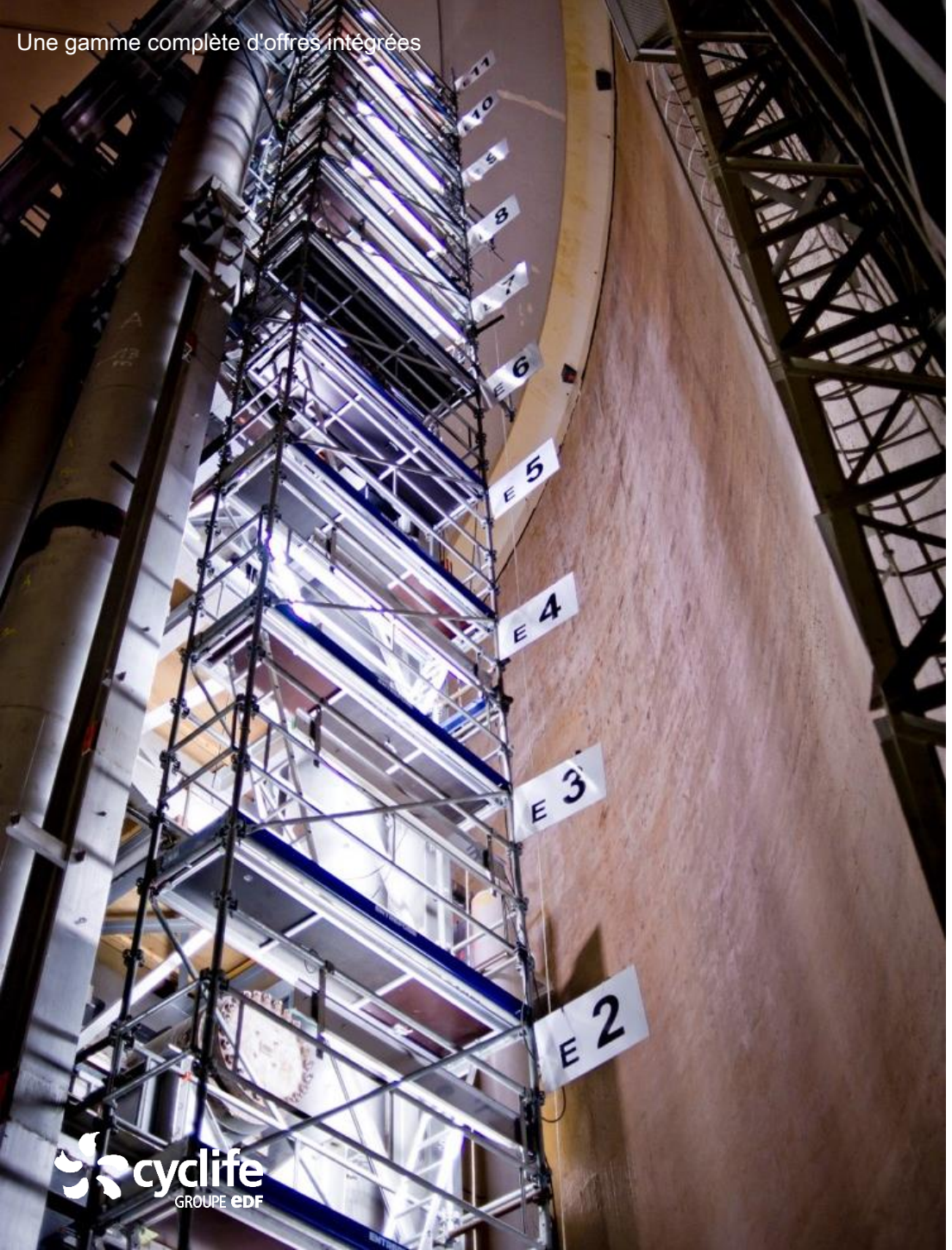
Application of Sustainability Principles and Circular Economy to Nuclear Decommissioning

Presentation by C Maufrais

June 2019



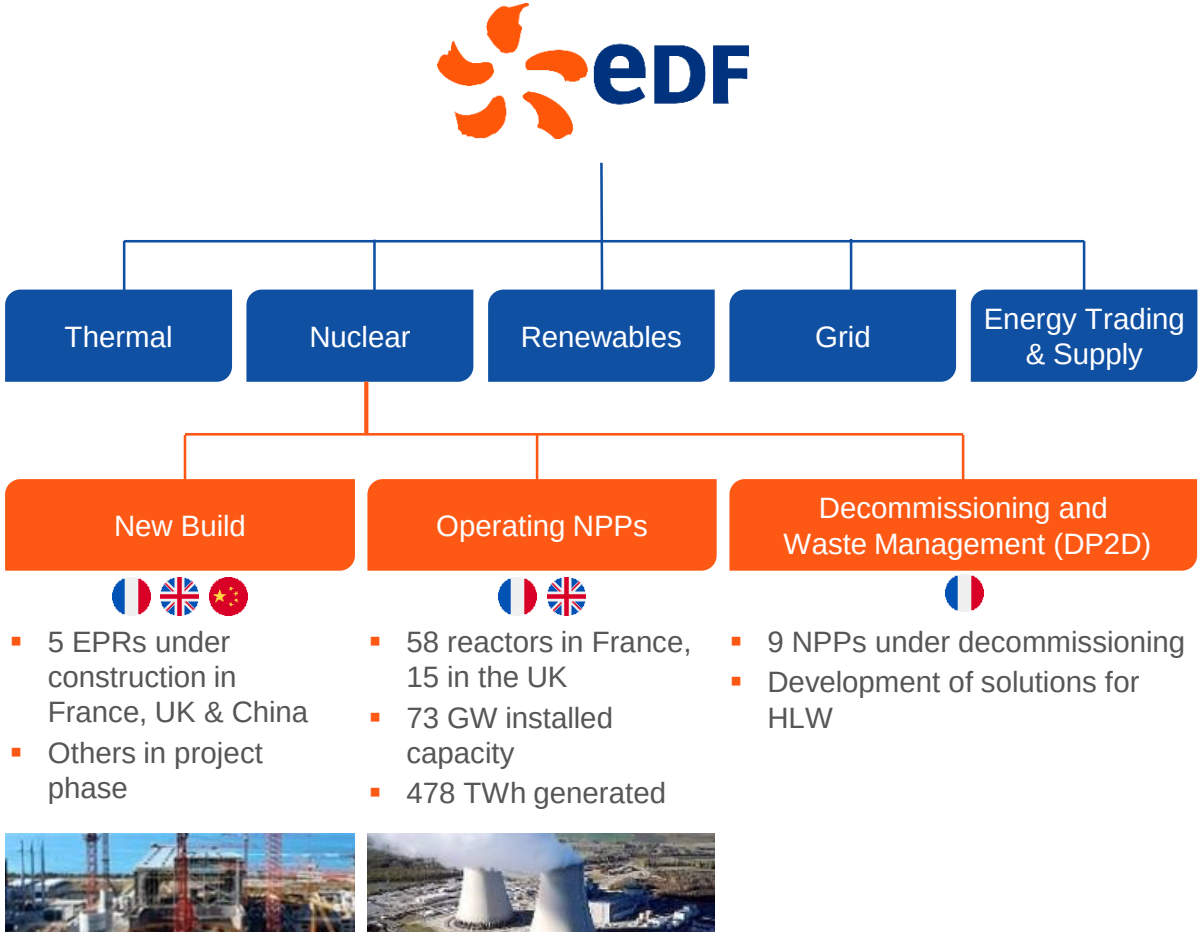
AGENDA

1. **Decommissioning within EDF Group**
2. EDF experience on its own fleet
3. Cyclife: A full Integrated Range Of Offering
4. Our Assets
   - Cyclife France (Socodei)
   - Cyclife UK
   - Cyclife Sweden

DECOMMISSIONNING AND WASTE MANAGEMENT
ARE KEY TO EDF STRATEGY IN THE NUCLEAR INDUSTRY

EDF, the efficient and responsible electricity company, **the champion in low-carbon growth**.

At the end of 2015, the EDF Group set up the "DP2D" (Direction dedicated to the Decommissioning and Waste Projects) **to take up this challenge**.

