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Delivering D&D Projects Through Sustainable, Innovative and Efficient Waste-led Decommissioning

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INTRODUCTION

DECOMMISSIONING AND RADWASTE MANAGEMENT CHALLENGES: TO CLOSE THE LIFE CYCLE OF NUCLEAR FACILITIES AND PROMOTE SUSTAINABLE SOLUTIONS ALLOWING RESOURCES PRESERVATION

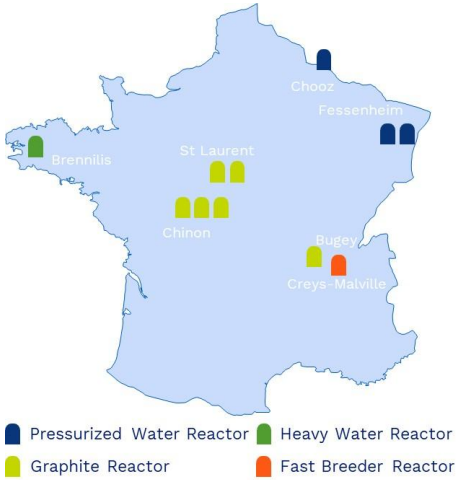
More than 200 reactors already shutdown

Fuel cycle facilities + research facilities More to come in the next decades – Large fleet in Germany, UK, US, France, Japan, Belgium…)

→ ***Demonstrate our capacity to close the life cycle of existing reactors***

In the coming years, significant **increase of radwaste production (metals, graphite…) from decommissioning operations**

→ ***Propose sustainable solutions with a circular economy logic to save repository capacities, raw materials consumption and CO2 production***



11 reactors owned by EDF under dismantling

+ nuclear facilities (graphite silos, nuclear laboratory, ….)

4 different technologies (PWR, BWR, graphite, FBR)

More than 500 000 tons of metallic radwaste produced in the next decades

Need to supplement the waste management system with **on-site or centralized treatment / conditioning / temporary storage facilities**

In 2016, decision of EDF to create a subsidiary fully dedicated to D&D activities:

- *To support its **own projects** / to provide proven solutions to the **international market***
- *To address dismantling and waste management subjects in a coordinated and optimised way **– A waste-led decommissing approach***

INTRODUCTION

A FULL RANGE OF INNOVATIVE SOLUTIONS FOR WASTE-LED DECOMMISSIONING

cyclife EDF GROUP

- Waste2Glass
- cyclife France
- cyclife Sweden
- cyclife UK
- cyclife aquila nuclear
- cyclife engineering
- GRAPHITECH
- cyclife Germany
- cyclife Japan
- cyclife digital solutions

About 1300 collaborators

Turnover 230 M€
40% à internationally

5 Regional Market Units
France, UK, Germany, Scandinavia, Japan

Off-site transport in large pieces to reduce operations on site (cuttings…) and associated waste production
Recycling and circular economy approach for storage/raw materials and CO2

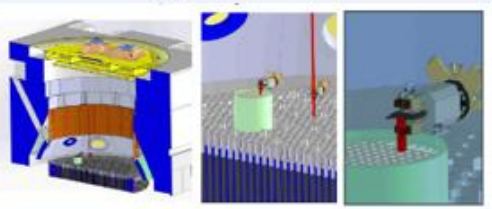
3 factories (Sweden, UK, France) and unique know-how in the processing of large metal components

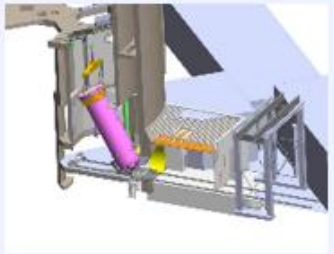
Design and build new capabilities

Expansion capacity in Sweden: 5,000 t/year

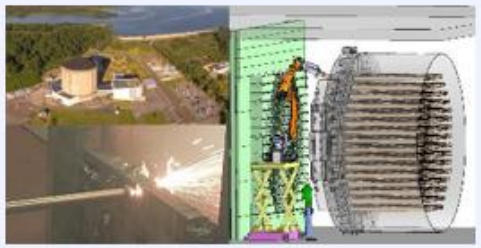
Design new workshops/new installations (Fr, Bel)

Scenarios, tools and processes for dismantling different types of reactors





Extraction of PWR steam generators (Fr, Ger)



Robots and advanced cutting tools for the dismantling of complex reactors (France, UK, Lithuania)

Digital tools to simulate operations and train operators

A systemic decommissioning/waste approach to reduce interfaces, optimize schedules, costs and final waste volumes

