



NEA Workshop on Innovative Techniques and Technologies to Support Characterisation and Decommissioning of Complex and Legacy Sites

29 November – 01 December
2022
France

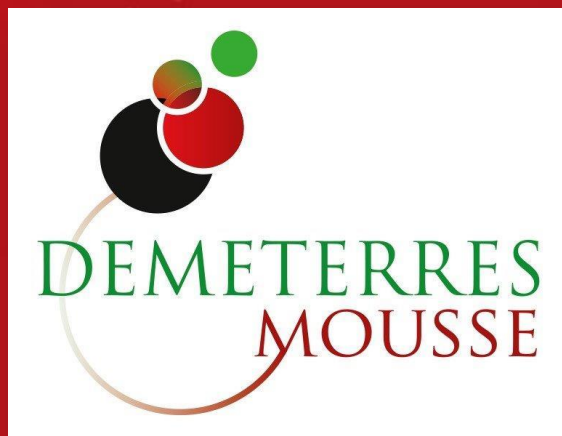
DE LA RECHERCHE À L'INDUSTRIE

Innovative Technologies for Soil Decontamination and Stabilization

1st December 2022

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- ▶ With the “**France Relance**” and “**France 2030**” investment plans, the French government supports **breakthrough innovation and its industrialization in the nuclear field**
- ▶ With regard to **radioactive waste treatment and conditioning, and decontamination**, a dozen projects have been proposed by CEA and fifteen partners who combine their skills and experimental resources.
- ▶ Regarding **soils decontamination and stabilization**, two projects are of interest:
 - **DEMETERRES MOUSSE** promoting the Flotation foam technology for soil decontamination and potential reuse
 - **SOLVERIS** for soil radiological stabilization by in situ vitrification using the GeoMelt® ISV™ technology to create a new waste management route in France, possibly decreasing the constraint on waste storage sites
- ▶ Their main generic objectives are related to:
 - development of decontamination, and treatment and conditioning methods
 - waste volume reduction
 - remediation of contaminated sites, even in post-accidental situations



This project has been funded by the French government as part of the French "Economy Booster Initiative"

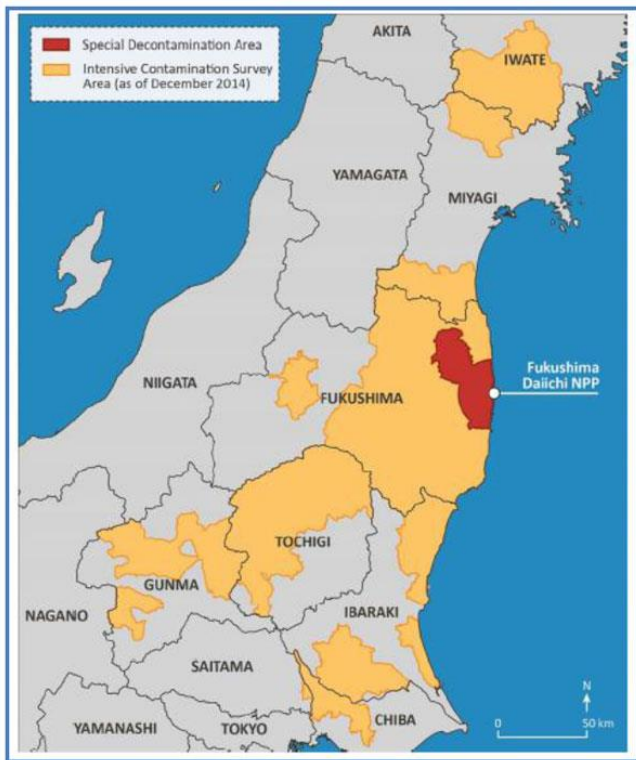
Ce projet a été financé par le gouvernement dans le cadre du plan de Relance

Remediation of contaminated soils in post-nuclear accident situations using the Flotation foam technology:

