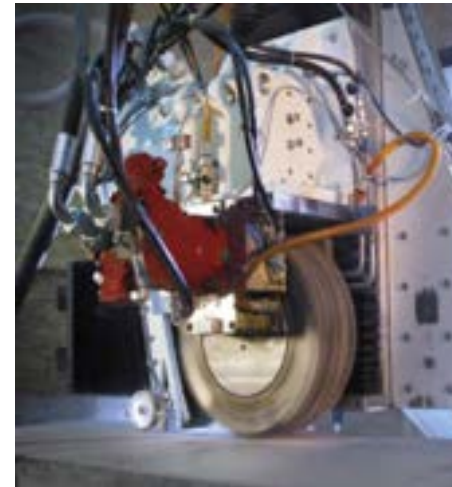
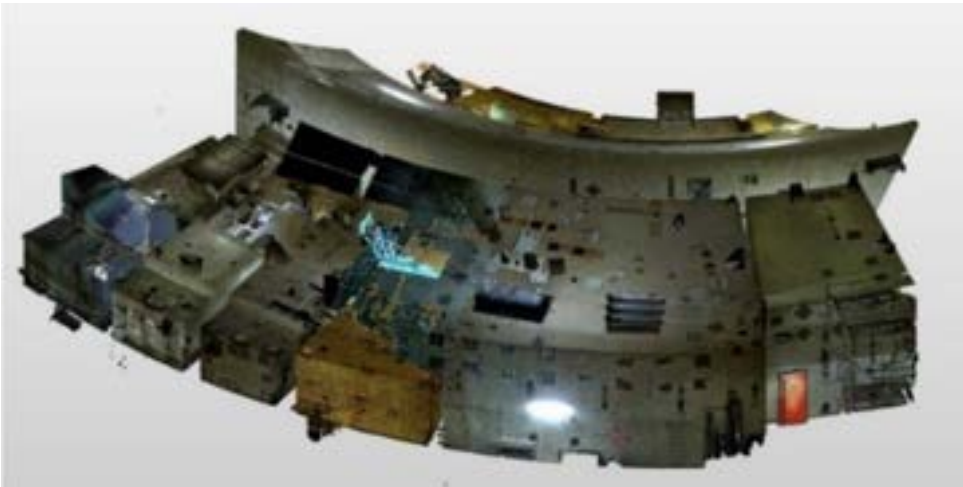


Decommissioning of nuclear facilities

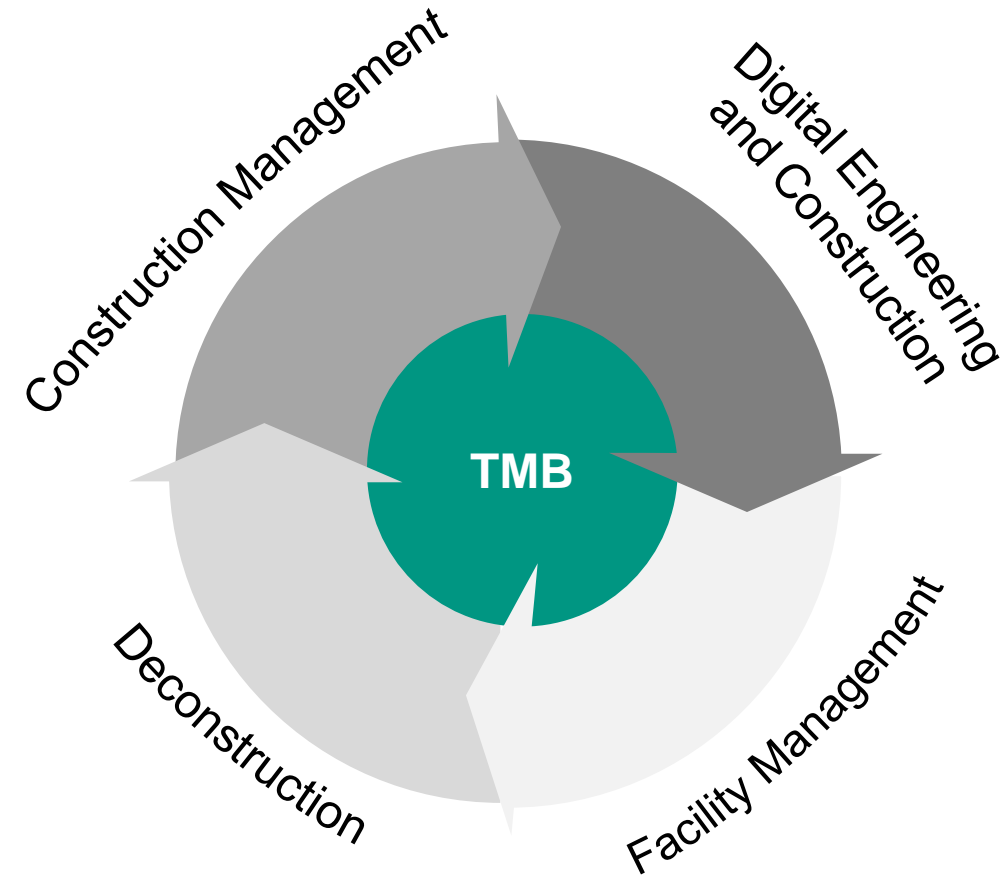
European Summer School, July 3rd 2024
Dr.-Ing. Carla-Olivia Krauß