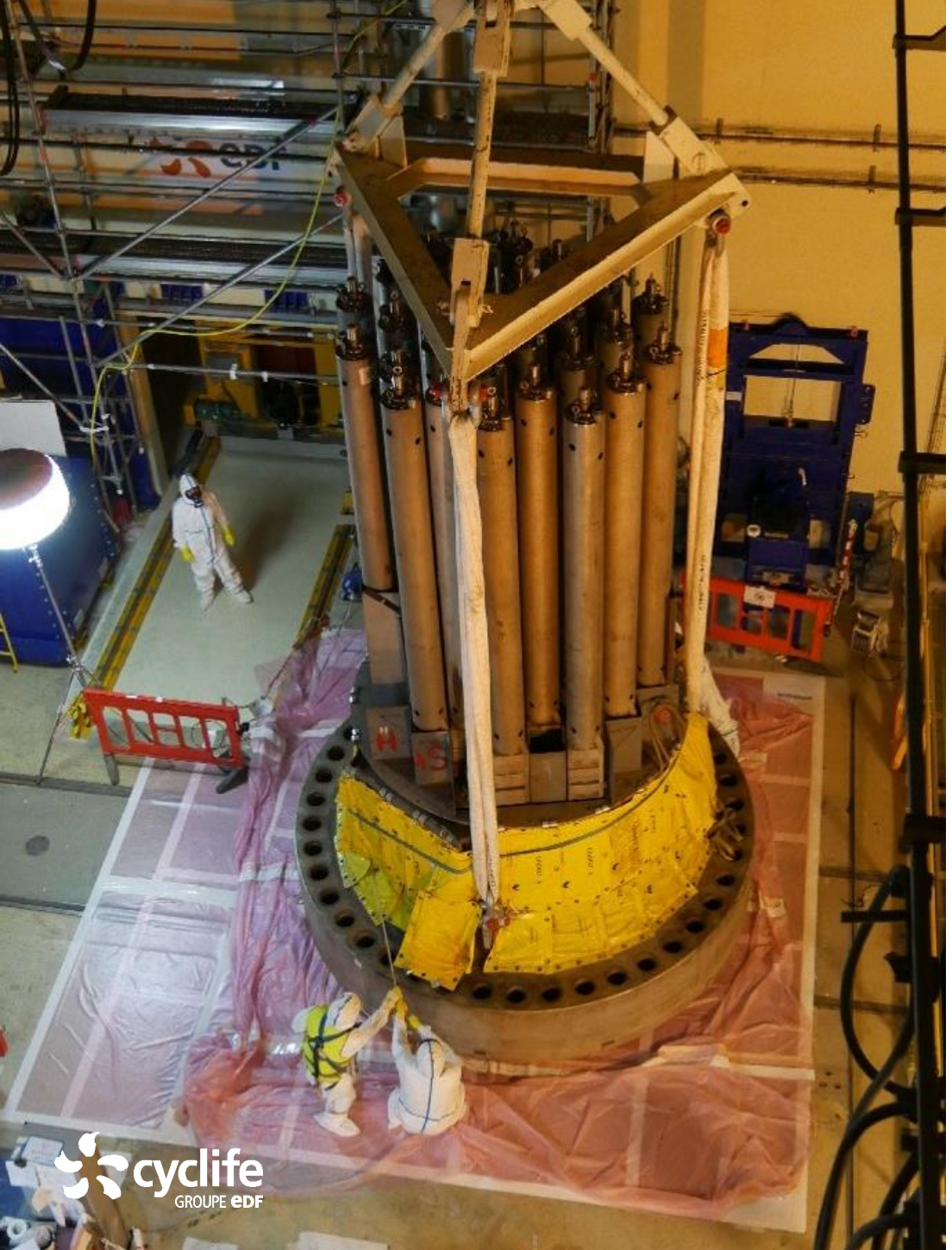


CAP 2030

Generating low-carbon electricity from nuclear power and renewables is a top priority of the CAP 2030 strategy.

As a responsible nuclear operator, demonstrate our full control along the entire life cycle, by efficiently managing decommissioning projects and waste generated by our power plants in operating or dismantlement phase.

cyclife GROUPE EDF



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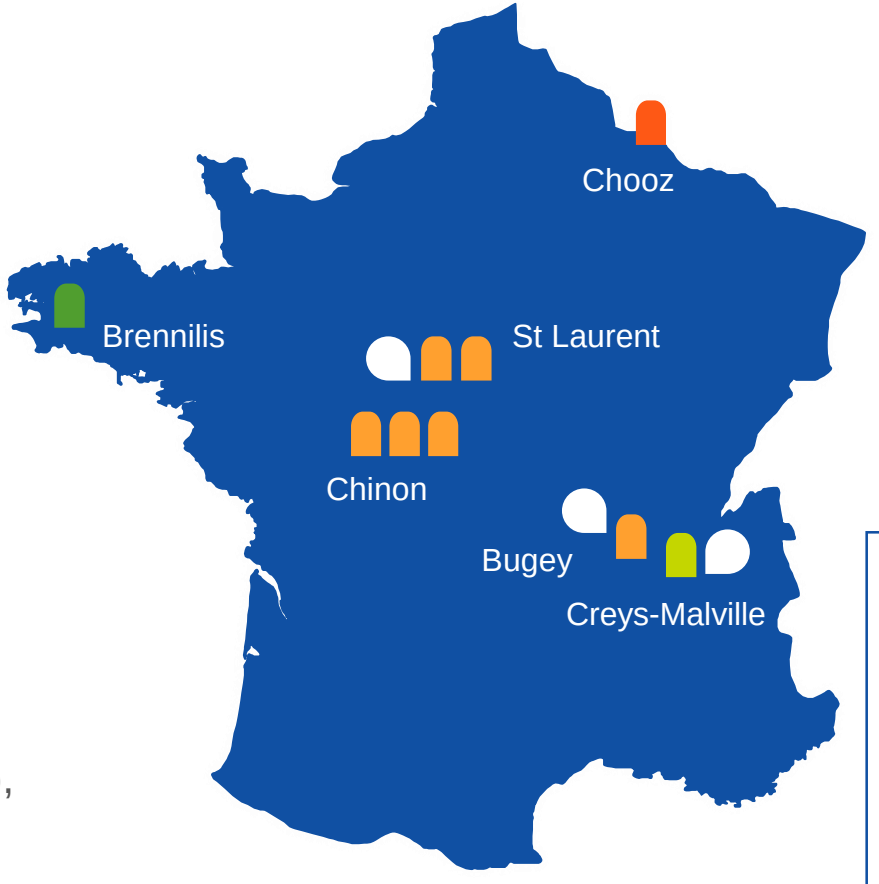
A LONG EXPERIENCE
IN DECOMMISSIONING

Through the French regulation context, EDF is the owner and the operator of its own fleet. Moreover, EDF is also in charge of the decommissioning with dedicated funds **(~23Mds€).**

EDF applies its "Architect Integrator Model" across the entire lifecycle of units: mastering technical competencies (with privileged contractors/partners), costs, planning and risks.



+15 years of experience
on its own fleet decommissioning

EDF has taken
9 units
from operating to decommissioning

EDF is also preparing
AGR decommissioning in the UK
that will begin by **mid-2020s**

- **1** pressurized Water Reactor **(PWR)**
- **1** Heavy Water Reactor **(HWR)**
- **6** Natural Uranium Graphite Gas reactors **(UNGG)**
- **1** Fast Neutron Reactor **(FNR)**
- **EDF Main storage facilities**

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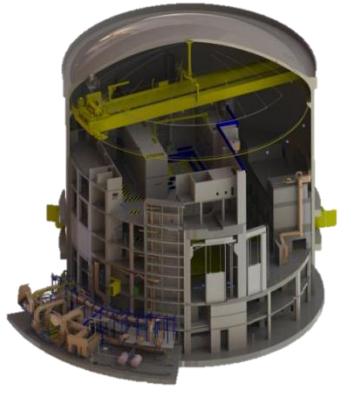
HWR BRENNILIS:
A PUBLIC ACCEPTANCE CHALLENGE

From safe store and delayed decommissioning authorisation in 1996 to 2nd decommissioning authorisation obtained from French Safety Authority in 2011.

Key achievements

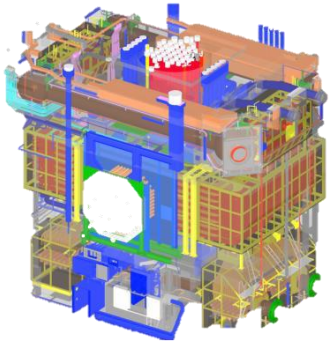
- Dismantling of heat exchangers
- Walls and ceiling of the effluent treatment building.
- Basic Design Study for the dismantling operation of the vessel inside the reactor building.

