operational control
- Carrying out our waste recovery and conditioning, clean-up and dismantling projects
- **Consolidate waste management processes**
- Control and optimize fixed costs

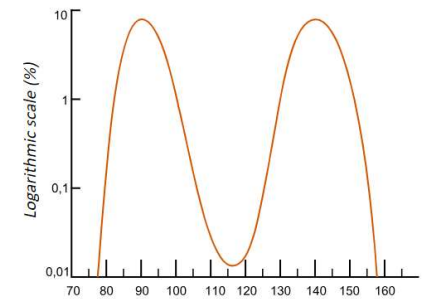


Waste vitrification : a wide range of compositions and constraints



- **Various types of nuclear waste/composition** coming from back- end of the fuel cycle and cleaning up and dismantling operations
- Used UOX Fuel : **Fission products** and **minor actinides** (neutron captures) ; among them, **platinum group metals PGM**...
 - Use **borosilicate glasses** (La Hague plants) « R7T7 », **hot or cold crucible melters**, **electromagnetic induction heating**
- Multirecycling Pu in MOX2 fuels in PWRs : increased contents of **minor actinides**
- ATF (accident Tolerant fuels) : adding new chemical elements (**chromium doped fuel**...)
- Research reactors : metallic fuels : **UMo** use of **glass-ceramics** ; **USi**...
- Advanced modular reactors (AMR) : HALEU, TRISO fuel (graphite and carbides...), used **molten salts** (chlorides, fluorides)
- Non nuclear glasses : *heavy/toxic metals (Pb, Cd, As, Sb...) + glass seals, PV glasses ...*

- **Various types of constraints :**
 - Molten glass physical and chemical properties : fabrication
 - Long-term resistance to self-irradiation
 - Long-term resistance to leaching in vapor and liquid water / environment
 - Cross effects
 - ...



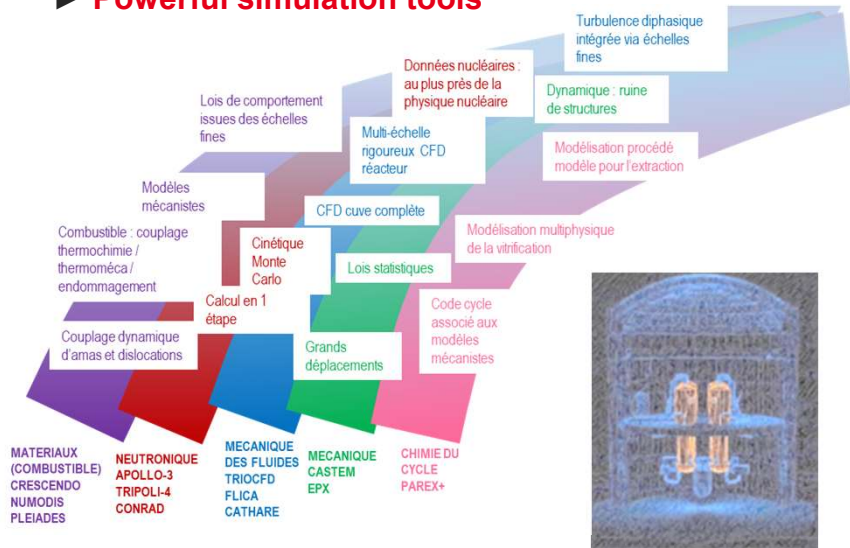
Distribution of Uranium-235 fission products (A)



The CEA simulation-experiment approach to accelerate the research and innovation for the energy transition

- Coupled multiscale & multiphysics simulation
- Increase the share of experiments at small scales
- Manage the uncertainties to drive smart experiments
- Use databases, AI and HPC numerical tools ; towards exaflop calculations and numerical twins