The DEMETERRES MOUSSE project

ASSESSMENT OF THE DEMETERRES PROJECT

- ▶ A project born in the post-Fukushima context and bringing together 6 partners: **CEA, Orano, Veolia, IRSN, INRA and Cirad**



- An emergency solution: **soil excavation** over ≈ 5 cm generating **several million m³** of waste (>4 mSv/year)
- Multiplication of **storage sites** in living areas



ASSESSMENT OF THE DEMETERRES PROJECT

- ▶ A project born in the post-Fukushima context and bringing together 6 partners: **CEA, Orano, Veolia, IRSN, INRA** and **Cirad**
- ▶ **Key figures.** 4 patents, 2 marketing agreements, 14 doctoral and post-doctoral students, 28 rank A publications, 3 Franco-Japanese seminars
- ▶ **Effluent decontamination. 10 processes tested** that have enabled the commercial development of a specific Cs adsorbent called **Sorbmatech®Cs**
- ▶ **Phytotechnologies. Phytoremediation** (*Arabidopsis* and rice) enabling the increase of the Cs extraction from the soil and **Safe Use** (*Arabidopsis*) ensuring the absence of Cs in the plant
- ▶ **Soil decontamination. 4 technologies tested:** supercritical CO₂, 2 leaching methods and **flotation foams**

GOALS AND CHALLENGES

- ▶ Increase TRL and industrialize an innovative soil remediation technology: the **Flotation foam technology** useful for **post-accident decontamination** or **contaminated soil remediation operations**
 - **Selective** for contaminants having an affinity with clays (*e.g.*, radiological: Cs and Sr, or not: heavy metals...), through **radioactivity concentration** in the soil particles <20 µm
 - **Non intrusive**, *i.e.*, enabling reuse of decontaminated soils
 - **Reduce waste volumes** and thus limit their storage costs (declassification)
- ▶ Apply **decision making tools** and **models** developed to support the **French post-accident management strategy**, in order to provide operational assessment elements to decision-makers to choose and implement **decontamination strategies**

BUDGET

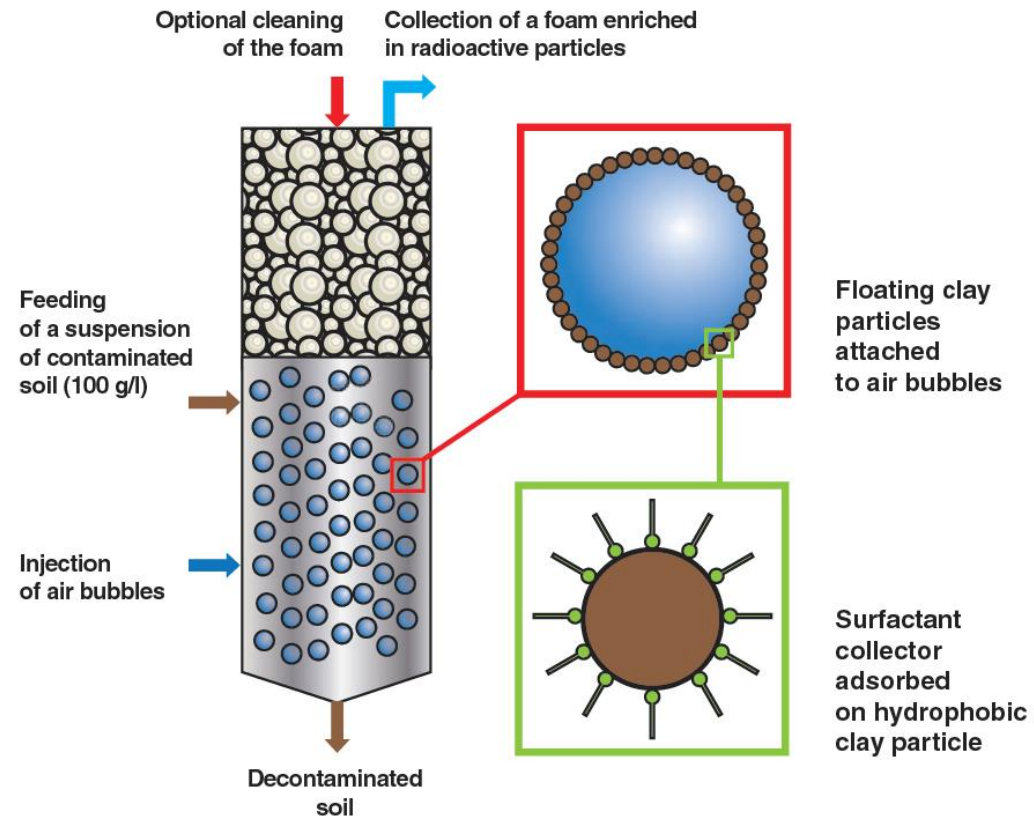
- ▶ 6 M€ budget supported at ≈30% by the French state