3D modelization and laser scan of the reactor & reactor building



Added-value for future customers' projects

- Knowledge on methodology for concrete decontamination and soil release with the French Safety Authority
- Expertise in discussions and negotiations with the stakeholders



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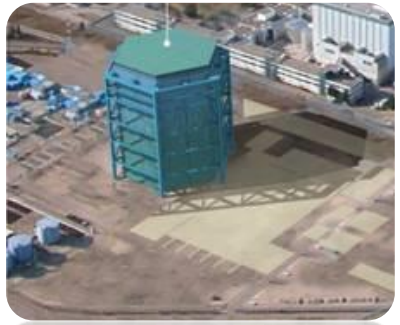
GRAPHITE REACTORS :
A NEW DECOMMISSIONING STRATEGY SET UP



- **Industrial demonstrator before application to dismantle the first reactor as lead fleet site and to extend methodology to the 5 other reactors**
- **A new decommissioning strategy set up : from under water decommissioning to dry decommissioning**
- **A schedule to reach a secure configuration**

Key achievements & on going operations

- **Chinon:**
  - Design studies on the Industrial Demonstrator
  - Preparatory works for sampling campaigns
  - Dismantling of CHA3 heat exchangers
- **Saint Laurent:** Dismantling of all the electromechanical circuits & Radiological clean-up
- **Bugey:** Decommissioning of electromechanical circuits and materials demolition of external buildings

Added-value for future customers' projects

- Setup of the new strategy : from under water decommissioning to dry decommissioning
- Ability to work with alpha contaminated waste and in asbestos conditions
- Large and Heavy components treatment
- Samples for large components for chemical and radiological characterisation
- Soil remediation

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PWR : CHOOZ A NPP:
FIRST PWR UNDER DECOMMISSIONING IN FRANCE

The first reactor Chooz A, an early PWR built and exploited by EDF, was shut down in 1991 after an operational life of 22 years. The decommissioning permit has been granted in 2007 and the decommissioning should be done by 2022

Key achievements

- Initialisation of the under water vessel internals segmentation before vessel segmentation
- Design of the strategy to optimize & secure the global fleet decommissioning : 58 PWR in Operation across 19 sites (3 NPP models with very closed design : 900MW, 1300MW, 1450MW)

Added-value for future customers' projects

- Strategic choice between retrieving special operating tools for dismantling and developing new tools
- Nuclear Steam Supply Systems (NSSS) Decontamination strategy (primary circuit)
- Waste strategy & large components management

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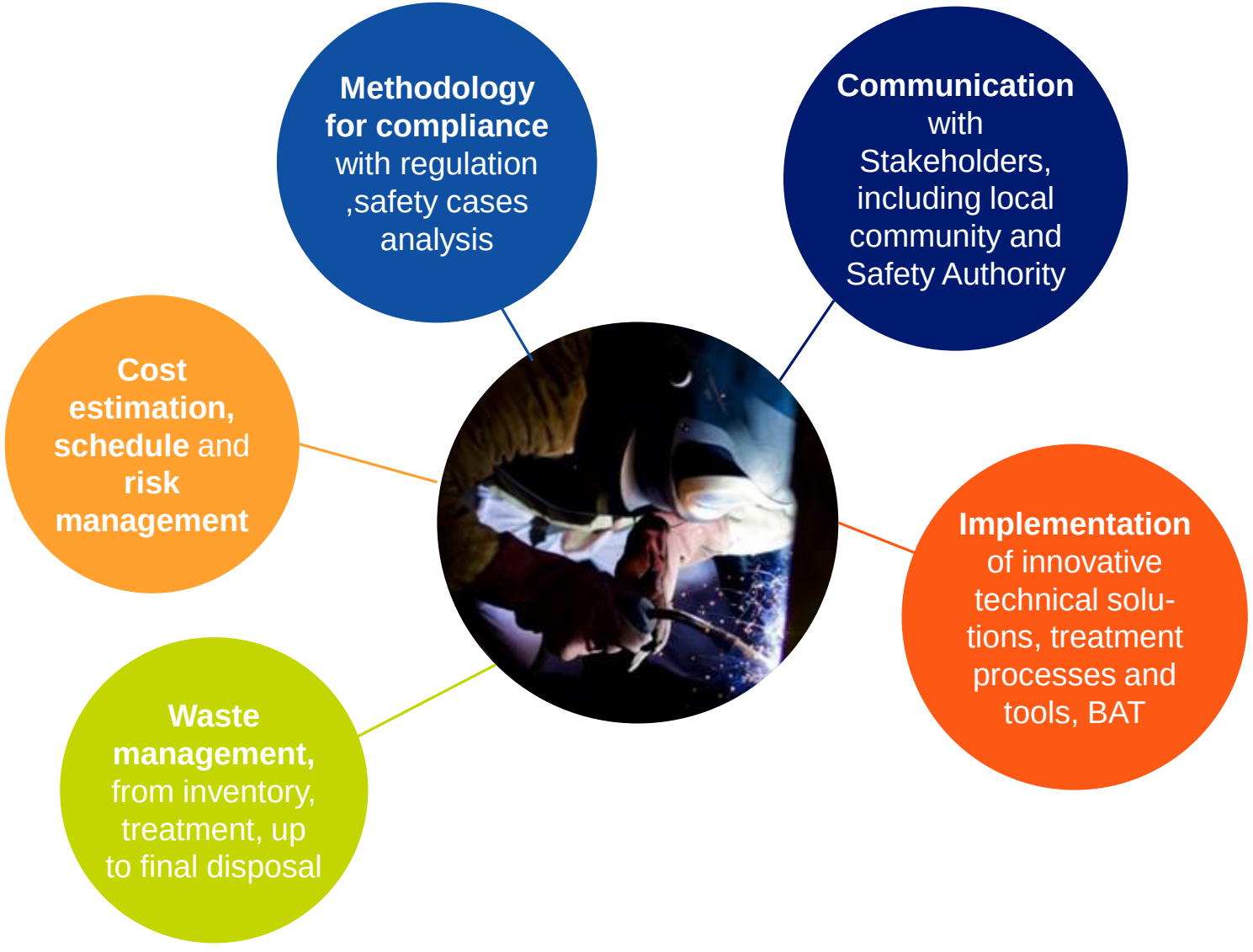
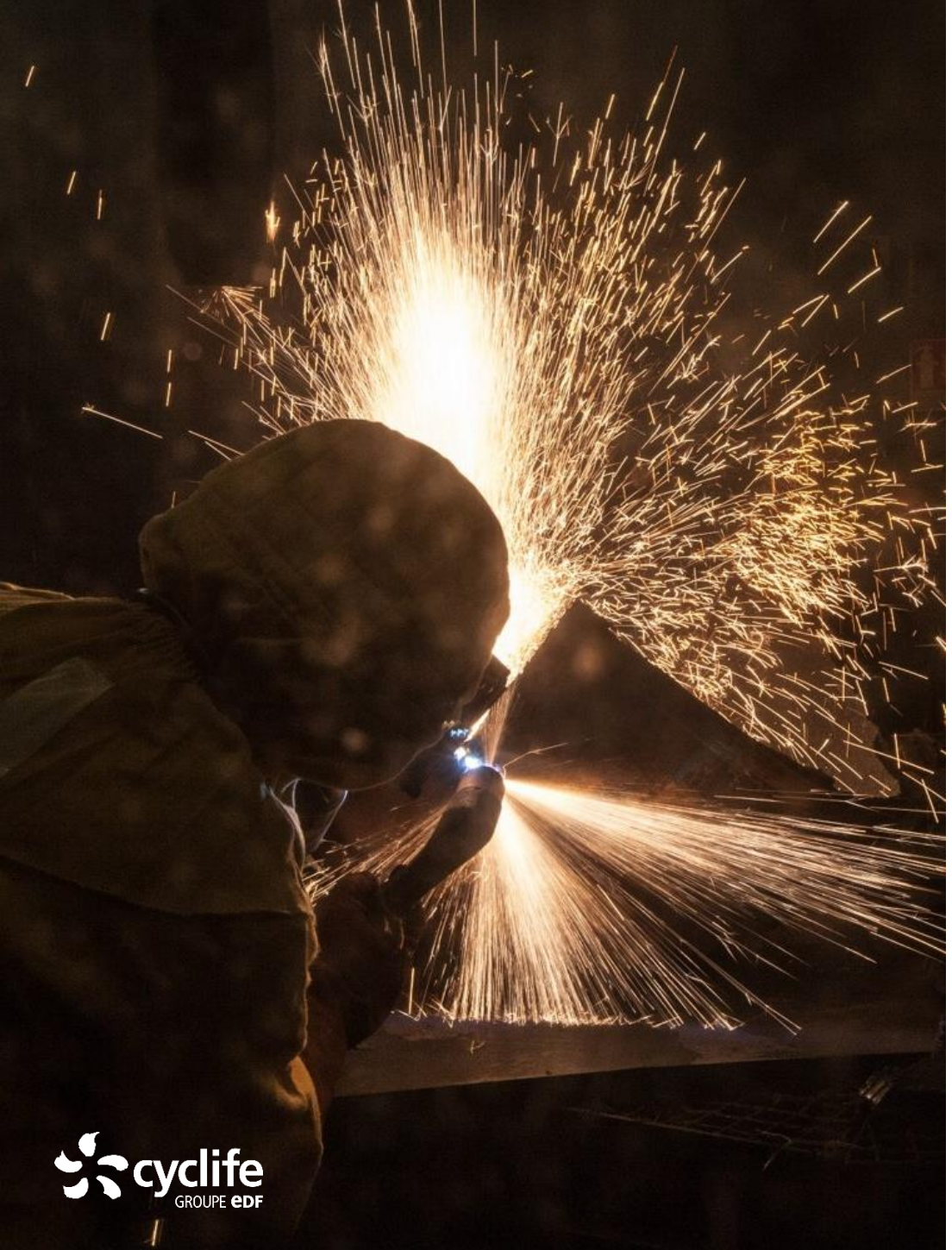
EDF LARGE SKILLS
IN WASTE LED MANAGEMENT LEADING TO A3R

EDF developed **large skills in complex Decontamination & Decommissioning (D&D) Projects management responding to A3R concept (Avoid, Reduce, Recycle and Release)** from past and ongoing nuclear decommissioning operations on its fleet.