Agenda

- Introduction of our institute
- Decommissioning of nuclear facilities
- Research projects in decommissioning of nuclear facilities
- Digitalization lab & Building Information Modeling (BIM)

- About 50 employees:
 - 4 Professors
 - 35 Research associates
 - 5 Workshop employees
 - 1 Construction engineer
 - 5 Administrative staff



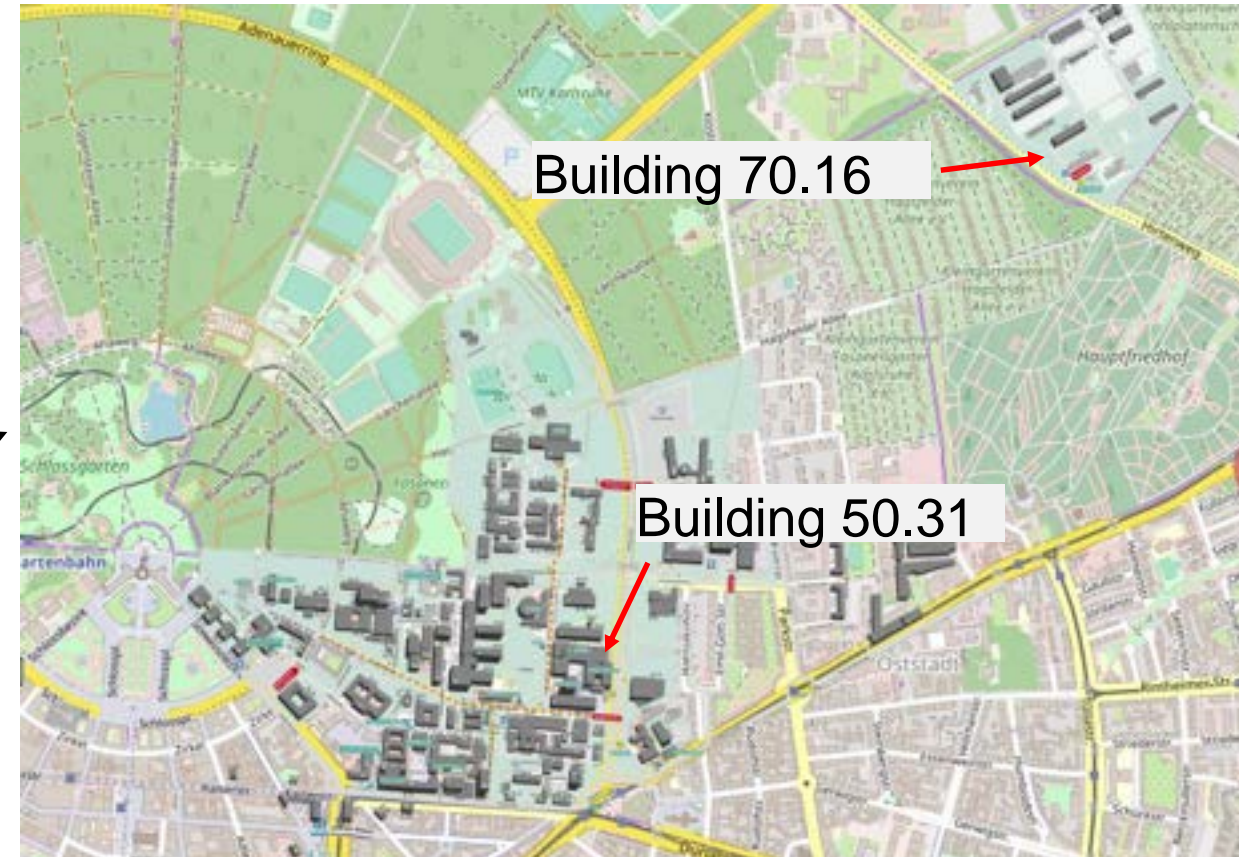
Our Institute



Campus North

Campus East

Campus South



Building 70.16

Building 50.31

Test Facilities



- Test hall
- Workshop
- Test ground (6 hectares)
- Digitalization lab

Our Department

Deconstruction and Decommissioning of Conventional and Nuclear Buildings

- Head: Prof. Dr.-Ing. Sascha Gentes
 - 12 Research associates
 - 1 Construction engineer
 - 1 Workshop employee
 - 1 Administrative staff



