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Feedback from Reactor Internals Segmentation Projects in Europe

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Agenda

- Background and Technical Aspects
- Site Preparation
- Site Activities
- Waste Packaging
- Conclusions & Lessons learned
- Q&A

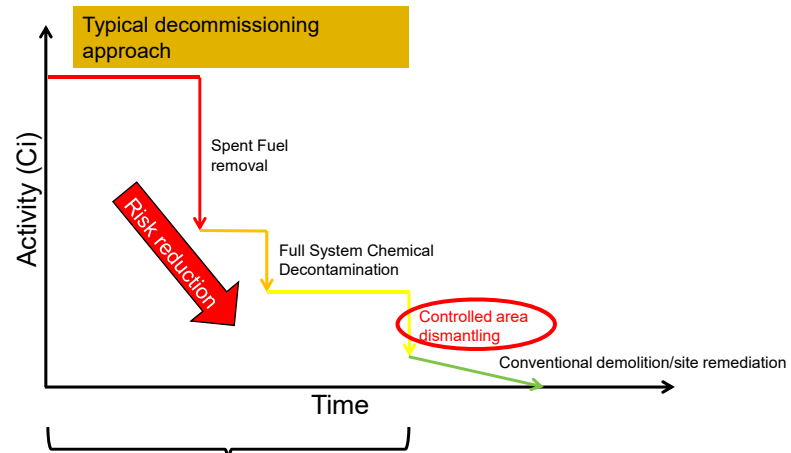


Key D&D and Waste Management capabilities

- Westinghouse has been involved in the D&D and Waste Management business for more than **35 years** with key activities for which we are a recognized market leader
- Westinghouse is currently very active on the commercial reactor decommissioning activities.
- Based on our proven experience, our main strengths are in the following areas:



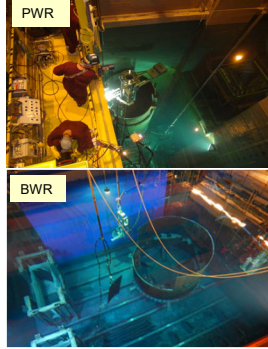
NPP decommissioning: From Hot to Conventional Dismantling



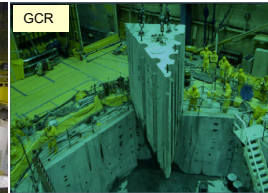
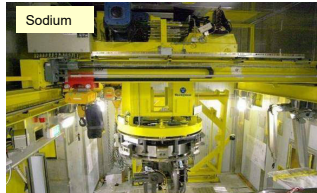
Background and Technical Aspects

Reactor Vessel Internals Segmentation

- Project management, cutting and packaging plan, tooling design, manufacturing & testing, on-site activities (cutting, packaging, handling, cleaning, ...)
- Proven experience since 1985 on all types of reactors: PWR's, BWR's, GCR's, Sodium
- Used all types of cutting tools: PAC, AWJC, MDM, mechanical



- More than 35 year experience in dismantling reactors worldwide
- What did we learn?

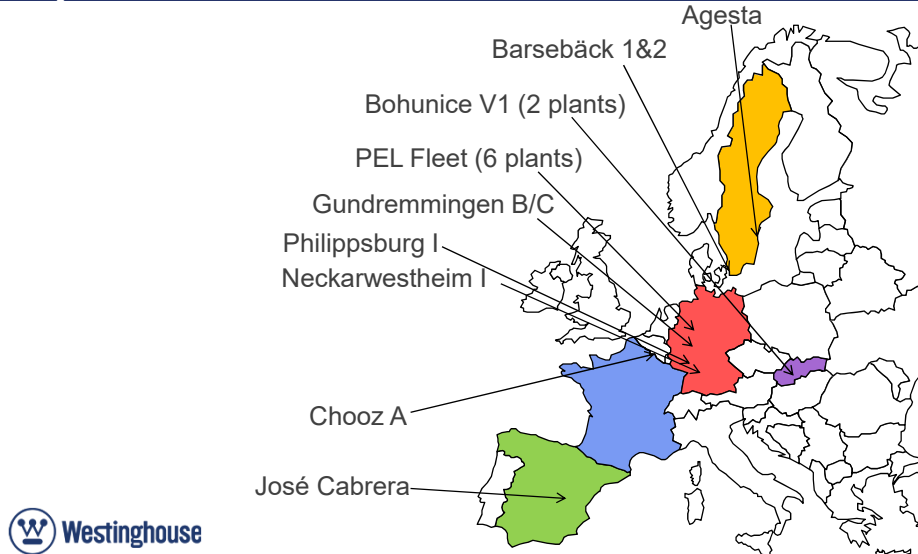


Choice of Cutting Technique on Recent Projects

- Advantages of mechanical cutting:
 - ❖ No aerosols or hydrosols produced
 - ❖ Excellent visibility in the water during the whole segmentation
 - ❖ Chips fall down to the bottom of the pool
 - ❖ Debris easy to collect with simple cleaning devices
 - ❖ Small amount of secondary waste (e.g blades, discs)
 - ❖ Almost all thicknesses and materials can be cut
 - ❖ Safe technology
 - ❖ Low dose for personnel