INTRODUCTION

3 facilities

Sweden, France and the UK

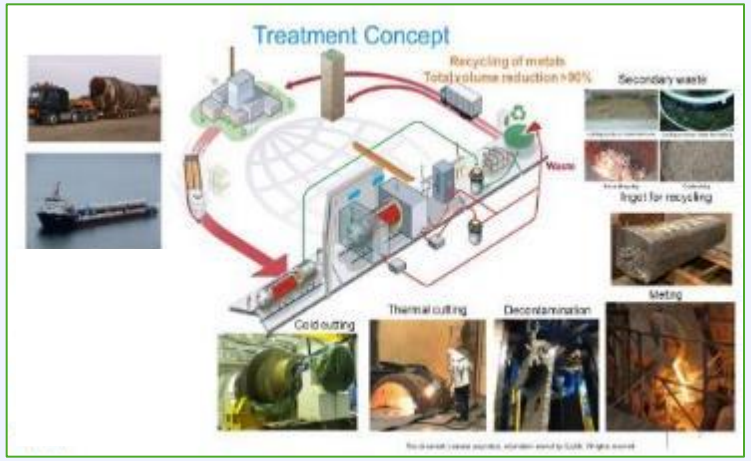
- ✓ Size-reduction and shot blasting
- ✓ Incineration
- ✓ Pyrolysis
- ✓ Large components cutting
- ✓ Melting
- ✓ Clearance

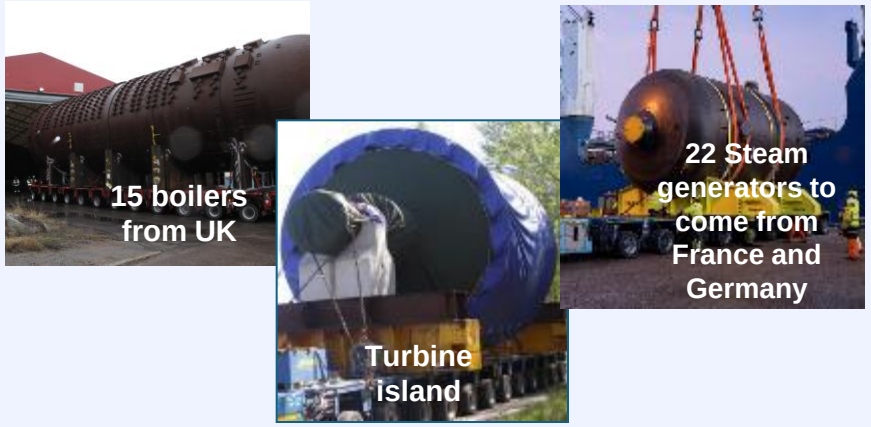
Off-site transport in very large pieces allows to reduce operations on site (cuttings…) and waste production due to these operations but also shorten decommissioning schedules (Risks and Costs reduction)

Recycling and circular economy approach for storage/raw materials and CO2

CYCLIFE CENTRALIZED WASTE TREATMENT SOLUTIONS

A unique know-how in large components treatment field

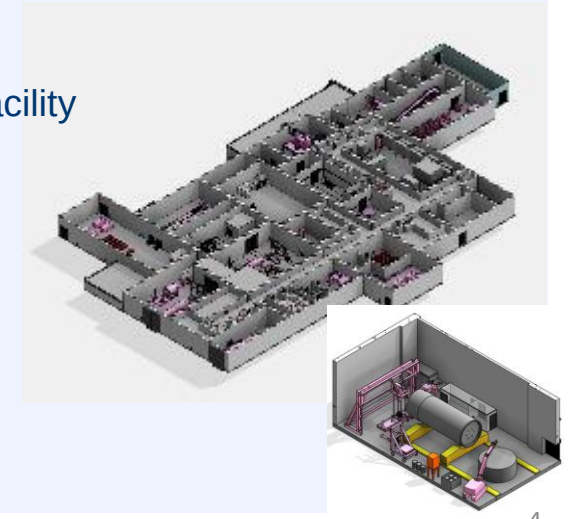




New capacities to come

Construction of capacities extension by Cyclife Sweden in 2025:
+5,000 t/an

French new facility **designed by Cyclife Engineering** in 2031:
16,000 t/an

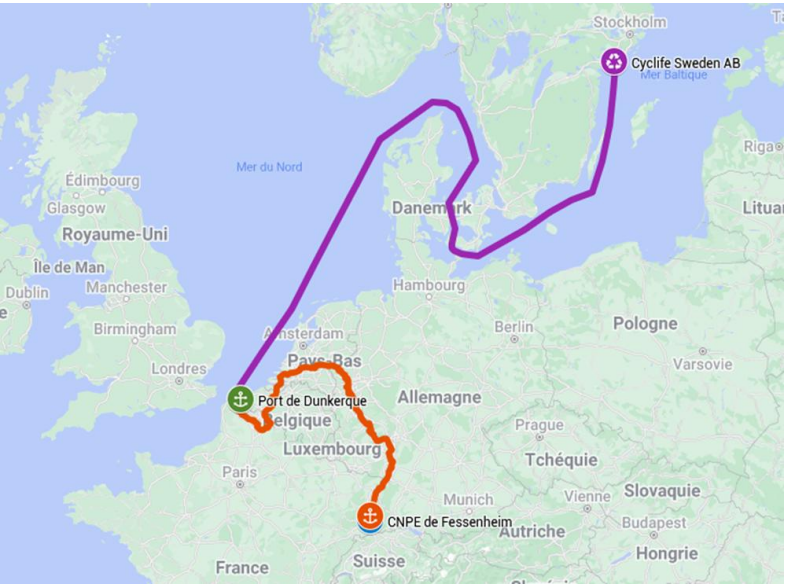


CASE STUDY

(FR) – UPPER PARTS OF STEAM GENERATORS

CYCLIFE SWEDEN

6 PWR steam generator upper parts - 650t
shipped from Fessenheim NPP to Cyclife Sweden for processing



Reloading at Dunkirk harbour

Arrival to Sweden

CASE STUDY

(FR) – UPPER PARTS OF STEAM GENERATORS

CYCLIFE SWEDEN

A successful pilot project

100% of the ingots generated recycled to new products
Residues to be disposed in France