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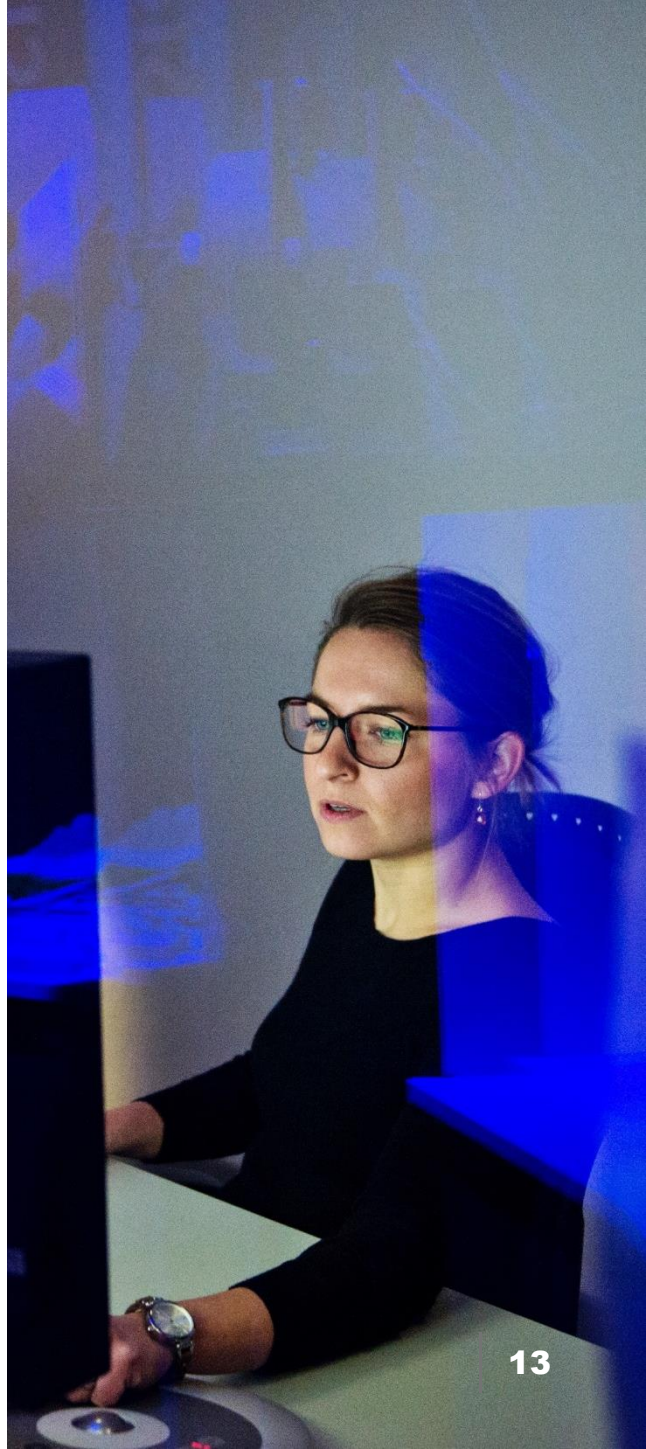
INTRODUCING CYCLIFE,
EDF'S INTERNATIONAL PLATFORM IN DECOMMISSIONING & WASTE MANAGEMENT

EDF supports its nuclear customers in **a sustainable approach** through each phase of the **nuclear lifecycle** with a comprehensive range of services & expertise

cyclife GROUPE EDF

- develops innovative **cost effective solutions** for **decommissioning and waste management,**
- uses EDF group's **skills (EDF DP2D, Framatome) and assets** to offer efficient decommissioning and solutions following a **Waste-led-decommissioning** approach,
- answers **A3R concept (**avoid, reduce, recycle and release**)** and the growing need to preserve disposal capacity.



CYCLIFE AMBITION
IS TO CREATE VALUE FOR ITS CUSTOMERS

Benefit from a unique and strong experience

- **Benefit from EDF's strong experience** with 9 Nuclear Power Plants (NPPs) under decommissioning in France and more than 40 years of experience in waste treatment through Cyclife subsidiaries
- **Benefit from specific techniques** and a seasoned staff that have already faced complex projects including onsite works

Integrated service through the EDF "Architect Integrator Model"

- **Secures** an efficient program progress
- **Reduces** interfaces and risks (services from supervision and management to engineering and designing)
- **Reliable** cost and planning management

"Waste-Led" decommissioning

- **Reduces** waste management & disposal cost
- **Minimises** scarce radioactive disposal capacity
- **Reduces** interfaces and risks by integration across the value chain

Sustainability & environmental benefits

- **Lifecycle approach** and whole loop integrating secondary waste
- **Experience** in opening international waste & material routes

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CYCLIFE WASTE TREATMENT FACILITIES

50-staff

UK | Workington facility

- Size-reduction and shot blasting: 3 000 tons per year

CYCLIFE can accept foreign waste with **residue repatriation**

90-staff

SWEDEN | Nyköping facility

- Melting: 5 000 tons per year
- Incineration: 600 tons per year
- Pyrolysis : 50 tons per year
- Clearance : 2 500 tons per year

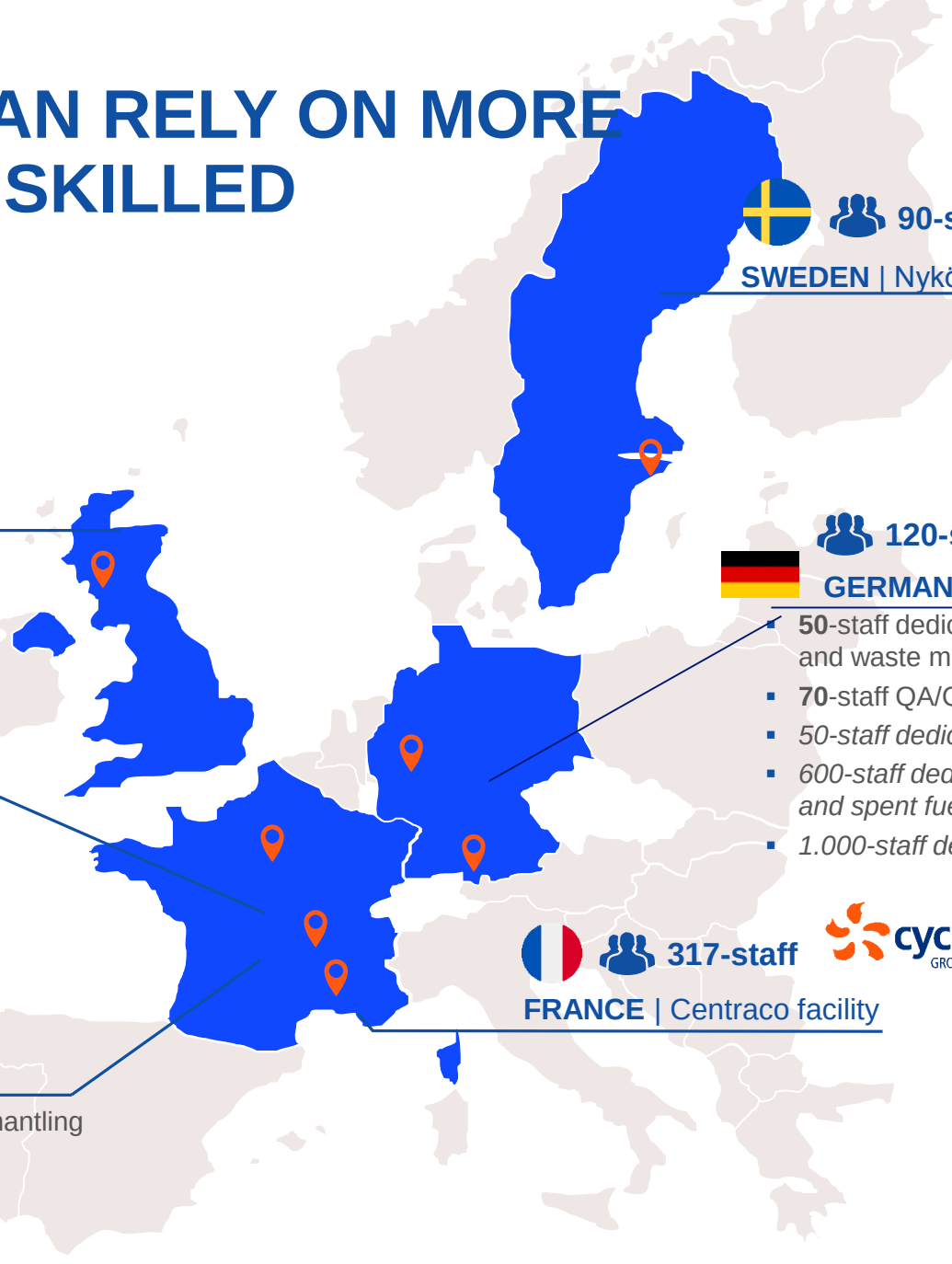
Nuclear Licensed facilities provide best available techniques for Volume Reduction/Stabilisation

