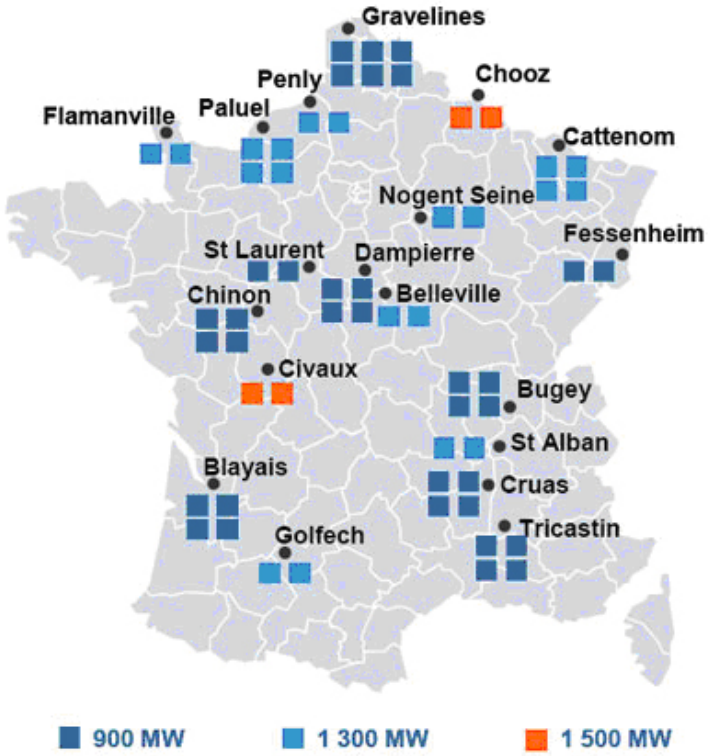
DE LA RECHERCHE À L'INDUSTRIE

cea den

Nuclear energy in France

Stéphane Bourg
Département de recherche sur les procédés pour la Mine et le Recyclage du Combustible, CEA-MARCOULE
CEA-DEN/DMRC

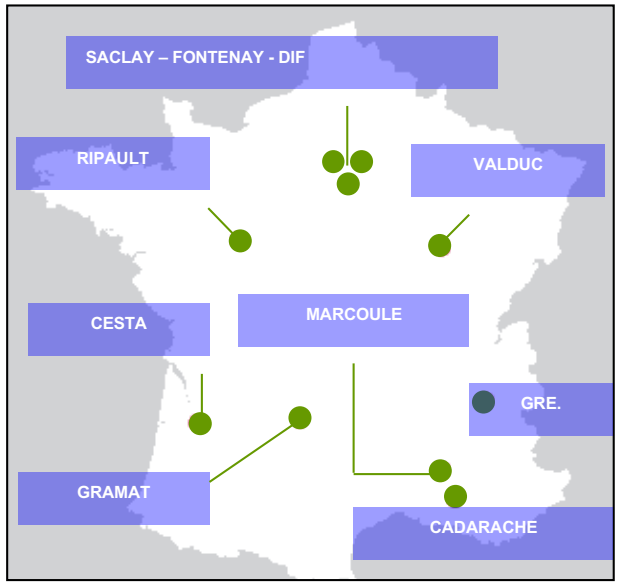
Nuclear energy in France
Current situation



19 production sites, 58 reactors
63,2 GW installed (max. allowed by law)