Ingots for recycling

Well characterized and documented residues for return

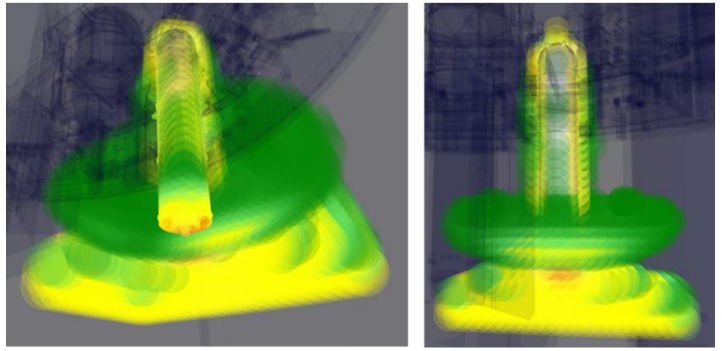
CASE STUDY

(FR) – PRESSURIZER DECOMMISSIONING SCENARIO SIMULATION

CYCLIFE DIGITAL SOLUTIONS

3D Model to simulate dismantling scenarios

Dose rate computation at the place of work obtained with DEMplus® for nuclear



Pressurizer 3D dose mapping displayed by DEMplus® for nuclear

The simulation software allows to reduce dangerous events and secure the critical path by identifying the critical elements, bottlenecks and stoppers.

Scenario	Collective dose (H.mSv)	Actual lead times (h)	Number of workdays (1x8)	Number of calendar days (1x8)
A	74	591	128	179
A bis	138	767	157	220
D	18	903	194	271
E	123	525	116	162

Example of 4 possible scenario simulation results obtained with DEMplus®

40% lead time savings

45% radiological risk reductions

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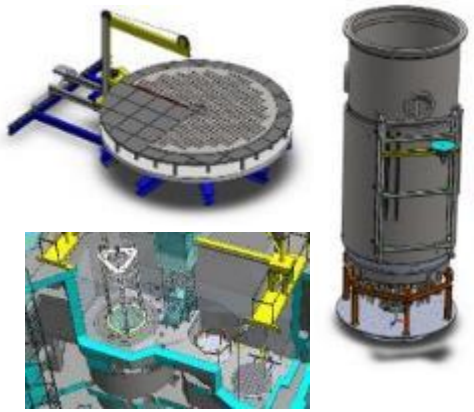
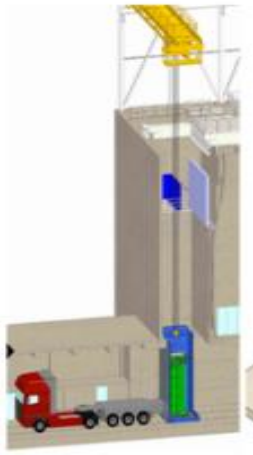
KEY STAKES FOR DISMANTLING AND WASTE EXTRACTION OF LWR REACTORS

The feasibility of LWR dismantling has been demonstrated, the main studies are now focused on: scenario, operations kinematics and tools design optimization
Another key issue is the reuse of tools for a fleet of reactors -scale effect

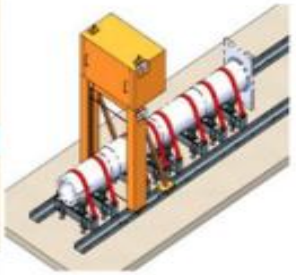
Example of works performed by Cyclife Engineering for Fessenheim NPP dismantling