MULTI-PARTNERS PROJECT

- ▶ **CEA** (coordinator), **Orano**, **Veolia**, and the French public expert in nuclear and radiological risks (**IRSN**)

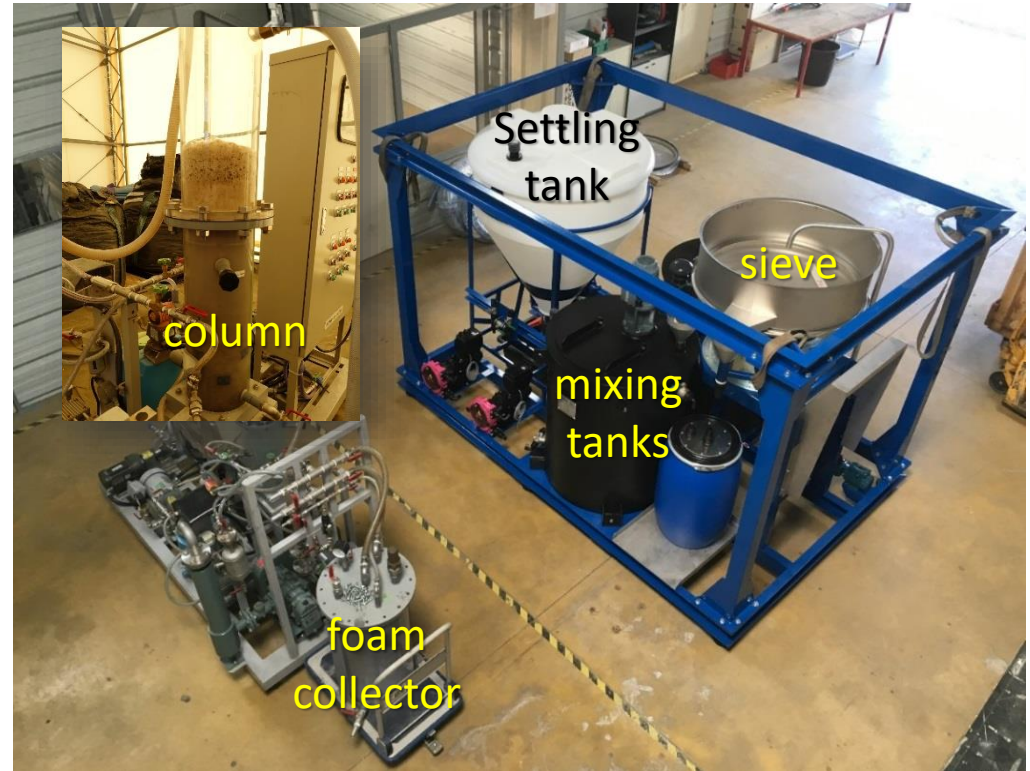
FLOTATION FOAM TECHNOLOGY PRINCIPLES

- Separation of the **smallest cesium-selective clay particles**, which **float** at the top of the column
- The foam represents **10 to 25 wt.% of the soil weight** and contains about **80 to 90% of the contamination**
- At the bottom of the column, **70 to 90% of the weight of the soil** can be **reused** and keep their fertility to be cultivated