317-staff

FRANCE | Centraco facility

- Melting: 3 500 tons per year
- Incineration: 6 000 tons per year
- Fabrication of concrete containers for nuclear waste transportation
- Fabrication and operation of mobile conditioning units

CYCLIFE NETWORK CAN RELY ON MORE THAN 7,000 NUCLEAR SKILLED PROFESSIONALS



90-staff

SWEDEN | Nyköping facility

50-staff

UK | Workington facility

framatome GmbH

120-staff

GERMANY | Erlangen & Karlstein

- **50**-staff dedicated to sampling, characterization and waste management solutions
- **70**-staff QA/QC service for D&D
- *50-staff dedicated to chemical decontamination*
- *600-staff dedicated to NPP services activities and spent fuel pool transportation*
- *1.000-staff dedicated to NPP engineering*

700-staff

FRANCE | Paris and Lyon

- Staff dedicated to decommissioning, characterisation, waste management solutions, safety and environmental studies

317-staff

FRANCE | Centraco facility

150-staff

FRANCE | Paris and Lyon

- Staff dedicated to NPP dismantling Engineering in Framatome

FROM CONCEPT TO DELIVERY:

CYCLIFE OFFERS A LARGE RANGE OF SERVICES IN WASTE MANAGEMENT AIMING TO REDUCE VOLUME

Waste characterisation

- Cyclife carries out an accurate physical and radiological waste inventory to optimise waste management by selecting the optimal route for each waste.

Waste routing

- Cyclife ensures that waste is routed to the facility which offers customers the best technical, economic and regulatory solution.

Waste storage & disposal developments

- Design of temporary waste storage facilities and design studies with Andra (French national radioactive waste management agency) for the construction of the French deep geological storage (Cigéo) dedicated to high-level waste.

Waste treatment engineering

- Cyclife provides engineering solutions for the design of waste treatment facilities and innovative processes in this field.

Waste treatment :

- **Decontamination :** dedicated processes to decontaminate waste either onsite or off-site
- **Sorting, segregating, packaging and transport:** Cyclife supports its customers for waste management and transport from their nuclear site.
- **On-site services:** Cyclife has developed processes to treat waste directly on production sites thanks to mobile processing and conditioning units and personnel able to operate on client's sites.
- **Metallic waste treatment, melting and recycling:** Cyclife processes metallic waste and operates blasting of metallic waste, size-reduction, melting operations and clearance.
- **Large components:** Cyclife own unique capabilities and expertise for the management of large components that saves storage and final disposal costs for customers. Cyclife's offer integrates chemical and physical decontamination.
- **Incineration:** Cyclife incinerates combustible, solid and liquid waste. Cyclife also treats waste arising from hospitals and laboratories.
- **Pyrolysis:** Cyclife also uses pyrolysis, in which material is treated by dry distillation without any oxygen.

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FROM CONCEPT TO DELIVERY:
CYCLIFE OFFERS A LARGE RANGE OF SERVICES IN DECOMMISSIONING

Plant physical & radiological inventory

- Cyclife provides a turnkey state-of-the-art physical & radiological inventory of the entire Nuclear Power Plant, from calculations to final on-site characterisation

Dismantling

- Cyclife can perform a wide range of dismantling services, including cold and hot segmentation (for example of primary circuits or other steam supply systems).

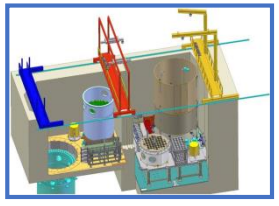
Technical support

- Cyclife can provide on-site decommissioning projects, taking benefit of its technical expertise in decontamination of systems, structures and sites (soil and groundwater).

Consultancy

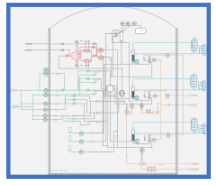
- **Preliminary studies and strategy:** Cyclife realises preliminary studies and decommissioning strategies: decommissioning scenario, waste management scenario, environmental impact assessments.
- **Program & Project Management:** Cyclife offers tools and professional expertise to deliver decommissioning project management solutions and actions to schedule transition period, thanks to the presence of technical experts throughout the entire duration of the project.
- **Costing**: Cyclife assesses, optimizes the risks and contingencies for cost estimates, using technical insights from best international practices, and benchmarking in-house.
- **Professional training**: Cyclife's experts provide bespoke training to decommissioning personnel, from on-site operators to program managers.

FRAMATOME AND EDF ACTIVITIES COVER A WHOLE SCOPE IN D&D PORTFOLIO



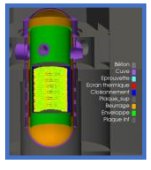
Safety reports

Scenario optimization



System shut-down optimization

3D MCNP advanced toolings



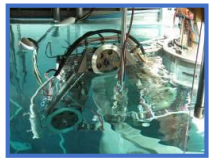
PREDEC : Engineering for the D&D activities preparation

+

SERVICE : Techno brick supplier for specific solutions &Operations

Decontamination

FSD CORD



Reliable cutting techniques

Operations

Waste management

PREDEC Engineering

SERVICES

Final shut-down | **Licence** | **Closure**

OPERATION — 0 — POCO — 4-5 — DISMANTLING — ~ 20

Indicative Time frame

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   - Cyclife UK
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CYCLIFE FRANCE : THE STRUCTURE

Cyclife France has been created **in 1990**

EDF

100%

socodei GROUPE EDF

317-staff

Certifications
- ISO 9001
- ISO 14001
- OHSAS 18001

- CENTRACO FACILITY
- MOBILE MACHINES
- ICEDA
- BAMAS MAINTENANCE BASE
- 51% CDB Conditioning of concrete waste

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CYCLIFE FRANCE : EXAMPLES OF SERVICES

Waste treatment engineering

Know-how to ensure proper handling of the special radioactive materials and waste by performing priori studies and customising the processes

WASTE MANAGEMENT By

cyclife GROUPE EDF

Waste treatment

- **Sorting, segregating, packaging and transport**
  - → Boxes and drums specially-designed for optimal use in collecting metal waste and containers and tanks for shipment, treatment and final package to disposal site.
- **On-site services**
  - → More than 4 000 m³ of exchange resins treated with Mercure mobil machins since 1996.
- **Metallic waste treatment, melting and recycling**
  - → More than 24 000 tons of waste treated by melting since 1999 by Socodei.
- **Large components**
  - → A workshop that allows components up to 200 tons and 12 meters for decontamination and cutting.
- **Incineration**
  - → **More than 65 000 m³ of waste treated by incineration since 1996 by SOCODEI.**

And more: **Plant management**

→ Daily plant operations, routine maintenance for industrial facilities
Ex: EDF maintenance base (BAMAS) operated by SOCODEI

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METAL RE-VALORIZATION
AT CENTRACO

CENTRACO aim to recycle part of the melted metal

CENTRACO manufacture tubes

Tubes are then inserted in concrete containers

to make additional radiological shields to save raw material

THE ADDED-VALUE OF CYCLIFE FRANCE SERVICES

Volume reduction factor:

$1/6$

including secondary waste

MELTING AT CENTRACO

Centraco has administrative processing capabilities of

3 500 tons of waste per year

Maximal specific activity of incoming waste Bq/g:

α : 370

β γ : 20 000

THE ADDED-VALUE OF CYCLIFE FRANCE SERVICES

Volume reduction factor:

1/6

including secondary waste

INCINERATION
AT CENTRACO

As a sustainable behavior, CENTRACO treats waste in substitution of raw material (e.g. contaminated oil instead of fuel, contaminated water instead of cooling water)

CENTRACO incineration unit is able to process:

- solid waste (as overalls, gloves, wood, plastics, and protective shoe covers, spent resins, filters)
- liquid waste (oil, concentrates, leaching solutions, solvents, bitumen, TBP..)

produced by nuclear facilities, labs, hospitals and other research centers.