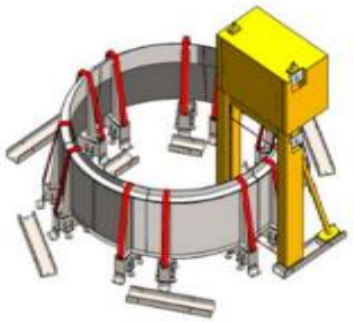


RPVi dismantling tools

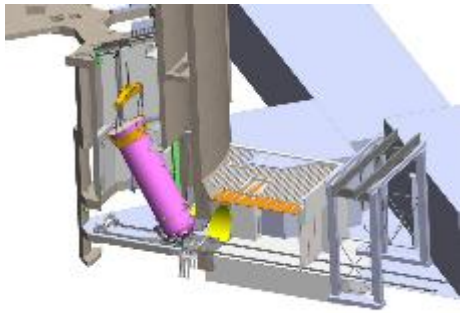


Fuel building dismantling





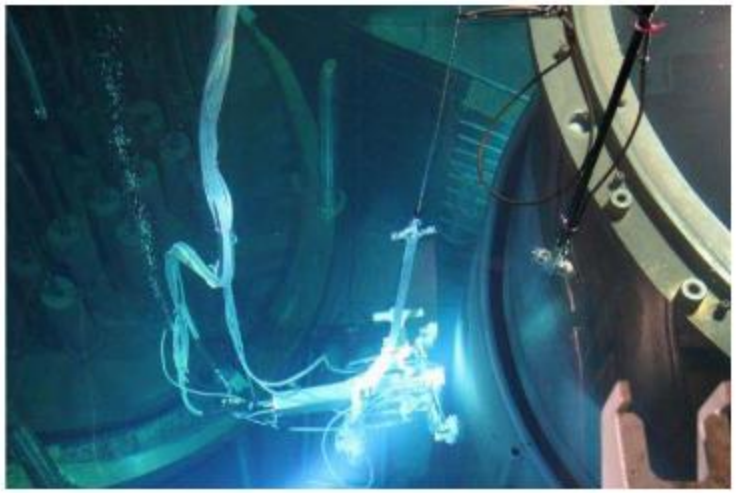
Extraction of steam generators scenario and tooling design



Steam generators and Large components off-site treatment and recycling

Preliminary works and especially characterization campaigns are essential for a waste-led decommissioning approach

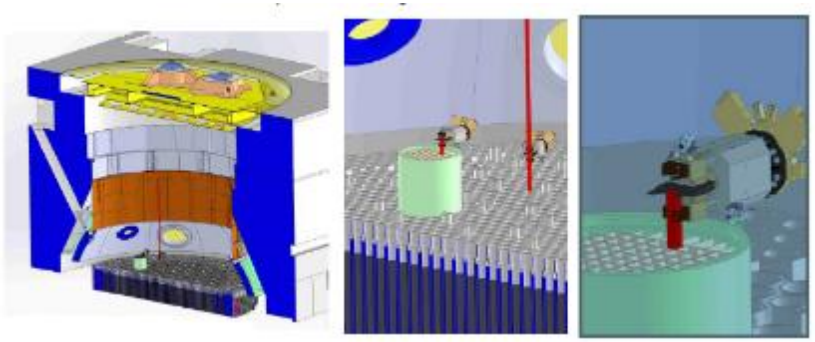
Sampling machine for LWR reactors

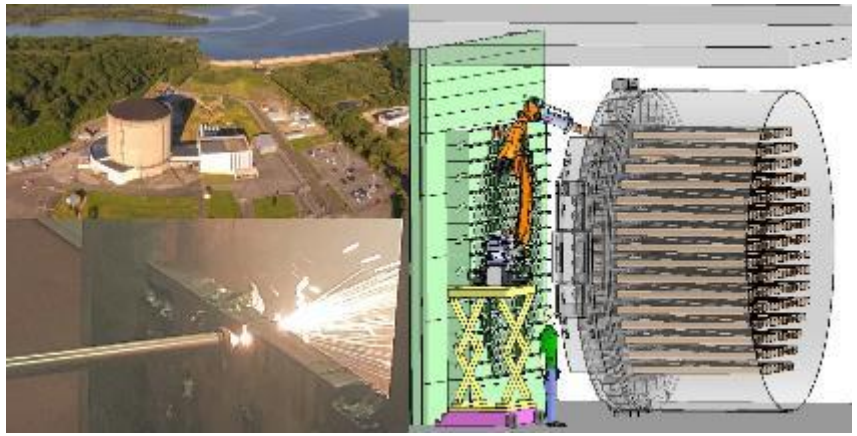


KEY STAKES FOR DISMANTLING AND WASTE EXTRACTION OF GRAPHITE AND OTHER TECHNOLOGIES OF REACTORS

Some reactor technologies are more complex to dismantle and needs to develop advanced and remoted solutions

Remoted-tools developed by Graphitech for Chinon A2 graphite reactor dismantling (France)





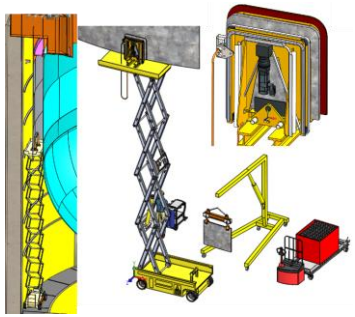
Robot developed by Graphitech to extract tubes from and horizontal HWR (France, Brennilis)

Preliminary tests on full-scale mocks-ups are very useful to optimize the final operations and Cyclife has the chance to have an « industrial demonstrator » to qualify

Graphite retrieval

Laser tests

Detailed engineering studies for the dismantling of FBR Creys-Malville



CASE STUDY

(FR) – GRAPHITE REACTORS DECOMMISSIONING

GRAPHITECH

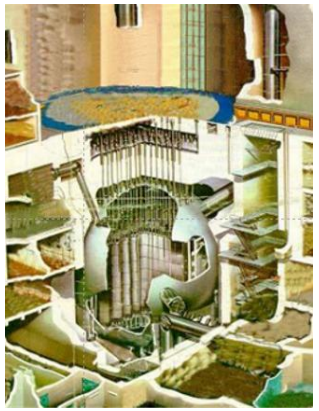
Graphite reactors technologies in the world

There are 4 distinct "families" of graphite-moderated reactor.