► Powerful simulation tools



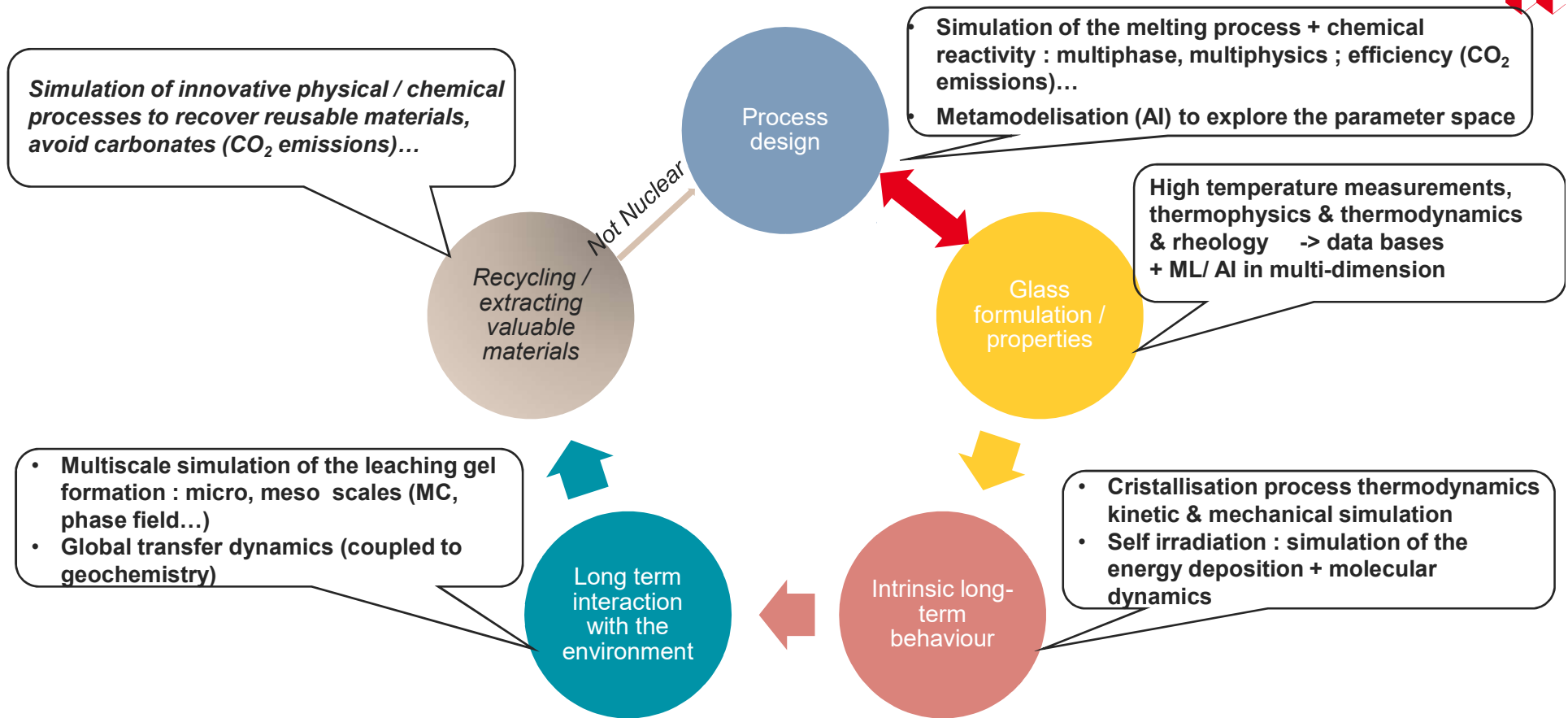
+ Databases

► Experimental facilities (inactive and active)

	Installations en actif pour l'étude des combustibles, des matériaux et des procédés de traitement LECI, LECA, ATALANTE
	Réacteurs de recherche et d'irradiation : CABRI (exploité pour les programmes de l'IRSN), absence de réacteur d'irradiation depuis fin 2015 (RJH en construction)
	Plateformes expérimentales nucléaires POSEIDON, RÉSÉDA, TAMARIS, HERA, JANNUS, PLINIUS, etc.
	Plateformes expérimentales NTE : salle blanche FabLAB PV, plateforme mobilité, plateforme hydrogène, démonstrateurs de systèmes énergétiques en région...
	Plateformes expérimentales transverses plateformes fabrication additive SAMANTA & POWDR'INNOV, plateformes de caractérisation,...



Avenues of research in a simulation-experiment approach





cea

Thank you for your attention



Institute of science and
technology for a circular
low-carbon energy economy

sumglass
September 25-29th 2023
3rd Summer School on nuclear
and industrial glasses for
energy transition