Recent Westinghouse Reactor Dismantling Projects



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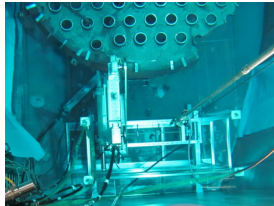
RVI Segmentation – Mechanical Cutting References

Segmentation Performed			Site finalized	Segmentation Performed			Site finalized
• Forsmark 2	Core Shroud, Core Grid		2000	• José Cabrera	Upper & Lower Internals		2013
• Forsmark 1	Core Shroud, Core Grid		2001	• Oskarshamn 3	Steam Dryer		2014
• Oskarshamn 2	Core Shroud Cover, Core Grid		2004	• Peach Bottom 2-3	Steam Dryer		2015
• Oskarshamn 1	Core Grid, Riser pipes		2004	• José Cabrera	Reactor Pressure Vessel		2015
• Olkiluoto 2	Steam Separators, 19 pcs		2004	• Mühleberg	Fuel channels		2016
• Olkiluoto 2	Core Shroud Cover, Core Grid		2004	• Barsebäck 2	All reactor vessel internals		2017
• Forsmark 3	Core Spray Piping & Support		2005	• Barsebäck 1	All reactor vessel internals		2018
• Olkiluoto 1	Steam Separators, 19 pcs		2005	• Neckarwestheim 1	Upper & Lower Internals		2019
• Olkiluoto 1	Core Shroud Cover, Core Grid		2005	• Mühleberg	Fuel Channels		2019
• Oskarshamn 3	Control Rod Shafts, 27 pcs		2006	• Philippsburg 1	All reactor vessel internals		2020
• Olkiluoto 1	Steam Dryer		2009	Segmentation Contracted			Site Start
• Olkiluoto 1	Steam Dryer		2009	• Chooz A	RPV, Upper & Lower Internals		2017
• Olkiluoto 2	Steam Dryer		2009	• Unterwester	Upper & Lower Internals		2019
• Forsmark 2	Core Shroud Cover, Core Grid		2010	• Bohunice V1 unit 1	RPV, Upper & Lower Internals		2020
• Forsmark 1	Core Shroud Cover, Core Grid		2010	• Bohunice V1 unit 2	RPV, Upper & Lower Internals		2020
• Oskarshamn 2	Core Shroud Cover, Core Grid		2011	• Fort Calhoun	All reactor vessel internals		2021
• Oskarshamn 1	Core Grid, Riser pipes		2011	• Agesta	RPV and Internals		2021
• Olkiluoto 2	Steam Separators, 19 pcs		2012	• Grafenrheinfeld	Upper & Lower Internals		2021
• Forsmark 3	Core Spray Piping & Support		2012	• Isar 1	All reactor vessel internals		2022
• Olkiluoto 1	Steam Separators, 19 pcs		2013	• Ringhals 1	RPV and Internals		2023
• Oskarshamn 3	Control Rod Shafts, 27 pcs		2013	• Gundremmingen B	RPV and Internals		2023
• Studsvik R2	Core Spray Piping & Support		2013	• Grohnde	Upper & Lower Internals		2023
• Oskarshamn 3	Core Shroud Cover		2013	• Ringhals 2	RPV and Internals		2024
				• Isar 2	Upper & Lower Internals		2024
				• Gundremmingen C	RPV and Internals		2026
				• Brokdorf	Upper & Lower Internals		2027

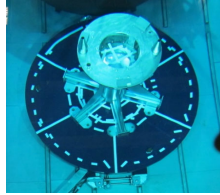
15 reactor dismantling projects currently under contract

RVI segmentation – A tool available for each task

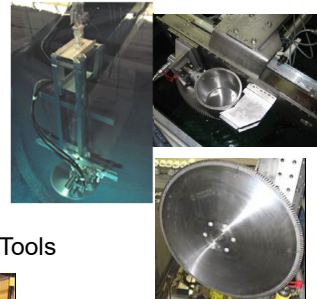
Band Saws with Stands



Turntables



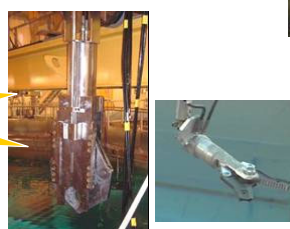
Disc Saws



Lifting Tools



Shearing Tools

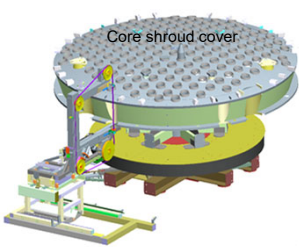


Continuous innovation
is important!