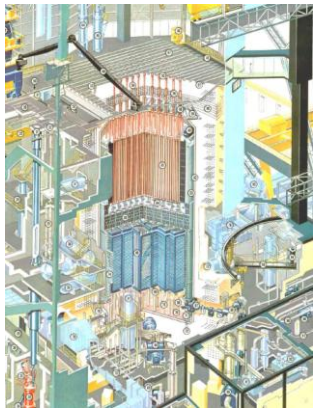
Each different in their functionality, type of fuel, coolant, etc.

UNGG

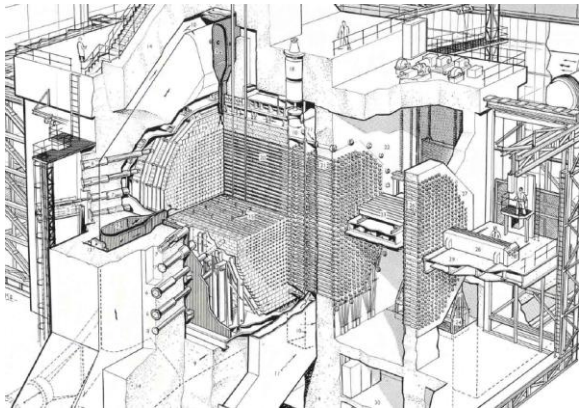
Chinon A2 (France)



St-Laurent (France)
Vandellos (Spain)

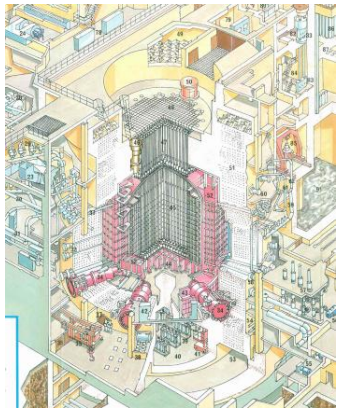


G1 (France)

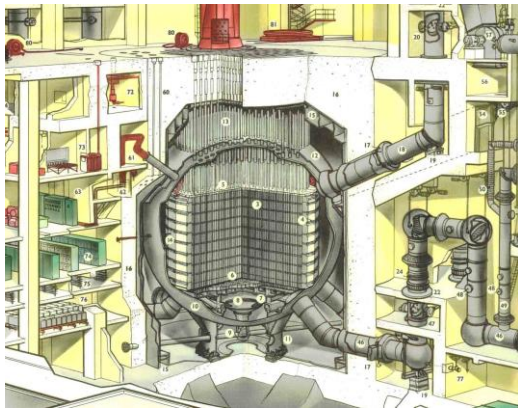


AGR

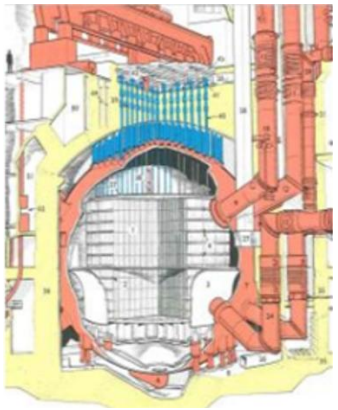
Heysham 2 (UK)



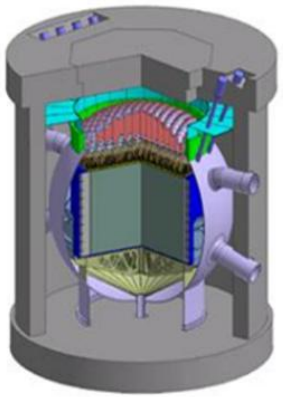
MAGNOX



Trawsfynydd (UK)

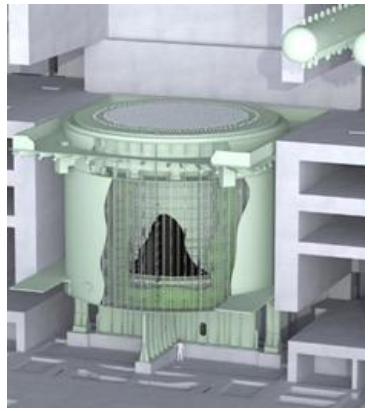


Latina (Italy)



Tokai (Japan)

RBMK



Ignalina (Lithuania)