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- ▲ *First version of the flotation foam pilot tested in Japan in 2017, whose technological maturity will be improved during DEMETERRES MOUSSE project*

AN HEIR TO THE DEMETERRES PROJECT (2013-2020)

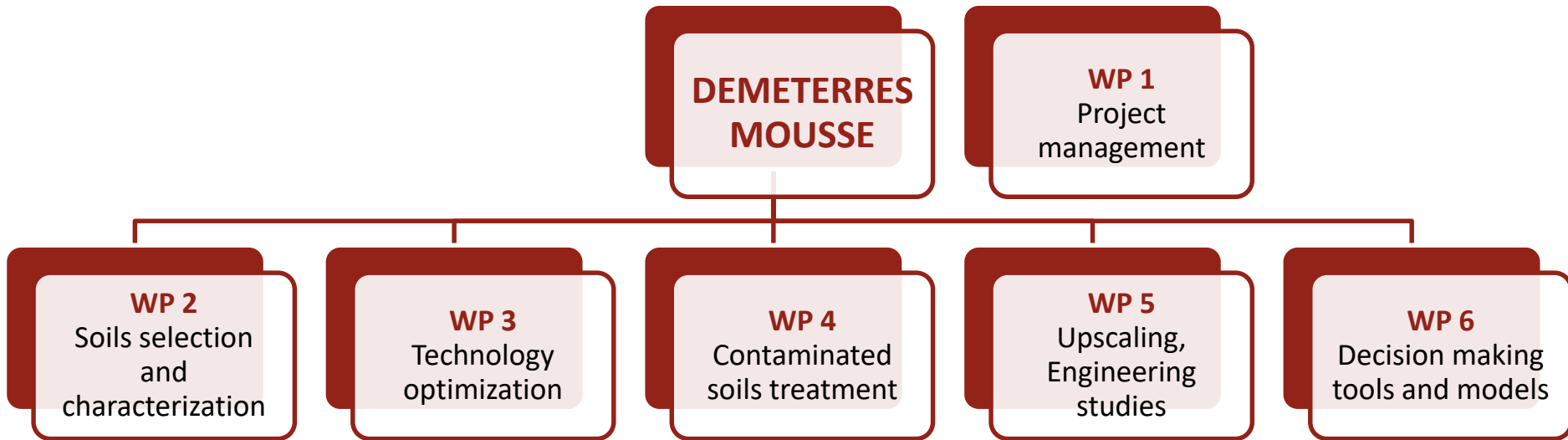


- ▶ **Patent WO 2013/167728 A1**
- ▶ **2 test campaigns in Japan**
 - Tsukuba: preliminary tests
 - Okuma: official tests sponsored by the Japanese Ministry of environment
- ▶ **Waste volume reduction:**
3.6 to 7.4
- ▶ **Decontamination factor:**
1.5 to 3.5
- ▶ **Reusable soil** that keeps its agronomic properties

DEMETERRES MOUSSE GUIDELINES

- ▶ **Characterization of the soils to be treated** to optimize the process parameters according to their physicochemical and radiological properties
- ▶ **Improve the foam flotation technology and increase its TRL** by drawing on the feedback from the tests conducted in 2017 and build a **2nd generation pilot** to improve **soil pre-treatment**, add an additional flotation module to **increase both treatment capacity and decontamination factor**, promote **water recycling** to limit the amount of secondary waste
- ▶ **Testing the versatility of the technology** in France **and overseas** with contaminated soils from waste storage or under decommissioning sites
- ▶ Design the basis for a **commercial model**: from a treatment capacity of 30 L/h to 200 L/h before being extrapolated to a **fully qualified system** up to 100 m³/h
- ▶ Development of **decision making tools** and **models** to support **the French post-accident management strategy**