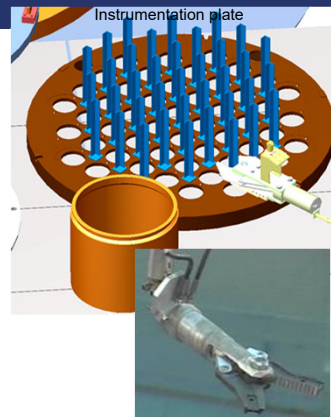


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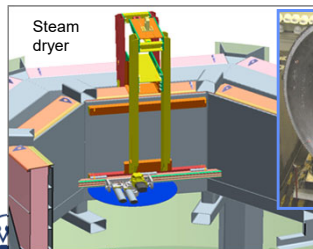
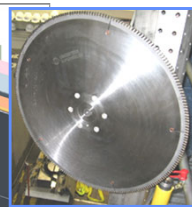
Tooling Design



Core shroud cover



Instrumentation plate

Steam
dryer

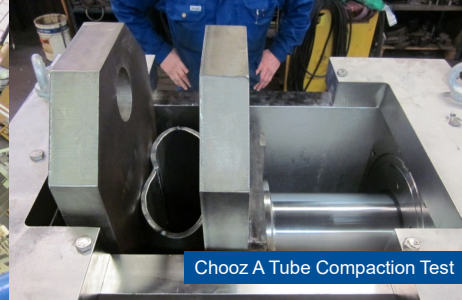
- Extensive 3-D modeling
- Adaptation of proven mechanical cutting technology

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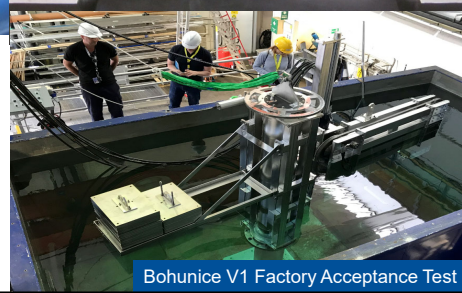
Mock-up Testing



Chooz A Factory Acceptance Test



Chooz A Tube Compaction Test



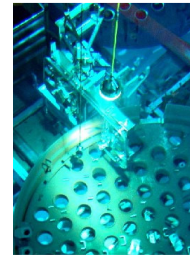
Bohunice V1 Factory Acceptance Test



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Mechanical Cutting: Process Control & Monitoring

- Remote controlled
- Cameras
- Displays
- Good visibility



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Site Preparation



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Importance of Site Set-up

- Upfront optimum set-up before starting any segmentation activities is key.
- Some preparatory works might include civil work modifications, securing pool integrity, retrieval of spent fuel racks, installation of new working bridges (or modifications of existing ones), complementary water filtration, sometimes new pool construction
- Segmentation of reactor internals must be done underwater and are usually done in the reactor cavity for PWR's and in the Storage Pool for Internals (SPI) for BWR's.



Site set-up must be thoroughly analyzed and preparatory works can take some significant time but they are key for a successful project.

Chooz A: Preparatory Works



Enlargement of
reactor cave entrance



SG3 pit closed

- Significant preparatory works needed

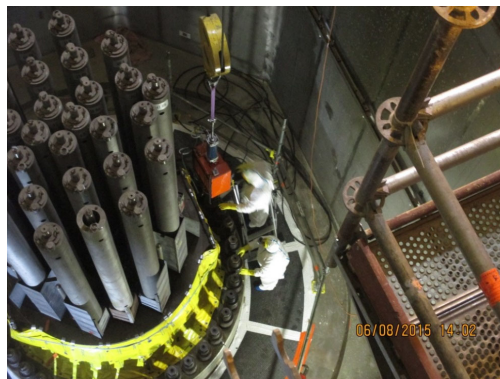


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- Installation of 8 new electrical cabinets (~ 400kVA)
- ~2 km of new cables and trays