1 EPR under construction

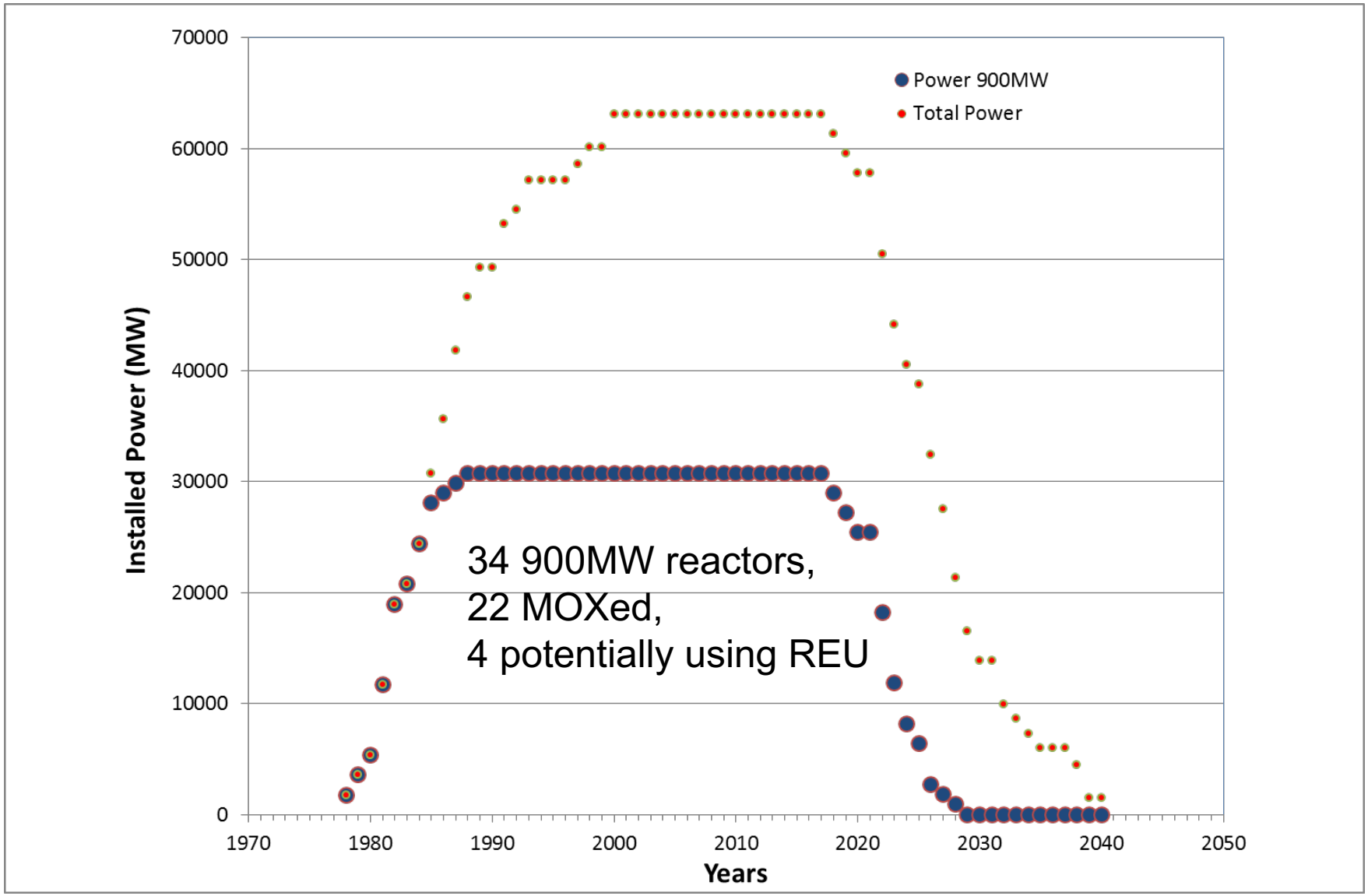
Production 400-450 TWh_e
70-80% of the French needs