CASE STUDY

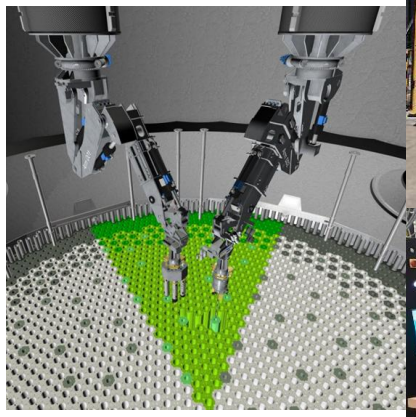
(FR) – GRAPHITE REACTORS DECOMMISSIONING

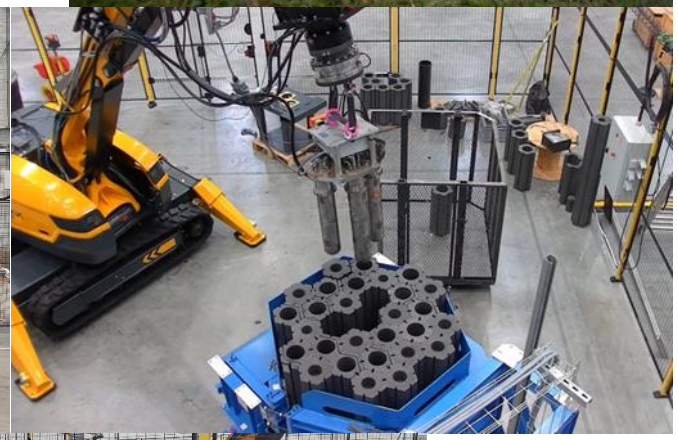
GRAPHITECH

Chinon A2: Graphitech is developing a robust and optimized methodology to be delivered by 2028

Includes design, manufacture and testing of the dismantling platform, the tool deployment system and remotely operated equipment in the Industrial Demonstrator

- Optimization of the dismantling methodology to reduce risks and optimize costs and planning
- Identification of dismantling tools and techniques to be developed and tested in the Industrial Demonstrator
- Design and manufacture of models and tools for developments, tests, training, etc.
- Design of the tool deployment system and remotely-operated tools that will be used in Chinon A2





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GRAPHITECH A JOINT VENTURE EDF VEOLIA

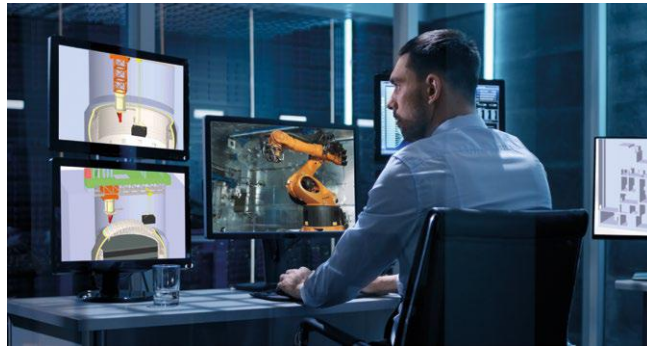
CASE STUDY

(FR) – GRAPHITE REACTORS DECOMMISSIONING

GRAPHITECH

Graphitech can provide key services through the operation of the EDF Industrial Demonstrator

Access to the Industrial Demonstrator and specialized skills to develop cutting-edge technologies and de-risk the most complex dismantling operations



Dismantling methodologies and design of associated tools and equipment: remote tooling, manipulators, platform

Carrying out physical trials to qualify and optimize dismantling tools and de-risk projects

Development and use of digital tools necessary to integrate equipment in the environment of different reactors

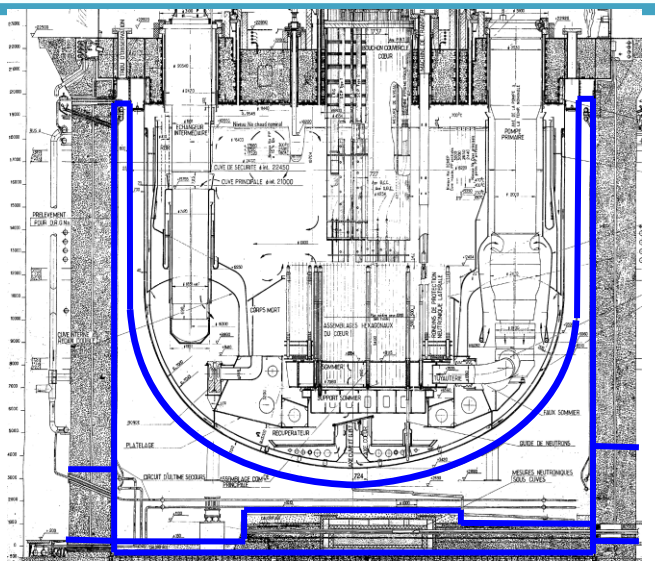
Training operators in the use of remotely-operated tools and the preparation of complex dismantling works

CASE STUDY

(FR) – FBR DECOMMISSIONING

CYCLIFE ENGINEERING

Engineering studies for dismantling the vessel well and the safety vessel – Creys-Malville, France