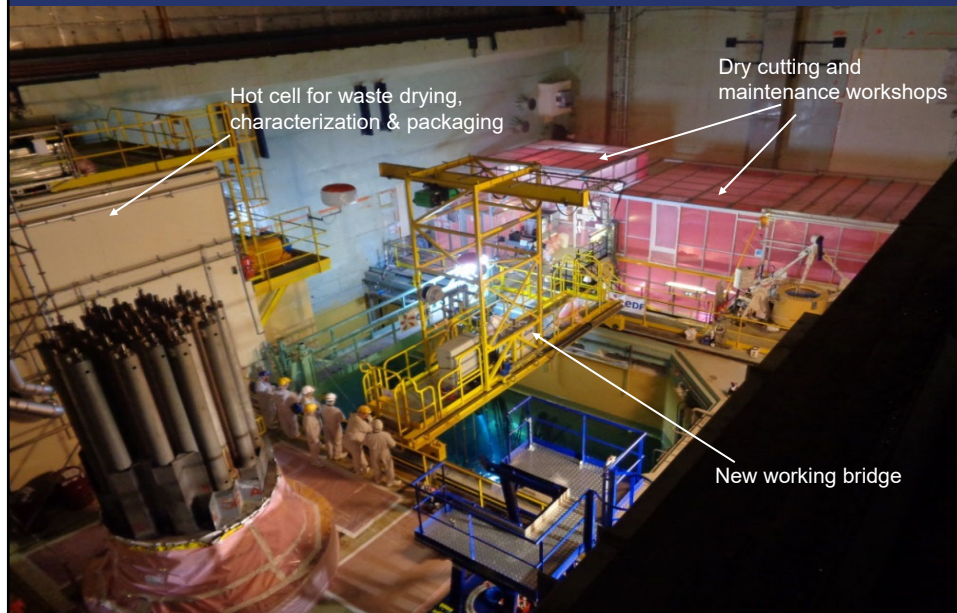
Studs de-tensioning



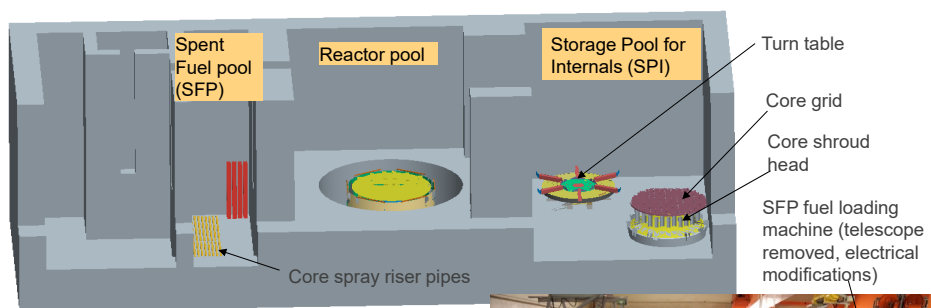
Original plant studs tensioning machine had to be re-conditioned

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Chooz A Reactor Cave: General Set-up



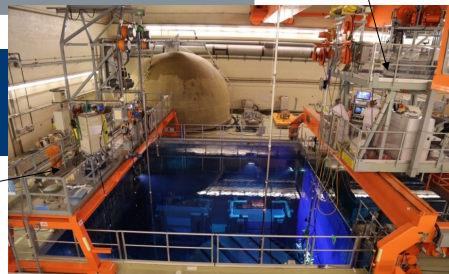
Barsebäck 1-2 Logistics



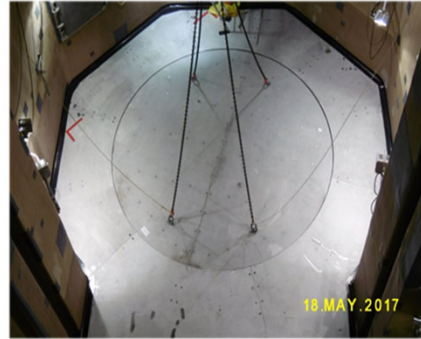
The Storage Pool for Internals (~10 m deep) has been used for all cutting activities.



SFP working bridge



Neckarwestheim I Logistics



- Spent Fuel pool not available at the beginning of the site work (i.e. Spent Fuel still in the pool at the beginning).
- Additional work space provided by installing a cover in the reactor cavity for the cutting and packaging activities.



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Neckarwestheim I: Working Bridge Installation



- Additional crane capabilities (1T and 3T) for optimum handling of equipment and cut pieces in the pool.
- Enables two teams to perform dismantling tasks in parallel



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Bohunice V1 Decommissioning: Two Units

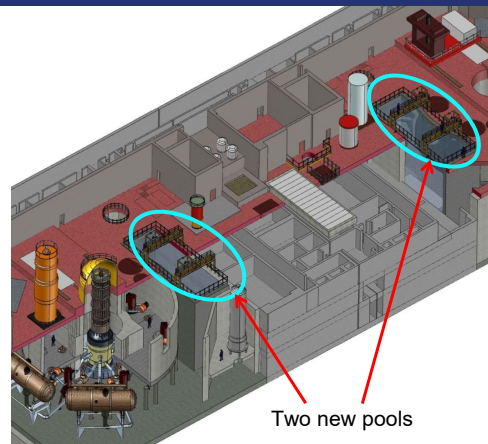
- Two-units VVER-440/V-230, 440 MWe each, commissioned in 1978 and 1980 and shut down in 2006 and 2008
- Scope:
 - ❖ Primary circuits including Steam generators, Main coolant pumps, Main isolation valves, Primary piping, Pressurizers, Bubble tanks
 - ❖ Reactor Vessels and Internals
 - ❖ Auxiliary equipment
 - ❖ Plant systems
 - ❖ Annular Water Tank
 - ❖ Activated operational waste
- Total quantity of materials
 - ❖ 10,000 tons ~ 20,000 packages
- Planning: ~ 5 years