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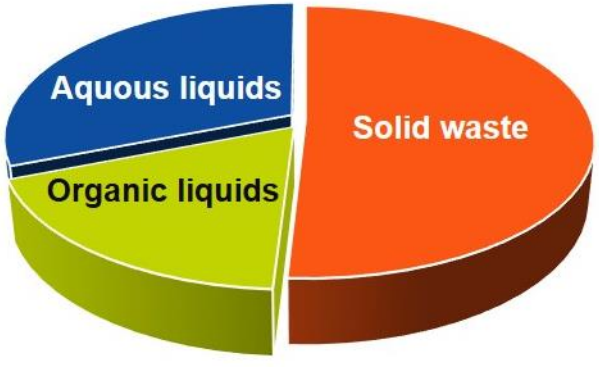
INCINERATION
AT CENTRACO

Centraco has administrative processing capabilities of

3,000 t / y of solid waste
3,000 t / y of liquid waste

Maximal specific activity of incoming waste (Bq/g)	
α **Total**	370
βγ Total	40 000
βγ Total except ^{3}H and ^{14}C	20 000
^{3}H	20 000



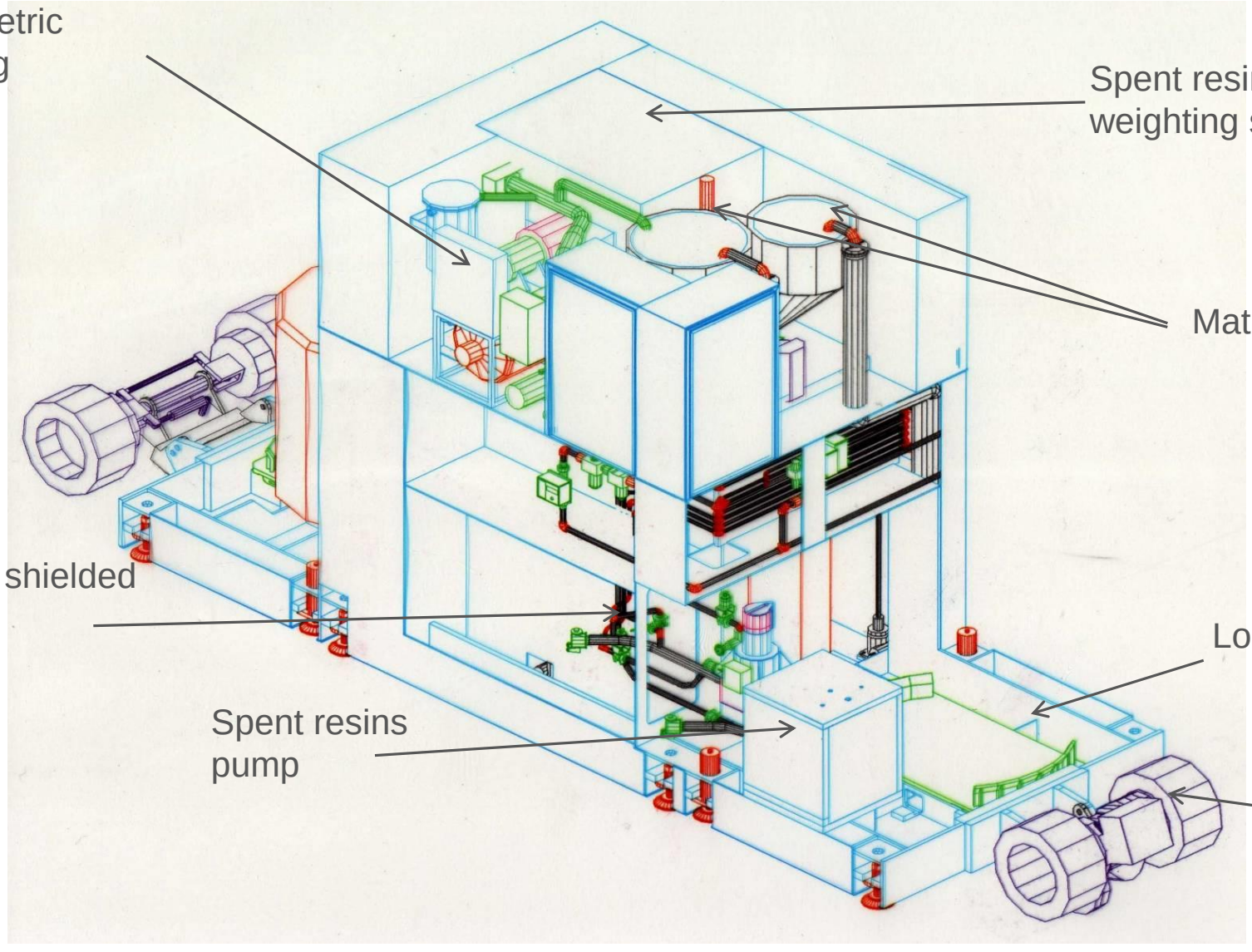
THE ADDED-VALUE OF CYCLIFE FRANCE SERVICES

Volume reduction factor:

$1/15$

including secondary waste

MOBILE UNITS : THE MERCURE EMBEDDING PROCESS



MERCURE OVERVIEW

The Service

Mercure is a mobile unit for the embedding of the high level X spent resins arising from the "primary" circuit of nuclear power plants.

The mobile process is installed in situ where it blend the spent resins in an epoxy matrix providing the highest performances for long term storage of such waste,