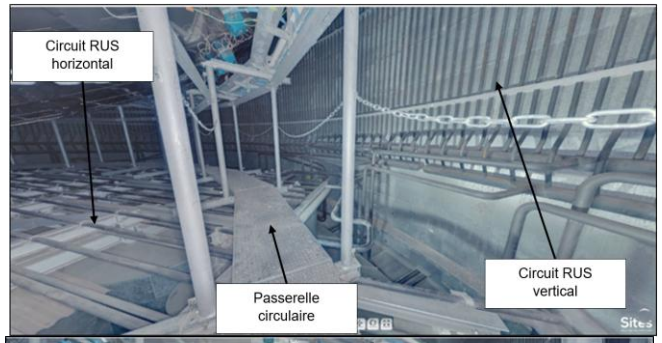
Equipment to dismantle in the vessel wells *(inside the blue zone on the left):*

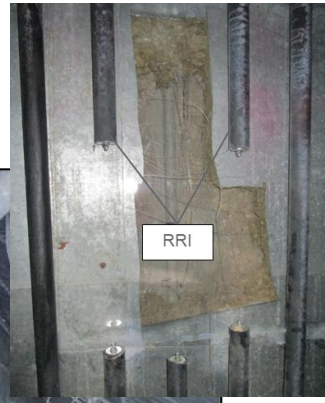
- Removing of the insulation from the safety vessel from vertical parts and domed bottom
- Removal of the cooling systems with horizontal and vertical pipes to cool the well (RUS) and the concrete (RRI)
- Removal of concrete / metallic plots
- Removal of the concrete block at the bottom of the vessel wells, housing the neutron measurement chain
- Dismantling of the **Safety vessel** (= double jacket of the main vessel, containing internals)

  Diameter: 22,5 m

  Weight: 300t

  Thickness of stainless steel: 25-30mm





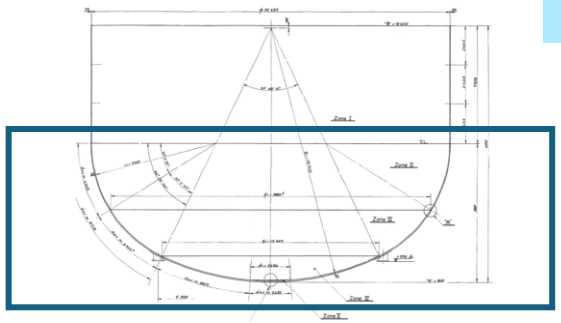
CASE STUDY

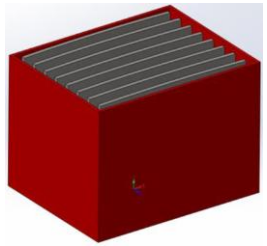
(FR) – FBR DECOMMISSIONING

CYCLIFE ENGINEERING

Engineering studies for dismantling the vessel well and the safety vessel – Creys-Malville, France

-> Optimizations proposed in the
cutting of the curved part of the vessel

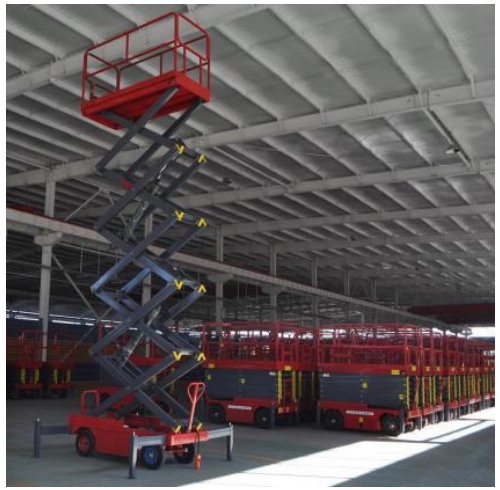


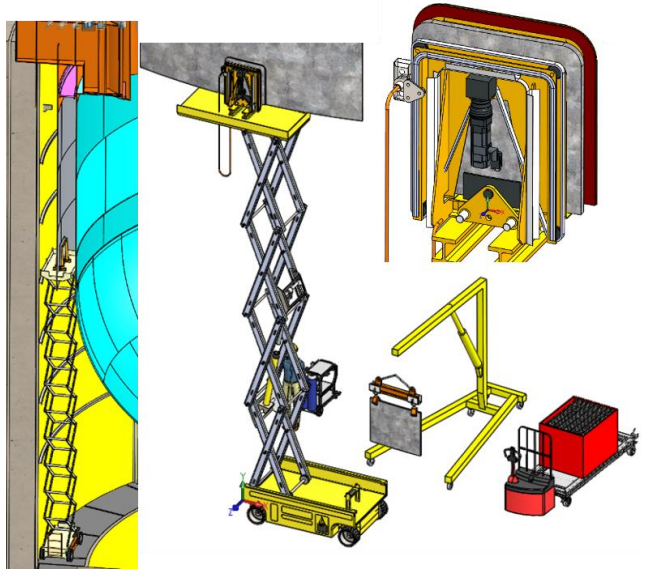


An adapted off-the shelf scissor lift equipped with a specific handling and remote plasma cutting tool compatible with the highest working height (around 12m)