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Bohunice V1: Dismantling Strategy

- **Activated Components** - Wet Cutting Workshops: two new pools with two working bridges each → parallel segmentation to meet project schedule
- **Contaminated Components** - Dry Cutting Workshops:
 - Primary piping, MCPs, MIVs and large auxiliary components cut separately in two Dry Cutting Workshops in Reactor Building
 - Steam Generators moved to Turbine Hall for dry segmentation
- **Other large components** (e.g. Reactor Shaft Protection Lid, reactor vessel upper block, pressurizer, bubble tank) were cut in-situ with dry cutting equipment.



Entire confinement dismantling, together with optimum dismantling concept, leads to good synergies for **cost reduction** and **shorter schedule**.

Site activities: Wet Cutting Workshop preparatory works



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Site activities: Wet Cutting Workshop erection



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Site activities: Reactor Vessel nozzle cutting

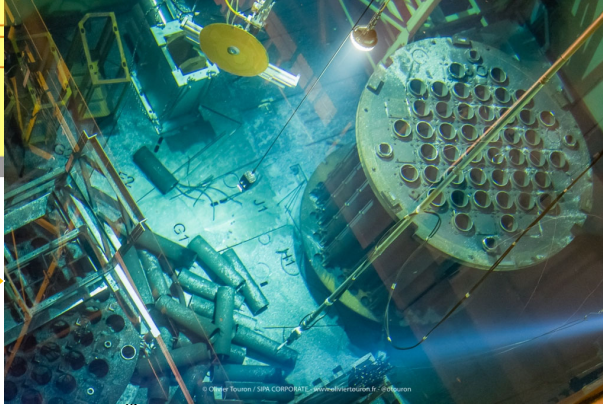
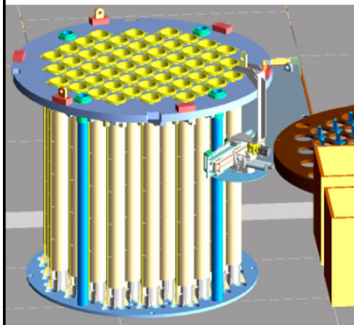


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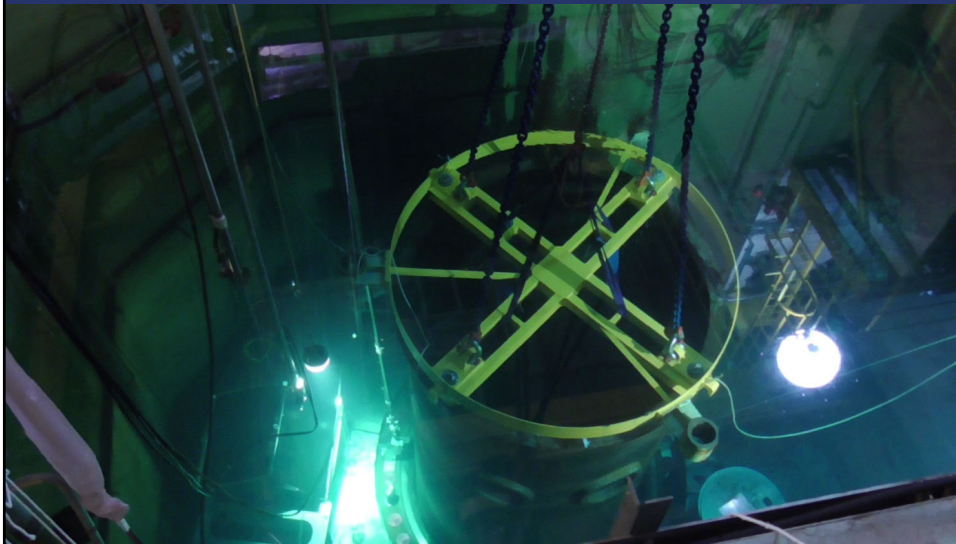
Site Segmentation Activities