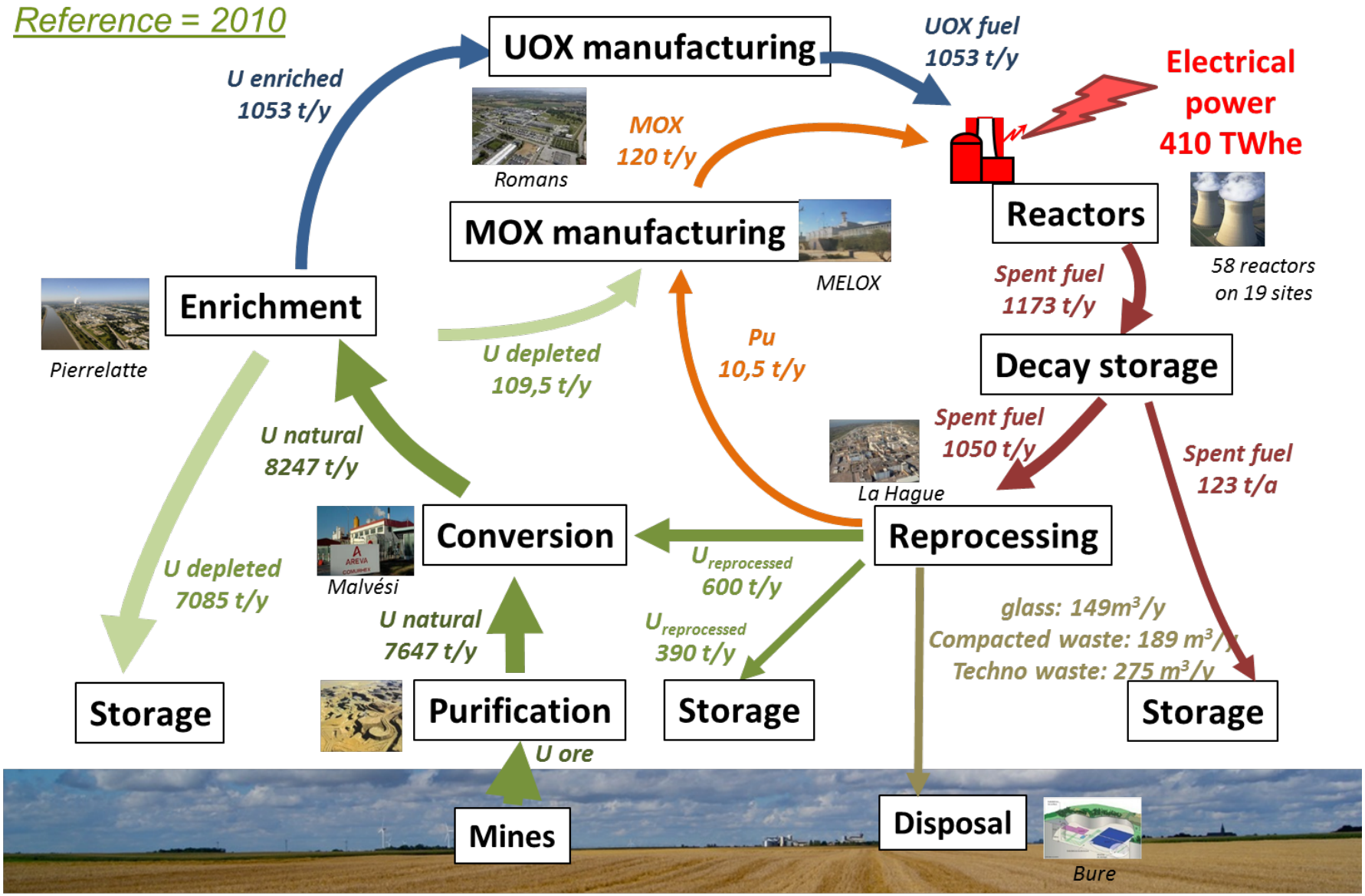
10 research centres

- Low carbon energies (nuclear, renewables)
- Defense and global security
- Health and information technologies
- Large research infrastructures
- Training and education
- Valorisation and technological transfer

The current reactor fleet lifetime, with a 40 year reactor operation time



The French nuclear fuel cycle
« twice through cycle »



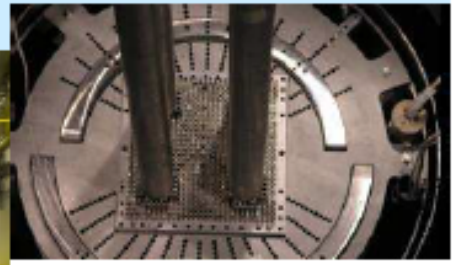
DE LA RECHERCHE À L'INDUSTRIE
cea den

R&D for the current nuclear indudstry reactors and cycle

Reactors

- Extending the operating lifetime of nuclear power plants
- Improving their performance level (availability, etc.)
- Increasing their nuclear safety level

Investigation of irradiated materials and fuels at the Saclay centre



Studying the fluence absorbed by the 1300 MWe reactor vessels in EOLE

Fuel cycle

- Meeting industry needs in a highly competitive market
- Supporting the recycling industry (La Hague & Melox), radwaste producers and Andra

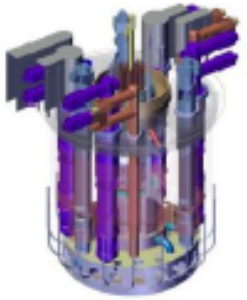
Platform of mixers and settlers to validate the performance of the selective uranium extraction process on a laboratory scale

General view of the evolving vitrification prototype equipped with a cold crucible melter adapted for nuclear environments at Marcoule

Maintaining a high level of expertise and skills for the current nuclear fleet (fuel cycle and reactors)

Preparing the future: 4th generation reactors ASTRID

- **Fast reactor technology assets:**
  - Plutonium multi-recycling
  - Preserving natural uranium resources
  - Support for high-level waste management