- Installation of 4 workstations in parallel.
- Possible re-use for other projects
- The right equipment for the right work (*initially, the scenario proposed was based on the use of a circular platform surrounding completely the vessel)*

Cut pieces: 900 or 1200 mm * 900 mm conditioned vertically in 1m3 boxes

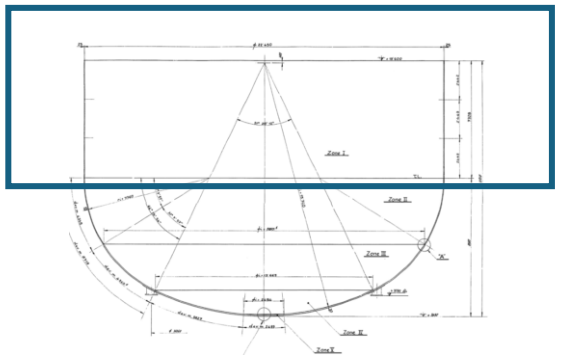




CASE STUDY

(FR) – FBR DECOMMISSIONING

CYCLIFE ENGINEERING



Engineering studies for dismantling the vessel well and the safety vessel – Creys-Malville, France

-> Optimizations proposed in the
cutting of the cylindrical part of the vessel

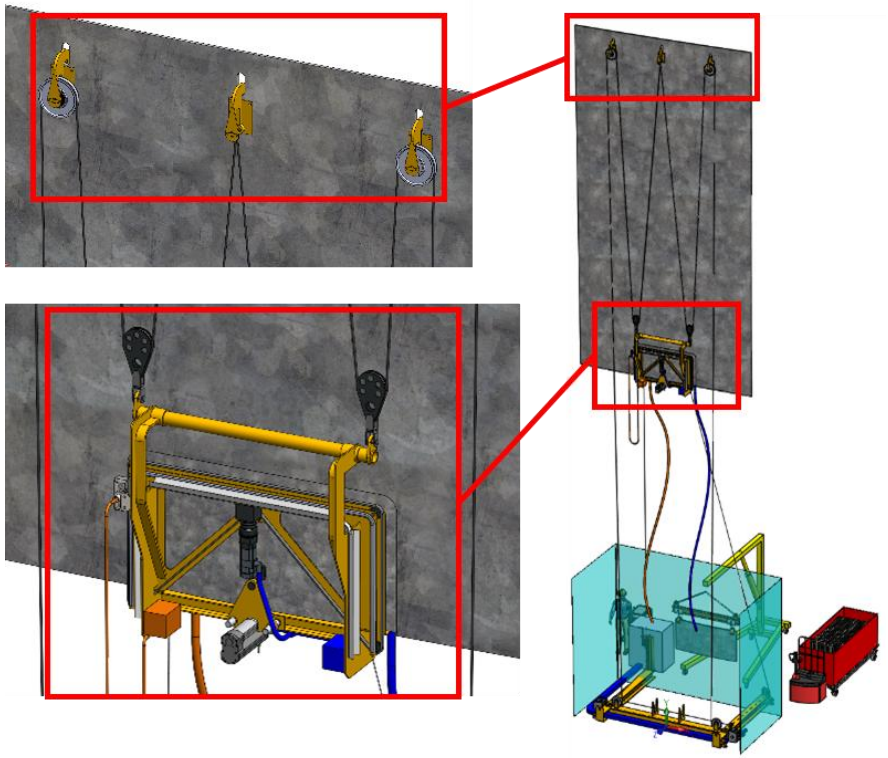
Solution: Use of a spreader bar with pulleys fixed at a height of 19m and a cable handling system incl. installation of 4 workstations in parallel

Reuse of the specific handling and remote plasma cutting tool

All operation done remotely

Once pieces are cut, they are lowered with the cables and then carried by a gallows and put in the 1m3 box as final waste.

✚ Optimization of production of waste produced (related to equipment)



-> CAPEX reduced by 20%

-> Planning reduced by 18 months

THE CRUCIAL ROLE OF DIGITAL TOOLS IN D&D ACTIVITIES

Cyclife has developed digital technology as an essential tool for the success of its deconstruction and waste management projects, both for customers and for its own plants.

- ❑ **Data capitalization and a better knowledge of the facilities (to dismantle of to operate) → Digital twins of reactors**
- ❑ **Simulation of the operations → Multicriteria optimization (dose rate, waste volumes, schedules, risks…) and risk assessment**
- ❑ **Flowrates simulation (waste, logistics…)**
- ❑ **Project management and**
- ❑ **communication with stakeholders**
- ❑ **Training of the operators**

CONCLUSION

- **Successfully delivering decommissioning projects requires waste-led decommissioning approach featuring industrial and innovative solutions,** including waste treatment, digital solutions, to reach full performance, secure decommissioning scenario and optimize solutions and operations.

- Combining **waste-led approach** and **metal recycling** enables **Cyclife teams to provide tailor-made, innovative, and proven solutions to the civil nuclear power industry at every stage of the lifecycle of a nuclear installation**, in support of a responsible and sustainable future for society and the environment.

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Thank you

www.cyclife-edf.com