Our Department

Deconstruction and Decommissioning of Conventional and Nuclear Buildings

Two topics:

- Decommissioning of conventional buildings:
 - Management and treatment of hazardous substances during the decommissioning
 - Reuse of material
 - Digitalization of building models

- Decommissioning of nuclear facilities:
 - Decontamination of nuclear power plants (NPP)
 - Optimization of mechanical processes for dismantling and decommissioning projects

Our Department

Currently two lectures:

- Environmentally and recycling-friendly dismantling of buildings
- Decommissioning of nuclear facilities

In planning for next semester:

- New lecture about digitalization of decommissioning of conventional buildings and nuclear facilities

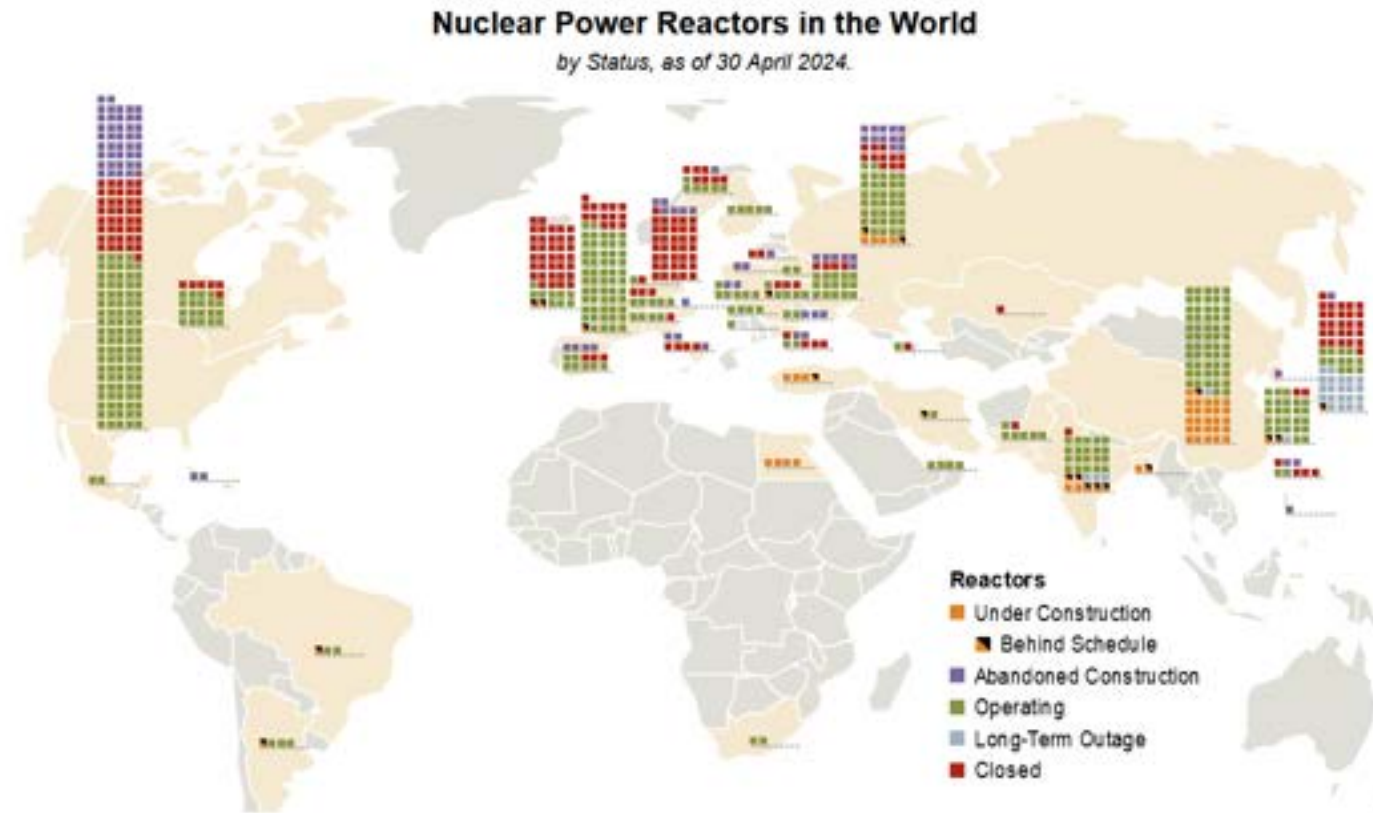


Excursion to a demolition site

Decommissioning of nuclear facilities

Nuclear energy in the world

- Operating reactors:
416 reactors
- Under construction:
60 reactors
- Abandoned construction:
92 reactors
- Closed/long-term outage:
239 reactors