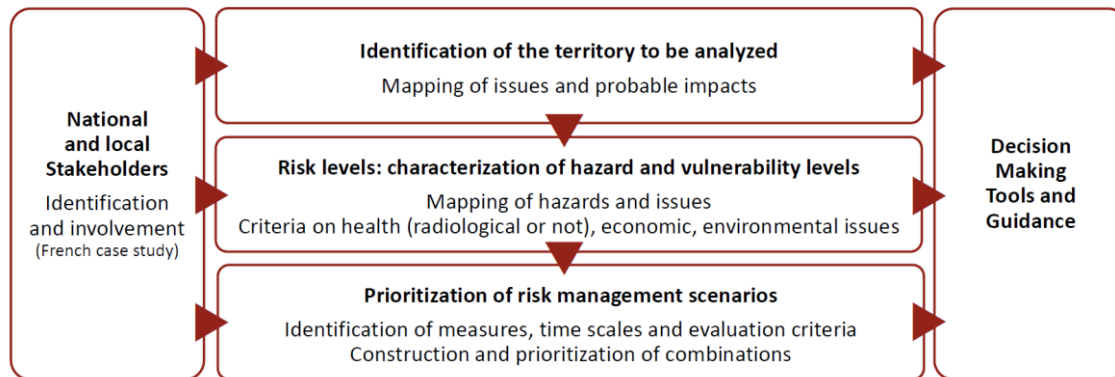
STRUCTURE OF THE DEMETERRES MOUSSE PROJECT



- ▶ **CEA** Project management and scientific and technical expertise
- ▶ **Orano** Conduct of decontamination and engineering operations
- ▶ **Veolia** Technical expertise and engineering
- ▶ **IRSN** Development of decision making tools for post-accident management

MAJOR PROGRESS AND OUTLOOKS AT A GLANCE

- ▶ Research and selection of **various French contaminated soils** (clay contents) of interest for **pre-test campaigns : preliminary soils characterization** phases
- ▶ Preparation of the **final design** of the optimized pilot and preparation of supplies for a construction in 2023, before **onsite test campaigns**
- ▶ Discussions with French or foreign institutions interested in the industrial demonstration of the decontamination process on their soils
 - the first tests in 2017 in Japan were linked to a post-accident decontamination phase
 - the case study of DEMETERRES MOUSSE will focus on **soils remediation during D&D**
- ▶ Methodology for **decision making tools** and models development to support the French post-accident management strategy





*This project has been funded by the French government
as part of the "France 2030" plan*

*Ce projet a été financé par le gouvernement dans le
cadre de France 2030*

soil radiological stabilization by in situ vitrification using the GeoMelt®
ISV™ technology

The SOLVERIS project



SOLVERIS PROJECT (2022-2025)

GOALS AND CHALLENGES

- ▶ **In situ treatment** of contaminated soil and buried radioactive waste to **reduce radiological and chemical risks**
- ▶ Develop an **industrial route** for the **stabilization** of contaminated sites in support of the radioactive waste management strategy in France
- ▶ **Pre-industrial demonstration in France** of the **in situ vitrification GeoMelt® ISV™ technology** to radiologically stabilize soil, wells, pits containing waste or waste buried underground (VLLW, LLW, LL-ILW)
 - In situ waste stabilization pending complete remediation
 - Facilitation of the waste recovery (if necessary)