- **The favored options in France: sodium-cooled fast reactor (SFR) technology**
- A technology at a high level of **maturity.** To be **improved for the 4th Generation**: safety, savings, availability, in-service inspection & repair
- Close-knit coordination with French and foreign industrial partners around the Astrid SFR project

- Technology well developed at the **international level**

Major tools:
a unique fleet of experimental facilities

Hot labs : PIE on materials and fuels (LECI, LECA)

Hot labs dedicated to fuel cycle back-end (ATALANTE, G1)

Zero power reactors : Critical mock-ups

(PWR – EOLE/MINERVE, FNR – MASURCA)

Technological platforms (mechanics **/**seismic – TAMARIS, components – RESEDA, thermohydraulique – POSEIDON/AMETHYST, severe accidents – PLINIUS, hydrogen risks – MISTRA, …)

Major tools:
…continously updated, modernized and refurbished

Hot lab for irradiated fuel (MOSAIC*)

MOX R&D to be transferred to ATALANTE (2017)

Jules Horowitz Reactor MTR

Zero power reactor ZEPHYR* for PWR neutronics studies

PLINIUS 2 / R&D for severe accidents GEN-2,3 et 4

(* opportunity study in progress)

Jules Horowitz Reactor (JHR)
ICERR certified

JHR : an original international user facility model, ICERR certified

- Participation to funding through right of access to experimental capacity during the reactor lifetime
- 20% of right of access so acquired by foreign organizations
- In consideration for an extend of the model to a use by hot laboratories

Objective of JHR

- **Offering capacity of experimental irradiation.** *(Study of materials and fuel behavior under irradiation)*
- **Produce radioelement for medical use** (25% - 50 % of European needs)
- Meet the needs of 2nd and 3rd generations and partly of the 4th generation of reactors, especially the **innovation of materials and fuels required by the various concepts of generation 4**

JHR consortium members	participation
EDF (France)	20%
AREVA (France)	10%
EURATOM/JRC (EU)	6%
SCK/CEN (Belgium)	2%
NRI (Czech Republic)	2%
CIEMAT (Spain)	2%
VTT (Finland)	2%
Vattenfall (Sweden)	2%
DAE (India)	3%
IAEC (Israel)	2%
NNL (UK)	2%
CEA(France)	balance

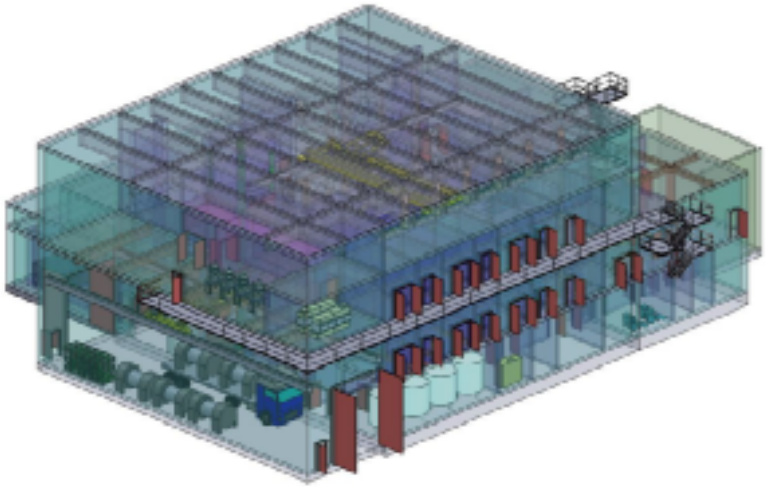
MOSAIC, a project of future hot-lab

- PIE on fuels & materials
- For PWR, SFR, MTR needs
- In Cadarache: close to JHR
- Preliminary design completed and optimized

- Embedding CEA now-how and lessons learnt for more than 50 years
- ~ 25 hot cells
- To replace the LECA-STAR hot lab.
- Opportunity study ongoing to reach decision point in 2017

ZEPHYR: A project of future Zero-Power reactors

- 2 ZPR in the same facility
- For Gen 2, 3 and 4 needs,
- Target for commissioning: early 2026
- To replace EOLE & MINERVE
- Decision point in 2018



Severe accidents - PLINIUS 2: objectives

- CEA future platform for prototypic corium experimental R&D : **Target date: 2021**
- Will replace the existing GEN2&3 PLINIUS platform (VULCANO, VITI, KROTOS)
- **Experimental support to GEN 2, 3 & 4** studies
- Design studies launched in 2015, decision to pursue construction at the end of 2017.