Chooz A: Cutting of Support Columns and Guide Tubes



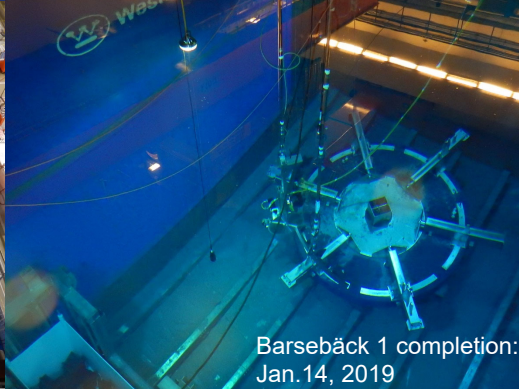
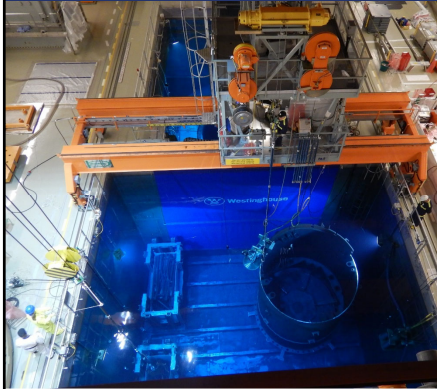
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Chooz A: Lower Internals Lifting



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Barsebäck 1-2: Core Shroud installation and segmentation



Barsebäck 1

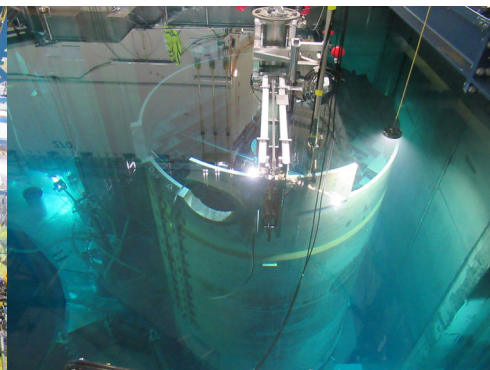
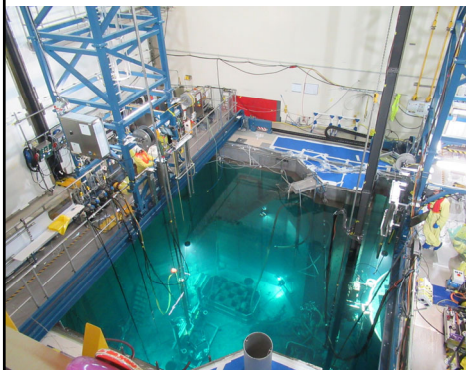
- Number of cut pieces = 2140
- About 1500 meters of linear cutting
- About 143 T of cut internals

Barsebäck 2

- Number of cut pieces = 2,176
- About 1,500 meters of linear cutting
- About 150 T of cut internals

PreussenElektra Fleet : Reactor Vessel Internals Segmentation Program

- Five PWRs: Unterweser, Grafenrheinfeld, Grohnde, Isar 2, Brokdorf
- One BWR: Isar 1
- WEC Scope: segmentation of reactor internals
- Consortium   Westinghouse
- Site work 2019 – 2028

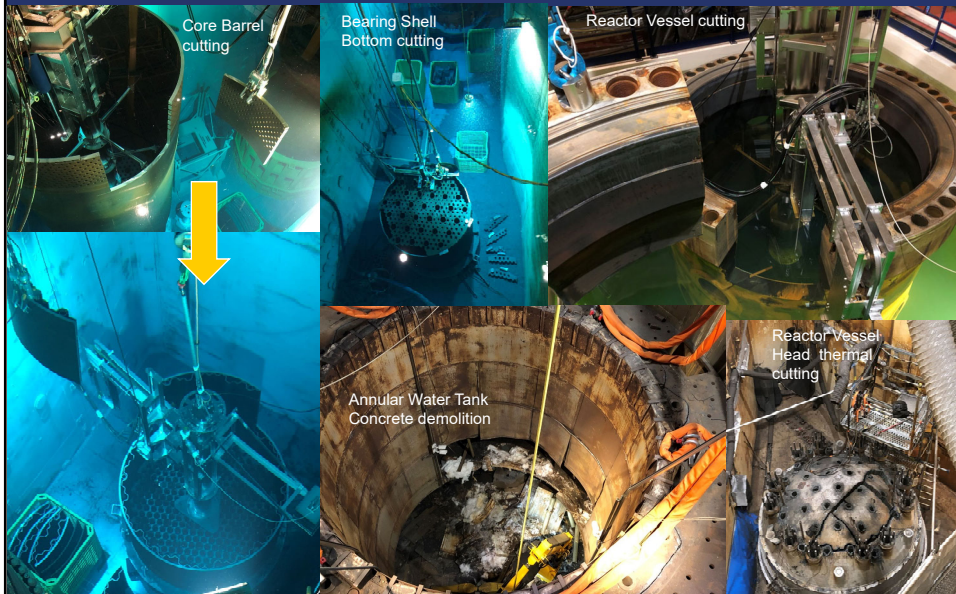


Bohunice V1 Site Work



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Bohunice Reactor Vessel and Internals Segmentation activities and Bioshield Demolition