Sumglass 2023' objectives and expectations

Sophie SCHULLER
R&D Project manager
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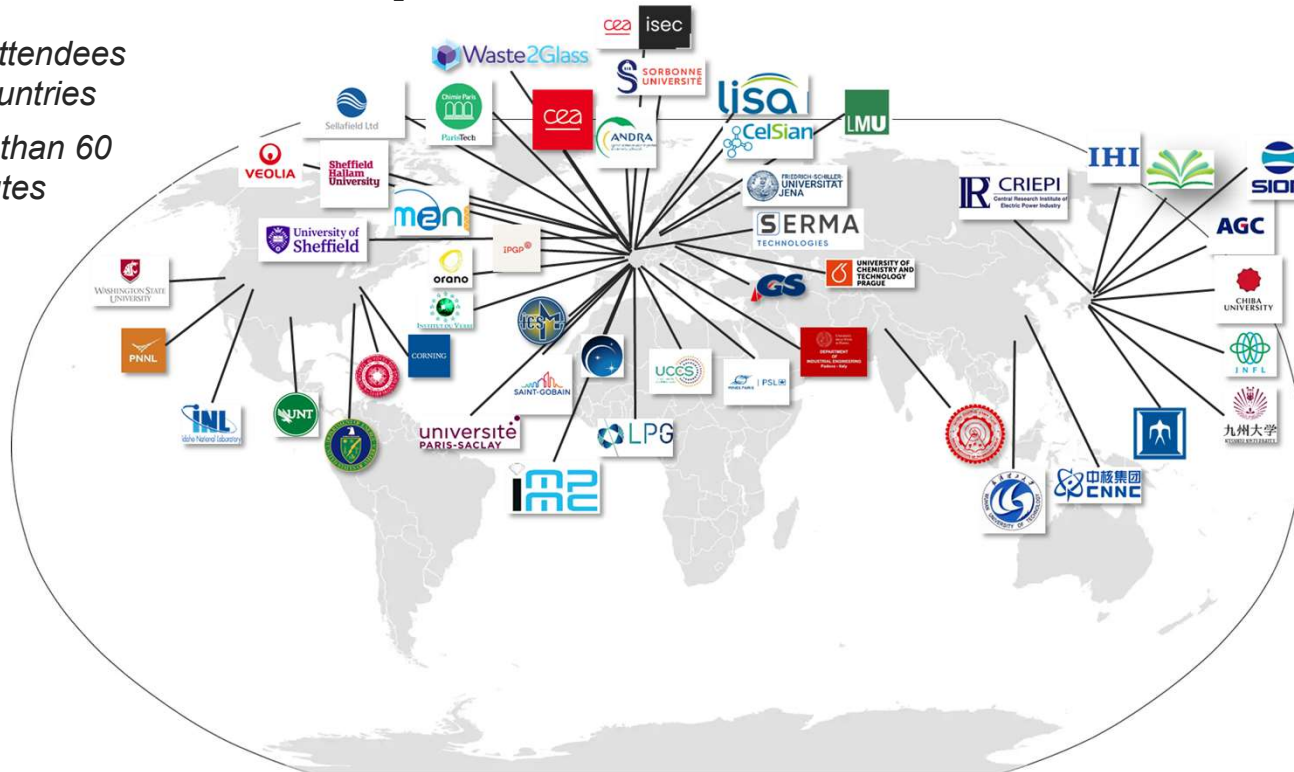
SUMGLASS 2023 – Nîmes – September 25-29th 2023





Reinforced our cooperation

145 attendees
10 countries
More than 60 institutes



To meet the challenges facing the nuclear fuel cycle and the non-nuclear industry as part of the net-zero energy transition 2050

Sumglass 2023





Meeting the major challenges of a sustainable future

- 01 Reinforce our potential of innovation**
- 02 Develop new approaches and modeling to accelerate nuclear waste management**
- 03 Develop new vitrification technologies, new glass compositions for energy transition**
- 04 Take into account the life cycle of nuclear waste management**

Sunglass 2023



Sumglass objectives and expectation

→ Share the main issues and methodologies developed on the vitrification of nuclear wastes and industrial glasses

Review the state of the art at international scale

- Challenges and development of Vitrification/treatment technologies and packaging matrices
- Challenges and key issues to the disposal of French vitrified glass
- Researches dedicated to the glass alteration of packaging and commercial glasses

(15 presentations, + posters)