GEN4

Corium-Sodium facility
Fuel Coolant Interaction up to steam explosion
Sodium Temp.: 400 to 850°C
Corium mass : 50 to 250 kg
Na test section + circuit ~2 tons
X-ray imaging

GEN4
GEN2&3

Material interaction facility
Ablation (core catcher material, ceramics, concrete, steel)
Corium mass : 50 to 500kg
With/without cooling
Size up to 3m x 3m x 1m

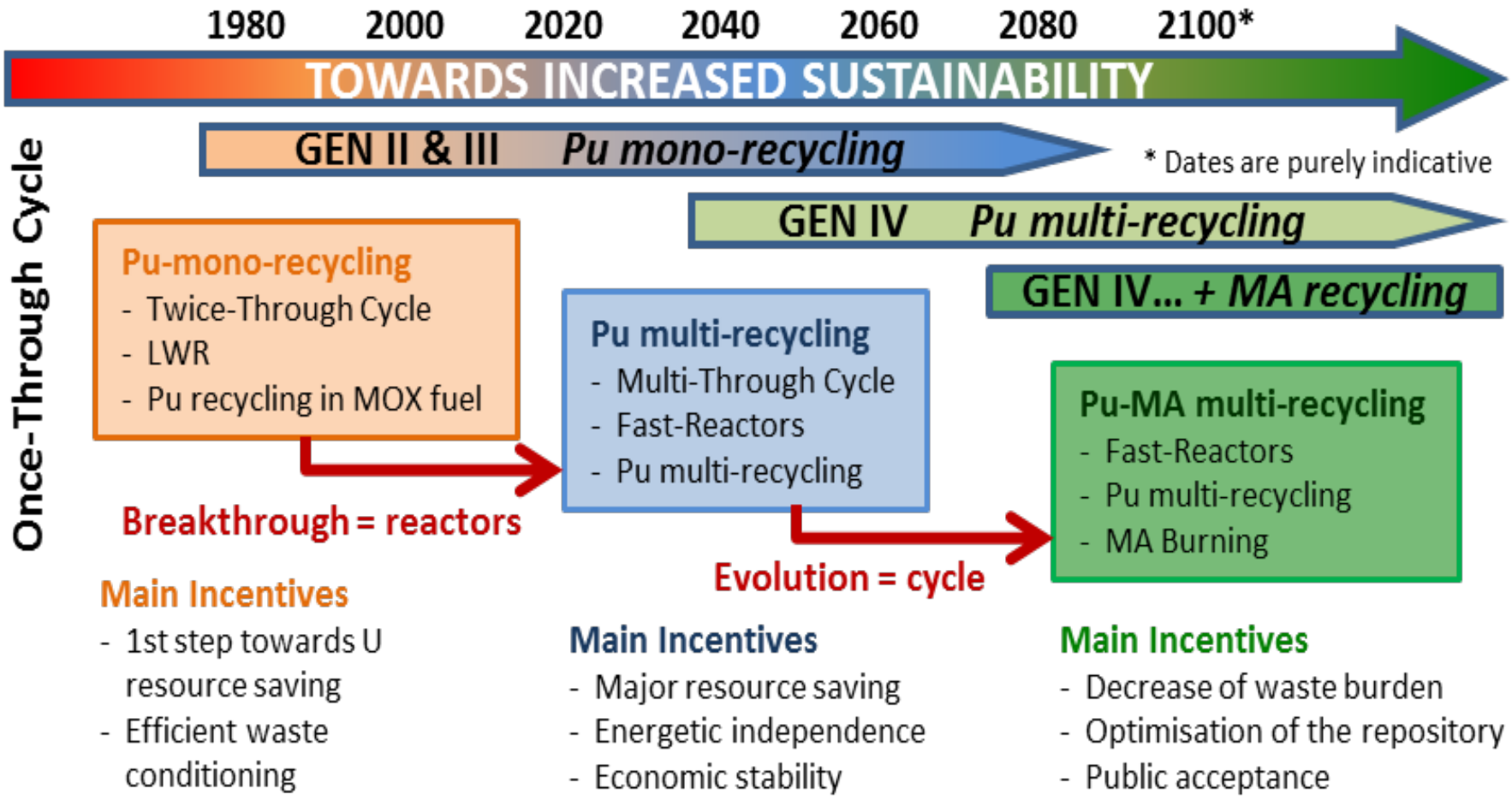
- **In vessel retention (stratification)**
  - Mass: 50 to 250 kg
  - X-ray imaging, ultrasonic methods