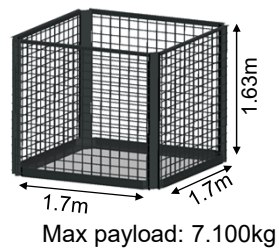
Waste Packaging



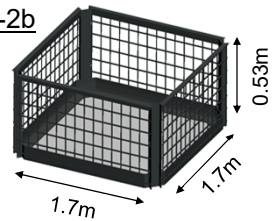
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Waste Packaging: Spain

CE-2a



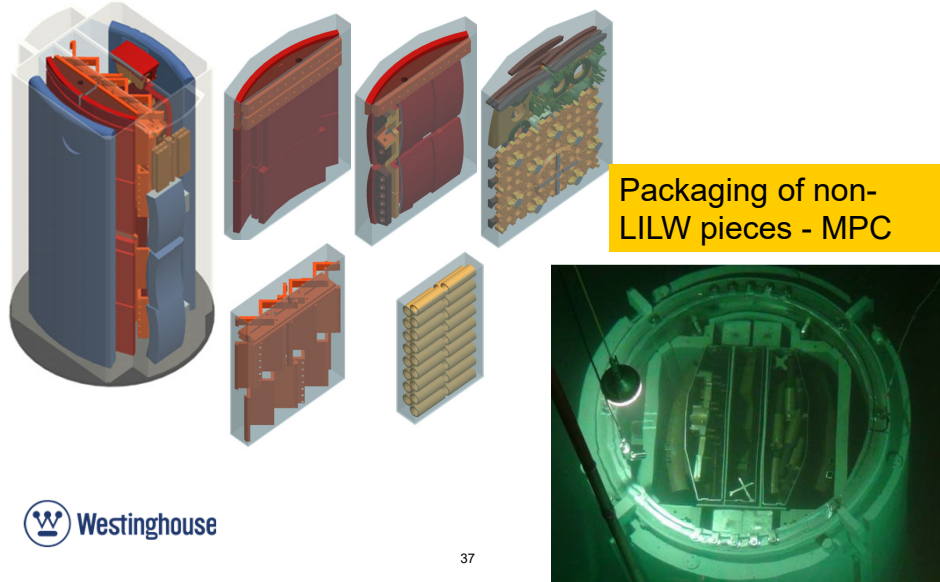
CE-2b



Packaging of cut LILW pieces -
CE-2b container

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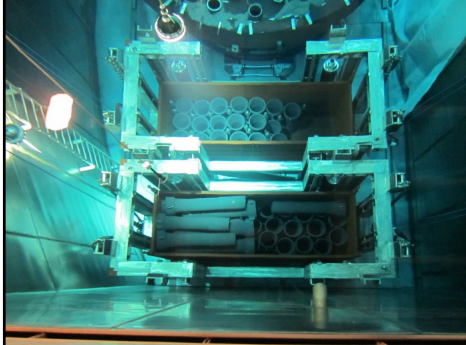
Waste Packaging: Spain



Waste Packaging: France



Waste Packaging: Sweden



Waste packaging is performed with long handling tools.



The "Wet Hood" system is used for waste package handling.

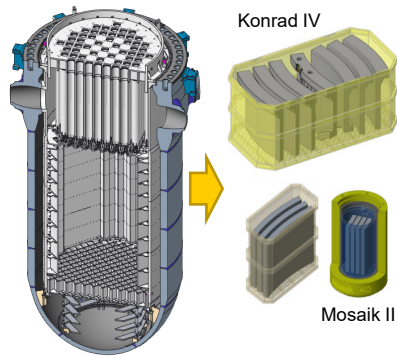


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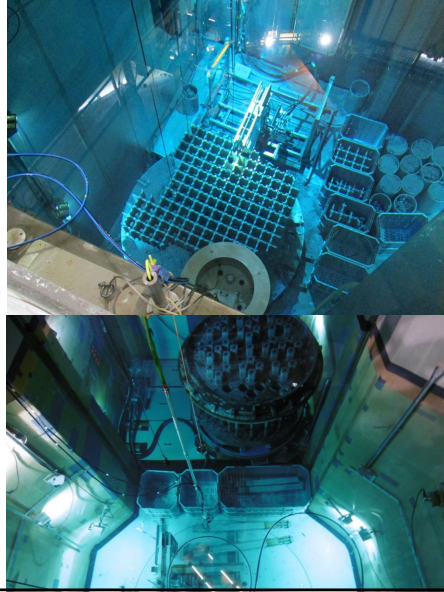
Barsebäck 1-2: Container Loading



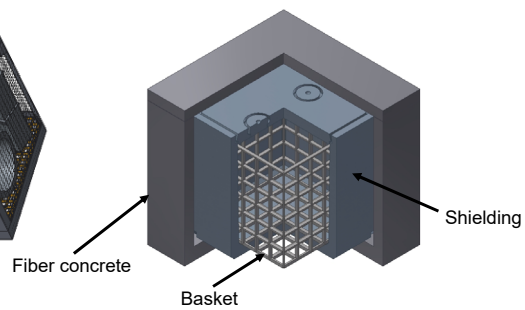
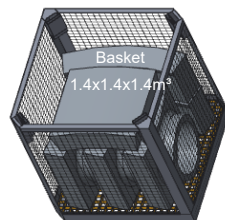
Waste Packaging: Germany