Radiological limit

- βγ fingerprint only: activity **up to 13.5 TBq/m³**

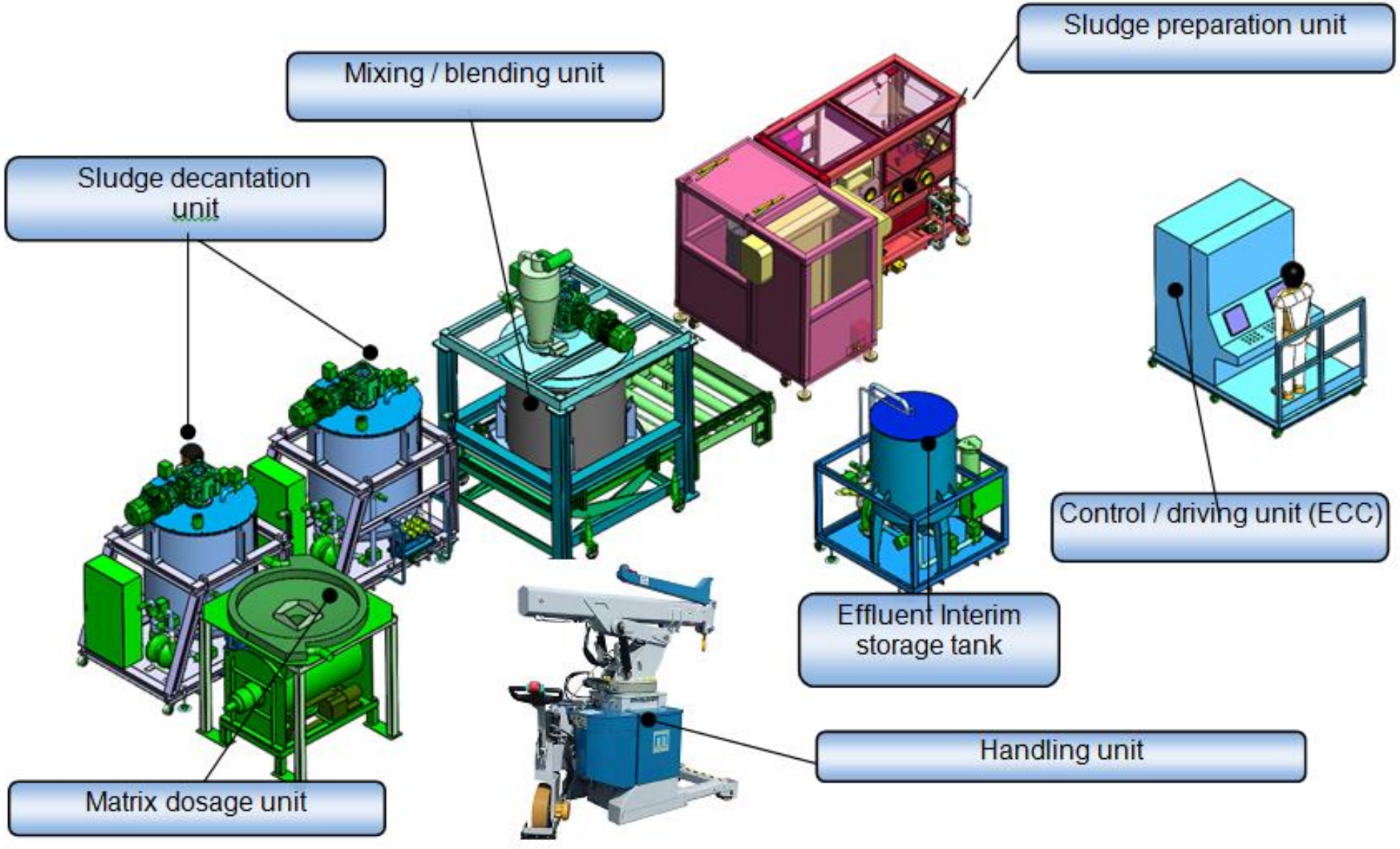
Physical properties

- Polystyrenic, phenolic, acrylic or formophenolic resins types
- Resin beads / grains form 0.3 to 1.2 mm ∅
- Cationic or anionic charge
- Chemical limits :
  - Limitation for borates, lithium, iron, cobalt, nickel, chromium, sodium, calcium

Other conditions

- Underwater storage before treatment
- Undisturbed drying for the sealed packages during 7 days

UM2B : MINERAL SLUDGE CONDITIONING MOBILE UNIT



UMIS : EASY « ON SITE » LEGACY CONTAINERS INSPECTION

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CYCLIFE UK LTD

Cyclife UK LTD has been created **in 2016** after the takeover by EDF.

EDF

100%

CYCLIFE UK LTD

50-staff

Certifications
- ISO 9001
- ISO 14001
- OHSAS 18001

Metal Recycling Facility (MRF)

CYCLIFE UK SERVICES

WITHIN CYCLIFE BRAND: FROM CRADLE TO GRAVE SUPPORT

Plant physical & radiological inventory

Provide a turnkey state-of-the-art physical & radiological inventory of the entire Nuclear Power Plant (NPP), from calculations to characterisation

DECOMMISSIONING by cyclife GROUPE EDF

Consultancy

- **Preliminary studies and strategy**
  - → Run preliminary studies such as decommissioning scenario, waste treatment plant design, nuclear safety reports, environmental impact assessments…
- **Program & Project Management**
  - → Provide assistance from experienced technical experts all along the decommissioning or on-site waste treatment plant building project
  - → Bring professional PMO tools and experience au client
  - → Transition period : Anticipate post-operation work during operation and provides technical support to optimise the scheduling of the end of life and post-operational phase
- **Costing**
  - → Assess cost estimates, risks & contingencies
  - → Optimise decommissioning costs using technical insights from best international practices
- **Training**
  - → Provide bespoke training from experienced Cyclife experts to decommissioning personnel, from on-site operators to the project managers

And more: **Radiological protection**

→ The Team of radiation protection professionals have experience in working with ionising radiation in a wide range of environments and are able to provide practical solutions to any issues arising from day to day work with radiation

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CYCLIFE UK SERVICES

WITHIN CYCLIFE BRAND: FROM CRADLE TO GRAVE SUPPORT

Cyclife UK designs cost-effective and waste-minimising waste management solutions tailored to the clients' needs & constraints

Waste treatment engineering

Know-how to ensure proper handling of the special radioactive materials and waste by performing priori studies and customising the processes

Conceptual design of waste treatment concepts and facilities

Waste characterization

Radiological characterisation, categorisation and measurements

WASTE MANAGEMENT

By

cyclife GROUPE EDF

Waste treatment

- **Sorting, segregating, packaging and transport**
  - → "Assured Disposal Service" - Managing waste from retrieval, characterization, transport, treatment and disposal
- **Metallic waste treatment, melting and recycling**
  - → Since 2009 MRF has successfully processed over 5 000 tons of wastes from over 21 sites including a wide range of public and private customers

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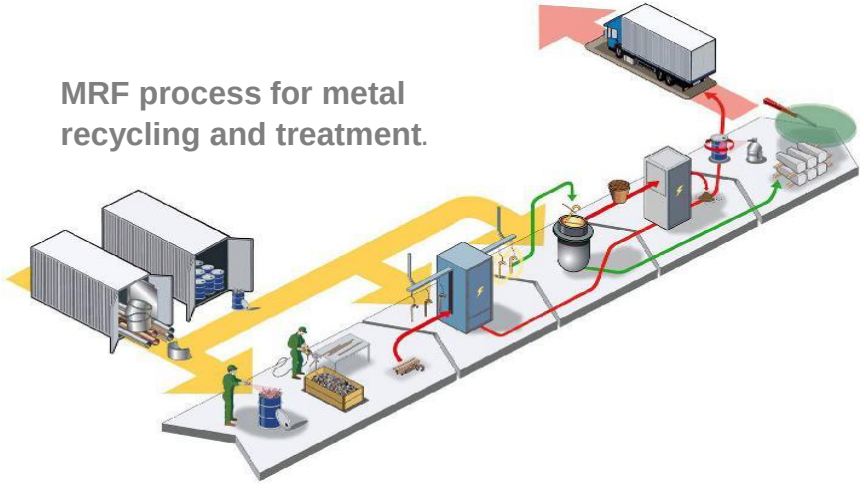
METAL RECYCLING AND TREATMENT
AT MRF

MRF processes low level radioactive metals at the facility by a range of innovative techniques including size reduction and shot-blasting.



MRF process for metal recycling and treatment.

THE ADDED-VALUE OF CYCLIFE UK LTD SERVICES:

- Real Environmental Benefits – potential dramatic 98% volume reduction
- Reduced risks via the initial treatment of waste within the UK
- Recycling of approximately 95% LLW metal for industrial re-use, approximately 5% of original waste disposed to LLWR

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CYCLIFE SWEDEN AB

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EDF

100%

CYCLIFE SWEDEN AB

90-staff

Certifications
- ISO 9001
- ISO 14001
- OHSAS 18001

NYKÖPING FACILITY

CYCLIFE SWEDEN AB SERVICES
WITHIN CYCLIFE BRAND: EXAMPLES

WASTE MANAGEMENT By cyclife GROUPE EDF

Waste characterisation

Radiological characterisation, categorisation and measurements

Waste treatment engineering

Conceptual design of waste treatment concepts and facilities

Waste treatment

- **Sorting, segregating, packaging and transport**
  - → Transportation and logistics
- **Metallic waste treatment, melting and recycling**
  - → Melting but also super compaction and clearance activities (clearance measurements in a heavily shielded measurement cell)
- **Large components**
  - → A workshop that allows components up to 400 tons and 30 meters for decontamination and cutting
- **Incineration**
  - → Treatment of organic waste for volume reduction and to form a stable end-product suitable for disposal
- **Pyrolysis**
  - → The pyrolysis facility is dedicated to uranium contaminated wastes that can originated from nuclear fuel factories

And more: **Radiological Services and Analysis outside nuclear sector**

- → Inspection, re-loading and decommissioning of sealed sources,
- → Characterisation and management of other radioactive material.
- → Radiological analyses in laboratory
- → Advisory services and technical investigations.