GEN2&3

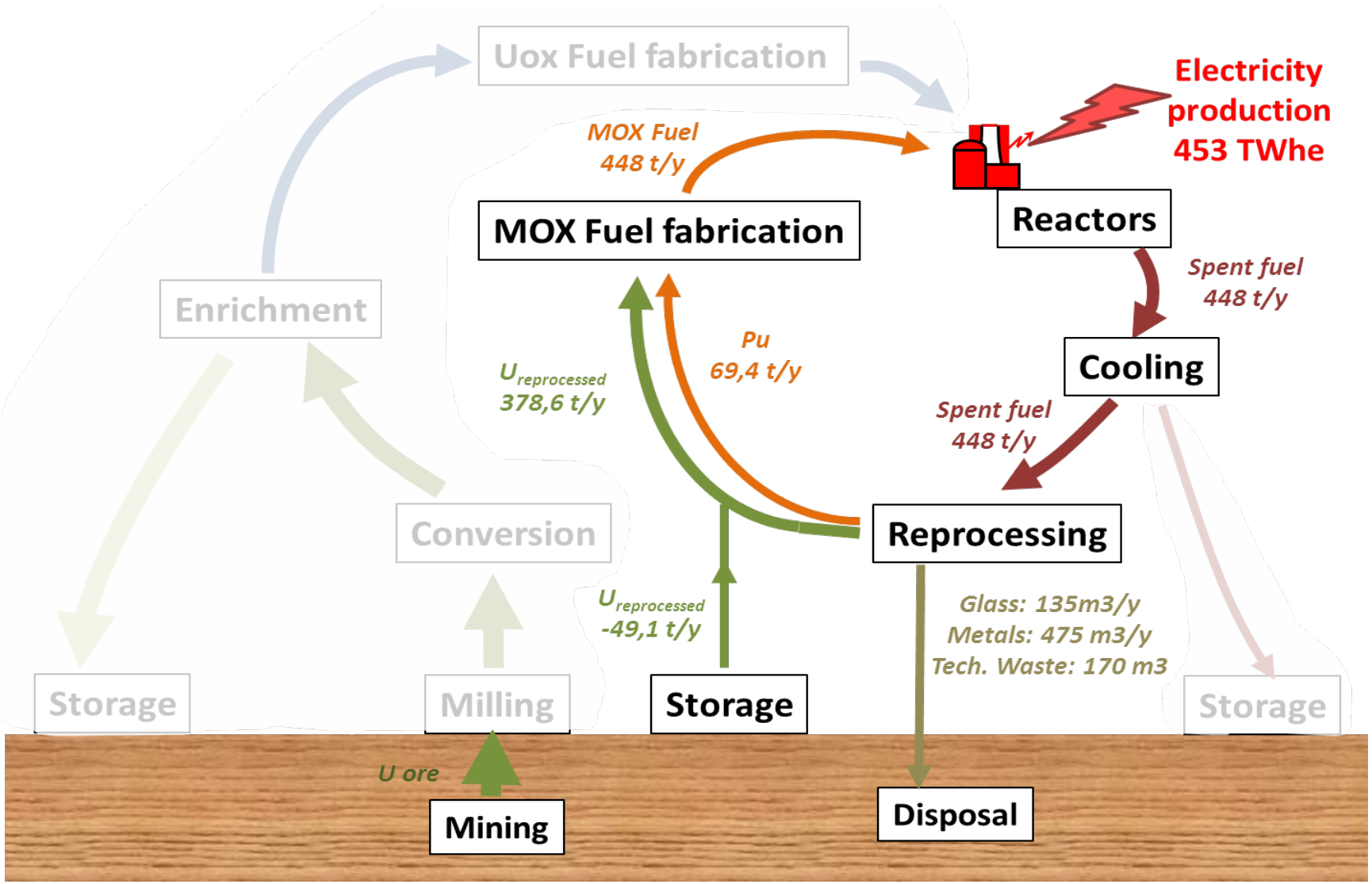
Corium-Water facility
+
FCI up to Steam explosion
Temp water : ~80°C
Mass: 50 to 500 kg
Steam quenching system
X-ray imaging

- ✓ **Corium temperature > 2850°C**
- ✓ **Separation Water/Sodium rooms**
- ✓ **Handling of large mass**
- ✓ **One furnace – 3 test facilities**
- ✓ **Electric power ~ 1 000 kVA**