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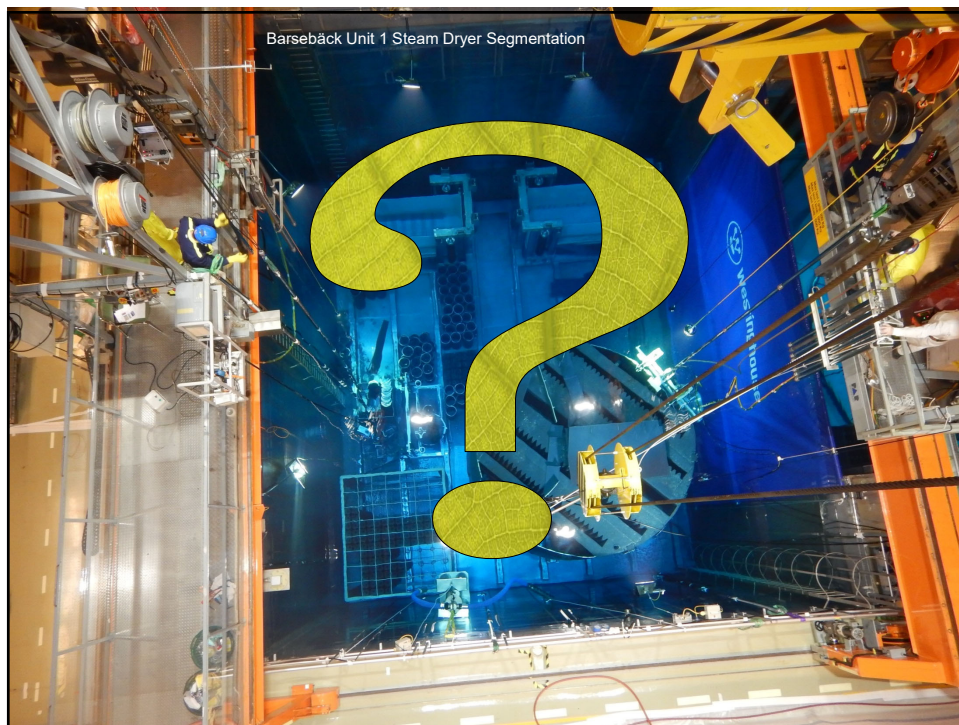


Waste Packaging: Slovakia



Conclusions

- Westinghouse has on-going segmentation contracts on **15 reactors** (14 in Europe).
- A detailed study of the **optimum dismantling scenario** must be done taking account of the available plant systems, infrastructure, waste packages, ...
- Reactor dismantling is not just cutting internals and a vessel. **Especially for old plants, significant plant modifications** need to be considered for meeting the project goals, including civil work modifications, new water filtration system, new power supply, new HVAC system, ...
- Dismantling success relies on good **upfront preparation** and **strict respect of safety rules**.
- **Integration** of reactor dismantling together with the rest of the reactor coolant system offers **excellent synergies for accelerating the planning and reducing cost** of the overall plant dismantling program.
- **Specific waste management constraints** may also require use of dedicated equipment (e.g. waste conditioning hot cell, shielded bell).



Some other news: New book just published

WOODHEAD PUBLISHING SERIES IN ENERGY



FUNDAMENTAL ISSUES CRITICAL TO THE SUCCESS OF NUCLEAR PROJECTS

Edited by
JOSEPH BOUCAU

Westinghouse

Fundamental Issues Critical to the Success of Nuclear Projects presents a complete analysis of the core considerations for those deploying nuclear power plants, managing existing plants, and also for those developing and building new plants. It includes critical considerations, such as cost-estimation, safety procedures, and regulatory compliance, manpower optimization and development, and the application of innovative technologies, such as the use of robotics. Those important issues have been addressed in a systematic way, and explanations have been provided on how the nuclear industry has continuously found solutions to mitigate and eventually solve them properly.

Key Features

- Discusses innovative technologies being implemented in international nuclear plants to improve efficiency, safety, and cost-effectiveness in new, existing, and decommissioned nuclear power plants.
- Provides guidance on difficult cost estimation for nuclear projects, as well as safety procedures, legislation, and regulatory compliance both inside and outside of the United States.
- Considers the future of nuclear energy and analyses the challenges ahead for a sustainable nuclear energy future.

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<https://www.elsevier.com/books/fundamental-issues-critical-to-the-success-of-nuclear-projects/boucau/978-0-08-102472-0>