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LARGE COMPONENTS WORKSHOP
AT NYKÖPING

The service

- Planning, on site supervision and logistics for transport
- Packaging, transportation and heavy lifting in compliance with regulation on the road transport
- Segmentation
- Decontamination
- Melting
- Analyses and free release
- Recycling
- Laboratory furnaces for thermal treatment tests

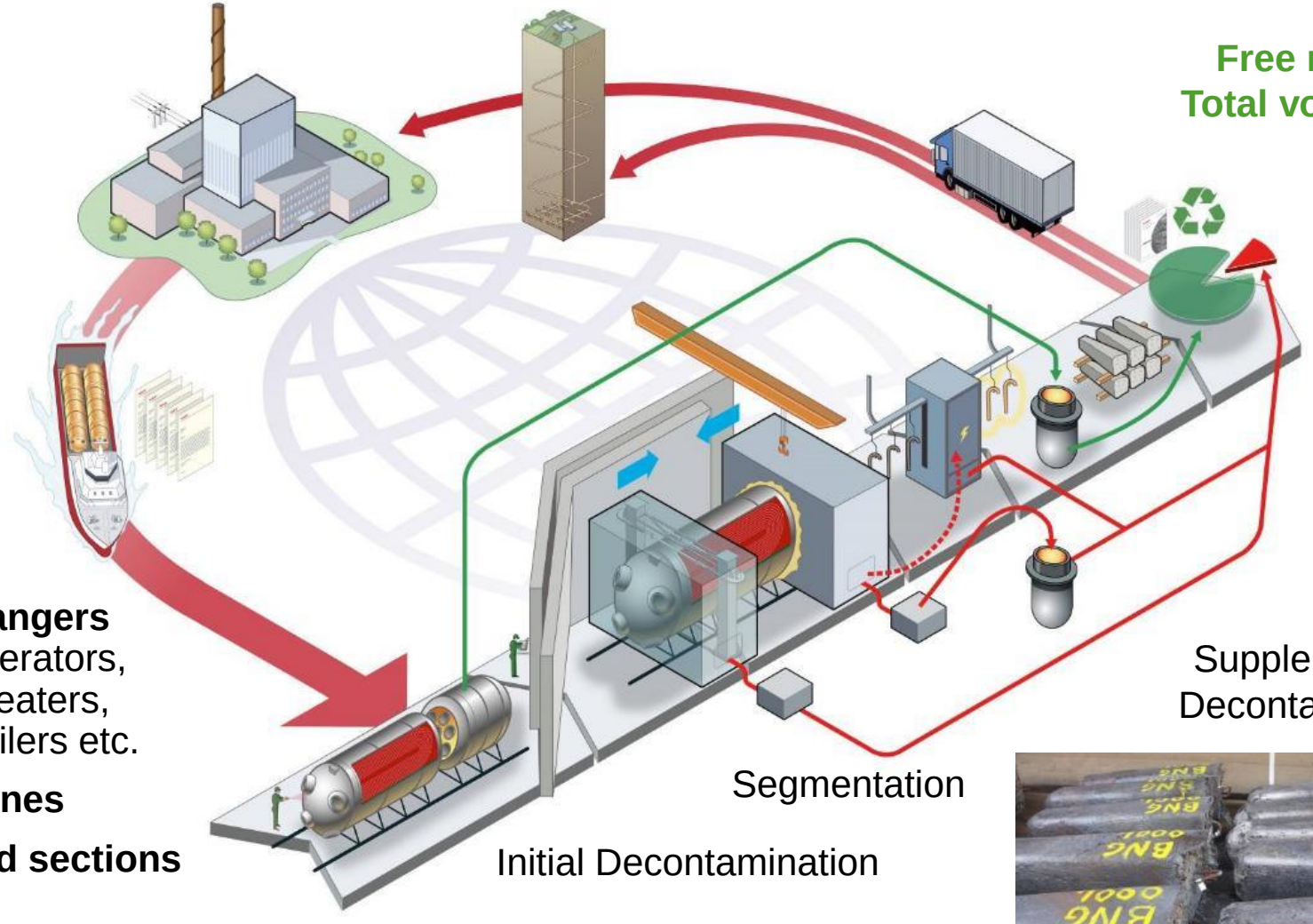
Size

- length up to **30 meters** and **400 tons** and **2,000 tons per year**

Material for treatment

- Heat exchangers : Steam Generators, BWR Re-Heaters, Magnox Boilers etc.
- BWR Turbines
- RPV lid and sections

LARGE COMPONENTS (LC) - TREATMENT CONCEPT



Free release of metal
Total volume reduction > 90%

Waste

Secondary waste Management

Melting

Supplementary Decontamination

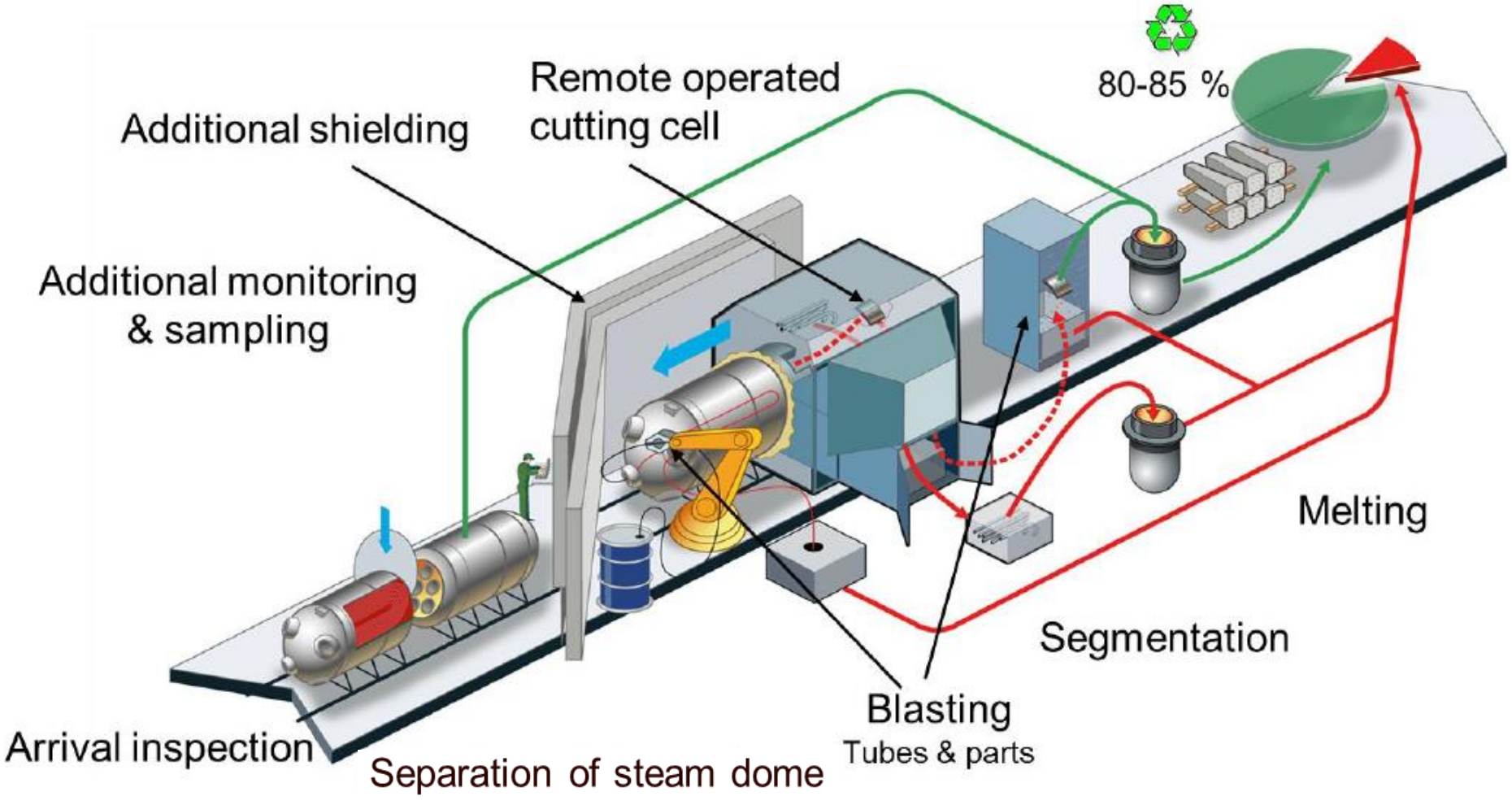
Segmentation

Initial Decontamination

Treatment of

- **Heat exchangers**
  Steam Generators,
  BWR Re-Heaters,
  Magnox Boilers etc.
- **BWR Turbines**
- **RPV lid and sections**

STEAM GENERATOR TREATMENT CONCEPT



MELTING
AT NYKÖPING

The service

- Logistics
- Melting & recycling
- Secondary waste management

The products

- Carbon steel
- Stainless steel
- Aluminum
- Brass
- Copper
- Lead

INCINERATION AND PYROLYSIS
AT NYKÖPING (1/2)

The Nyköping incineration and pyrolysis units process all of the:

- Dry radioactive waste
- Oils and liquids
- Activated Carbon
- Ion exchange resins
- U-contaminated waste

produced by nuclear facilities


Pyrolysis facility


Incineration facility

INCINERATION AND PYROLYSIS
AT NYKÖPING (2/2)

Maximum activity level:

Maximal specific activity per package of incoming waste (Bq/g)		
Waste type	**α total**	**By total**
DAW	< 80	**<4,000** (with ^{3}H and ^{14}C <50% of the total inventory)
Liquid oils	<4	
Liquid oils absorbed to solid state	∈ [4, 40]	
Activated charcoal, absorbed oils and lubricants	**< 40**	

THE NYKÖPING INCINERATION AND PYROLYSIS UNITS CAN PROCESS

600 tons per year of waste


Thank You
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