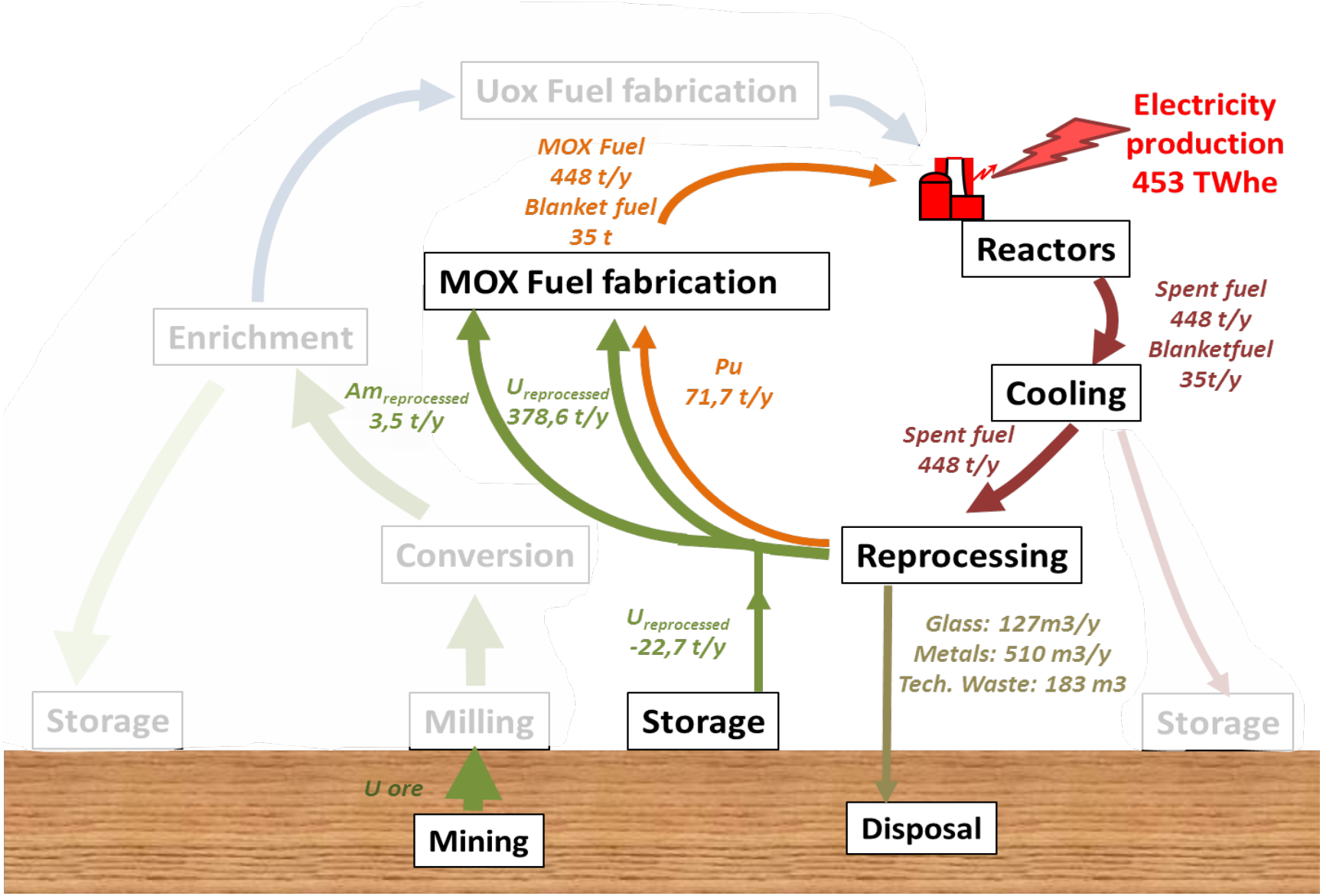
Future fuel cycle options



Future fuel cycle options



Future fuel cycle options

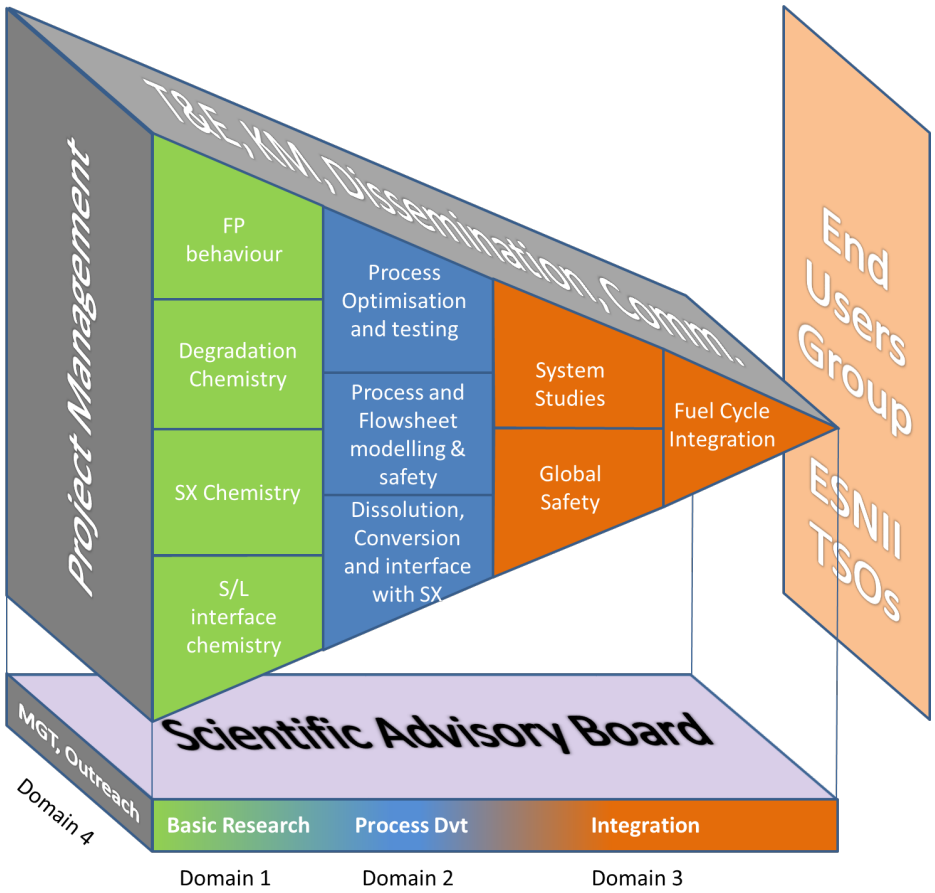


H2020 - GENIORS

GEN IV Integrated Oxide fuels recycling strategies

6/2017 – 5/2021
24 Partners, 11 countries
Budget 7,5M€, EU grant 5M€

CEA	JRC-ITU	UEDIN
CHALMERS	JUELICH	UNIMAN
CIEMAT	KIT	ULEEDS
CNRS	LGI	UREAD
CTU	NNL	ULANC
ICHTJ	POLIMI	UNIPR
IIC	SCK-CEN	EDF
IRSN	TWENTE	AREVA



Cooperation agreement with DOE in preparation,
following the one previously existing between SACSESS and DOE

Conclusion

- A very important research program on all the parts of the nuclear fuel cycle
- Several projects of new research facilities
- Numerous international collaborations

Conclusion

- From the president programme (March 2017)
  - Doubling the renewable energy production by 2022
  - Decreasing the share of nucelar energy down to 50% at « the horizon 2025 »

- At the state level (interview of the French Prime Minister, July 2017)
  - Nuclear power plants will close, at mid-term *
  - But no agenda yet**
  - Be prudent!
  - Reaching a more balanced energy mix always involving nuclear energy
  - Taking into account
    - technological elements on the current reactors
    - the evolution of the electricity consumption
    - the industrial maturity of the other energy sources (offshore wind farms)

* At least two, automatically, when the EPR will start to respect the 63,2GW_e installed power…
** The Minister of ecology announced that, mathematically, 17 reactors should be shutdown by 2025 to reach the 50% of nuclear electricity in the mix

DE LA RECHERCHE À L'INDUSTRIE

cea den

THE JHR AND ITS ANCILLARY FACILITIES AS AN "ICERR" : FIRST DESIGNATION –SEPTEMBER 2015

Fully compliant with the French Capacity Building Initiative based on 4 pillars:

- Human Resources Development
- Education & Training
- Knowledge Management
- Knowledge Network

IAEA ICERR labelling obtained on 14th September 2015

First institutes signed their affiliation during the 60th IAEA General Conference : **Slovenia (JSI), Morrocco (CNESTEN) and Tunisia (CNSTN).**