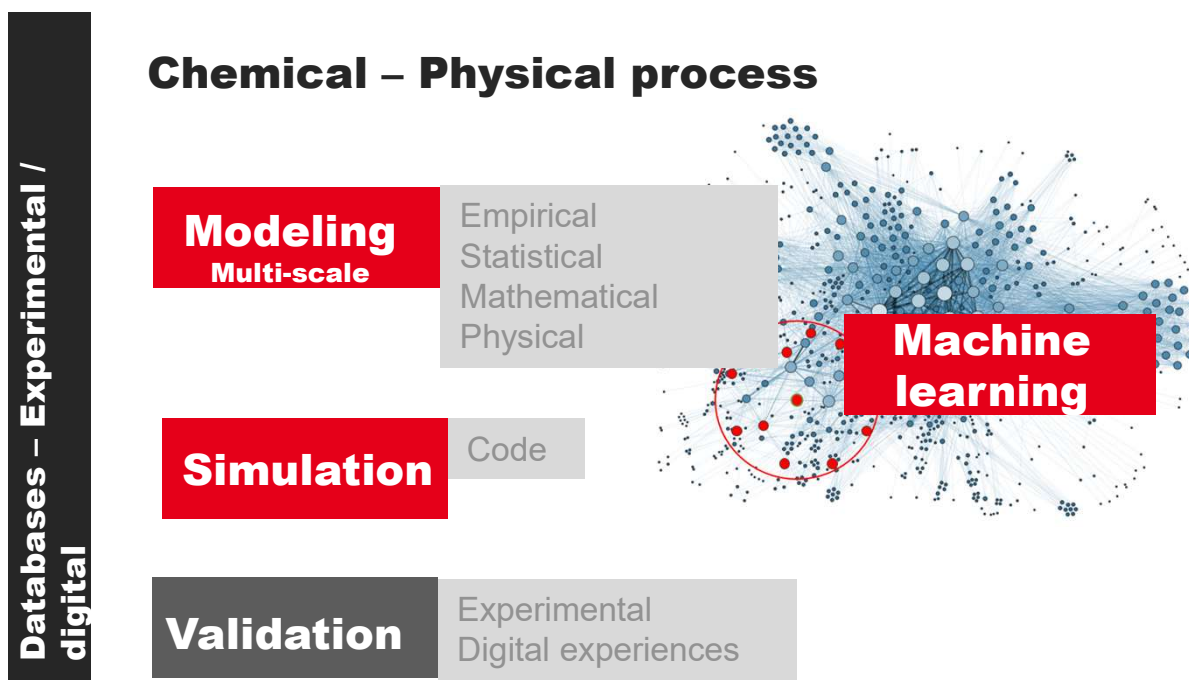
Provide an overview on the issues surrounding recycling and the use of raw materials to reduce carbon footprints

(2 presentations + posters)



Sumglass objectives and expectation

→ Share the modeling approaches



Technologies – Physico-Chemical properties – Long term behavior



Sumglass objectives and expectation

Give an overview of multiscale modeling and machine learning

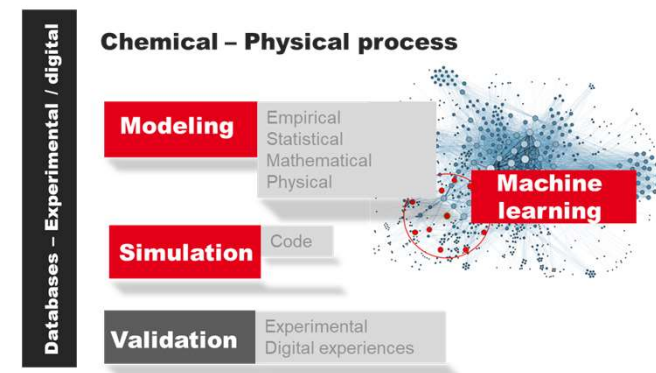
- Optimize furnace and glass compositions
- Understand and predict the long term behavior

→ Focus on modeling/machine learning implemented for nuclear waste vitrification and commercial technologies

(13 presentations + poster)

→ Provide data and key mechanisms on physico-chemical properties that can influence furnace operation (thermics, redox, foaming, diffusion, viscosity) *(5 presentations)*

→ Demonstrate the contribution of thermodynamics and knowledge of chemical processes (diffusion, crystallization, phase separation) to optimize glass compositions *(5 presentations)*



Sumglass 2023



Sumglass objectives and expectation

→ Share the characterization methodologies

Demonstrate recent developments and methods used to characterize physico-chemical processes (crystallization, phase separation, bubbling, chemical reactivity) in temperature - Parameter acquisitions (*4 presentations*)

→ Take a look on the new development on glass for energy transition

Focus on glass development for energy transition
(*2 presentations*)

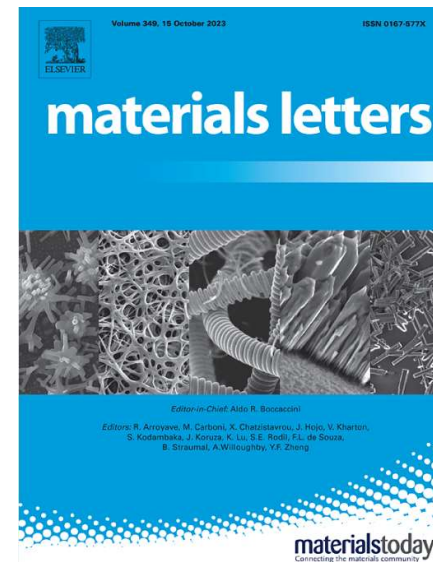


Sumglass objectives and expectation

Promoting and value our works and discussions in a special issue
Materials letters: Glass and sustainability

<https://www.sciencedirect.com/journal/materials-letters/about/call-for-papers#glass-and-sustainability>

Submission deadline: 15-Jan-2024



Sumglass 2023

The logo for cea, consisting of the lowercase letters 'cea' in a red, cursive-style font, with a horizontal red line underneath.

Thank you for your attention