BUDGET

- ▶ 6 M€ budget supported by the French state

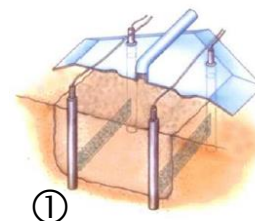
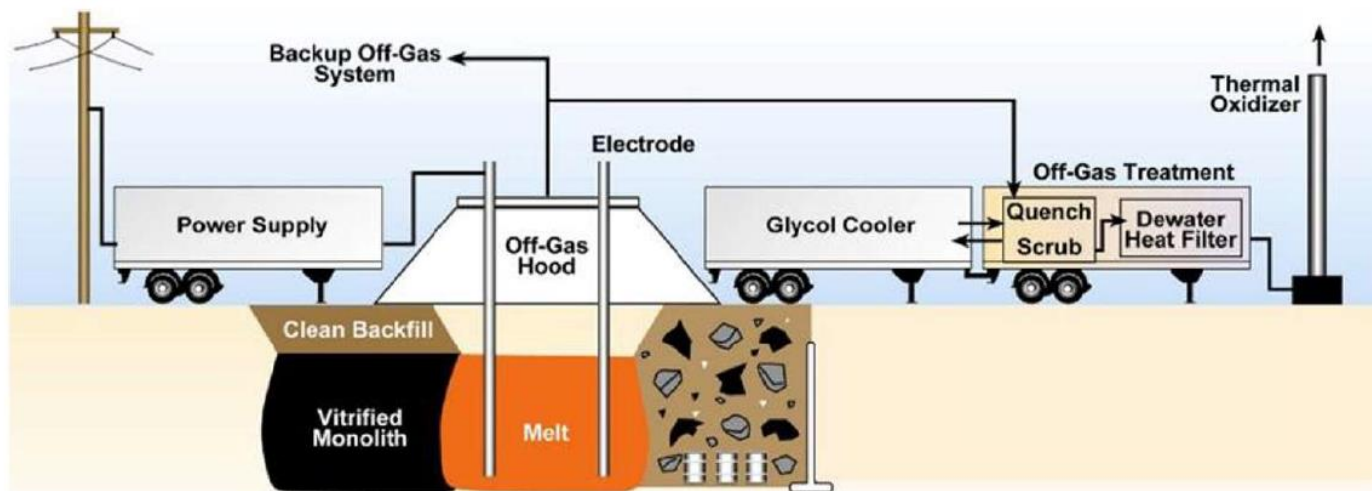
MULTI-PARTNERS PROJECT

- ▶ **Veolia** (coordinator), **CEA**, the French Geological Survey (**BRGM**), **Assystem** (Engineering and digital for energy transition), and **E.C.I. MECA** (Design and manufacture of special machines)

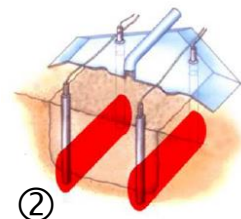


GeoMelt® ISV™ TECHNOLOGY PRINCIPLES

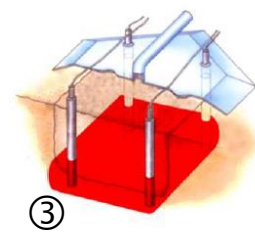
- ▶ Insertion of **graphite electrodes** in the soil
- ▶ Passage of current enabling a **heating** by Joule effect
- ▶ Soil **melting** (1,000-1,500°C) and formation of a **vitreous material**
- ▶ The **gases** produced are captured and **treated**
- ▶ The process is efficient for a **wide variety** of soils and waste
- ▶ Radionuclides are **trapped** in the **glassy matrix**
- ▶ Vitrified material is highly **resistant to leaching**



①



②



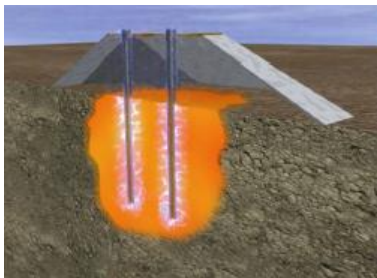
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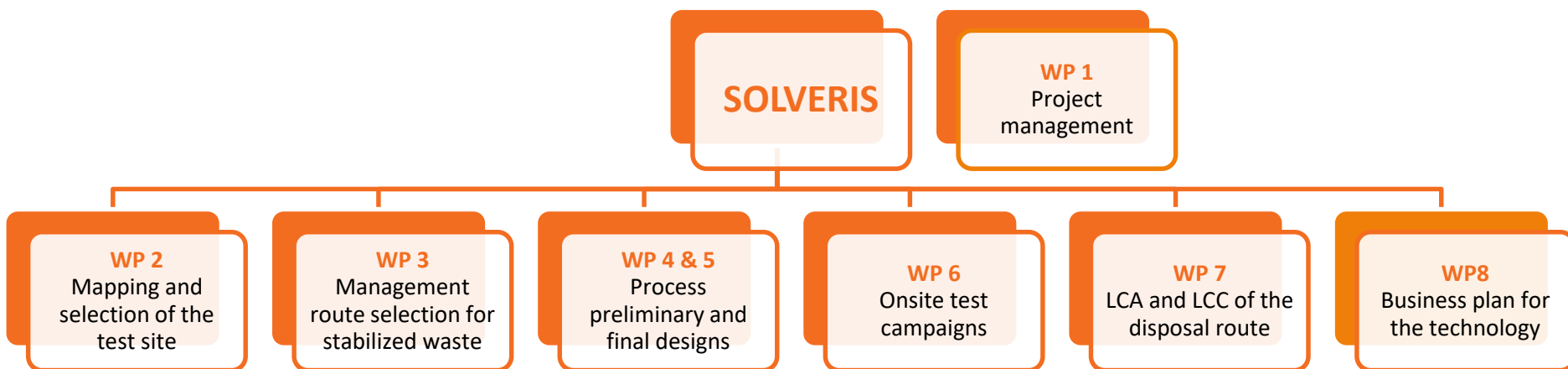
SOLVERIS GUIDELINES

- ▶ Define and implement the necessary **adaptations** of the in situ GeoMelt® ISV™ thermal treatment process for application in France
- ▶ Map the appropriate French sites (location, geometry, level of activity) for testing the technology and **select the ad hoc site for on-site testing**
- ▶ Develop and carry out **qualification test programs** for GeoMelt® ISV™ application for various industrial, environmental and regulatory contexts
- ▶ Develop **safety cases** for future industrial application of the technology
 - Demonstrate **vitrification in safe conditions**: efficient operation of off-gas treatment
 - Investigate **scenarios for waste management**: **design of materials meeting the WAC** and according to the site geology, or consider “**on-site storage**”
- ▶ Carry out the **technical, economic and environmental assessment** of this new disposal route for contaminated soil management





STRUCTURE OF THE SOLVERIS PROJECT



- ▶ **Veolia** Supply of the GeoMelt® ISV™ in situ vitrification technology and industrialization of the process
- ▶ **CEA** Expertise in vitrification and treatment of radioactive waste, owner of nuclear sites and waste to be treated
- ▶ **BRGM** Knowledge of the subsoil, expertise in the analysis of environmental performance, and sustainable management of resources
- ▶ **ASSYSTEM** Engineering skills, expertise in risk analysis, safety analysis, and stabilized waste management scenarios
- ▶ **E.C.I. MECA** Design and construction of the demonstrator



MAJOR PROGRESS AT A GLANCE

- ▶ Project very recently launched in September 2022
- ▶ Priority is given to the **site selection for onsite testing** through a **mapping** of all potentially suitable French sites
- ▶ Screening study of the potential sites through 4 main families of criteria:
 - waste/soil type
 - adaptation to regulatory constraints
 - technical constraints for setting up the GeoMelt® ISV™ process
 - ability to characterize the site before and after treatment



- ▶ DEMETERRES MOUSSE and SOLVERIS projects are structuring the CEA's research, development and innovation for the next 5 years
- ▶ These projects meet innovation needs in the field of radioactive waste management for nuclear operators, and contribute to promote the French nuclear industry internationally
- ▶ **Waste volumes limitation** by promoting decontamination and reuse of materials: DEMETERRES MOUSSE (CEA, Orano, Veolia, IRSN) targets the industrial development of the **eco-responsible Flotation foam technology** for **soils decontamination**, enabling the **potential reuse** of decontaminated soils
- ▶ **New treatment and conditioning methods** to improve radioactive waste management by creating **new management routes** and **increasing process TRL**: SOLVERIS (Veolia, CEA, BRGM, Assystem, E.C.I. MECA) creates a new industrial field for the **remediation of contaminated sites based on the GeoMelt® ISV™ vitrification process**, enabling the **radiological and chemical stabilization** of contaminated soils



Thank you for your attention



DEMETERRES MOUSSE and SOLVERIS projects have been funded by the French government as part of the “France Relance” and “France 2030” plans