© <https://www.worldnuclearreport.org/reactors.html#tab=iso/>

Nuclear energy in Germany

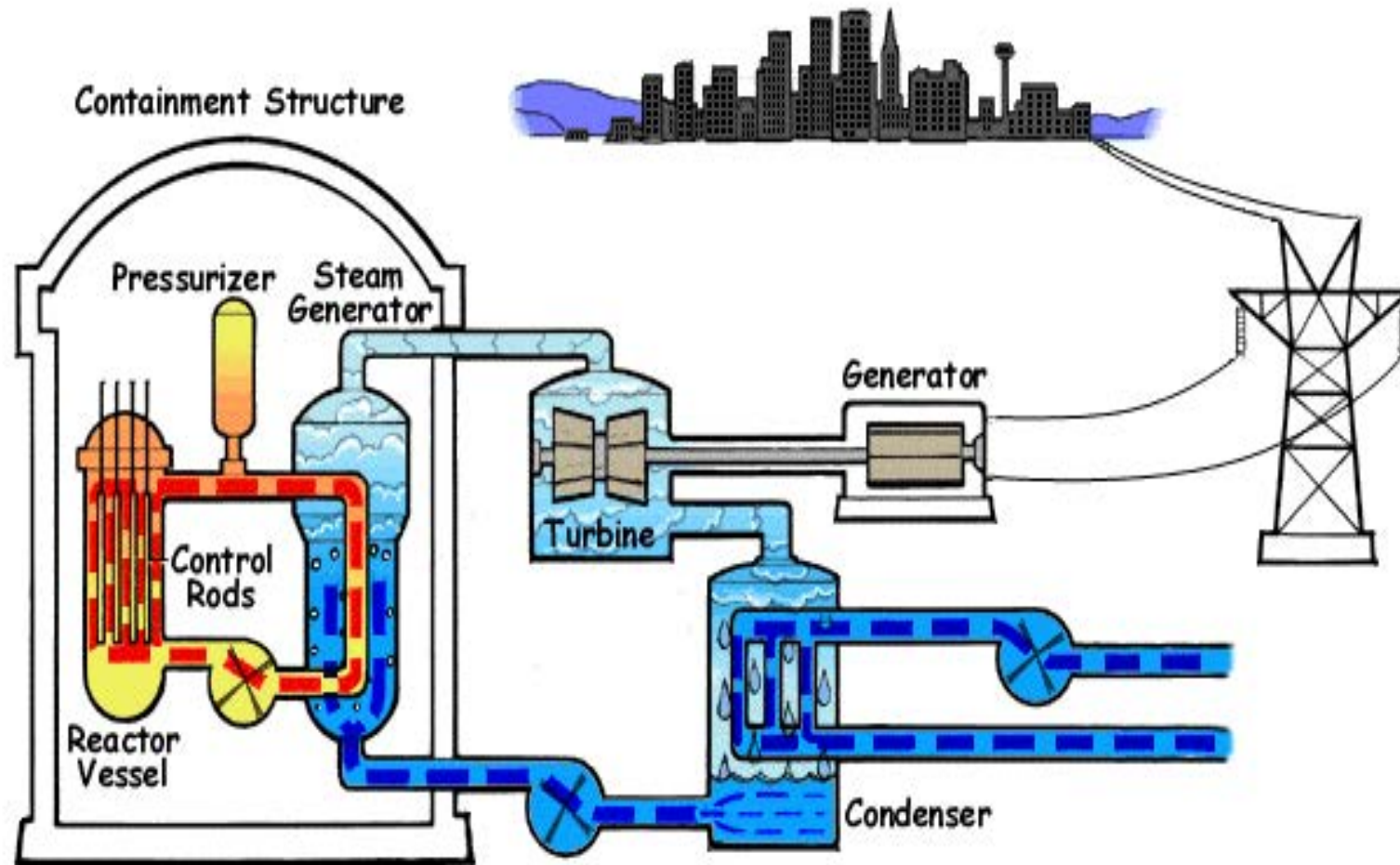
- After the Fukushima accident in 2011, the German government decided to stop nuclear power
- Presently, all nuclear power plants (NPP) are shut down
- 29 NPP's are in deconstruction phase
- The last NPP was shut down on 15th April 2023

Legend

-  On 15.04.2023 final shut down
-  Final shut down
-  In decommissioning
-  Decommissioning ended

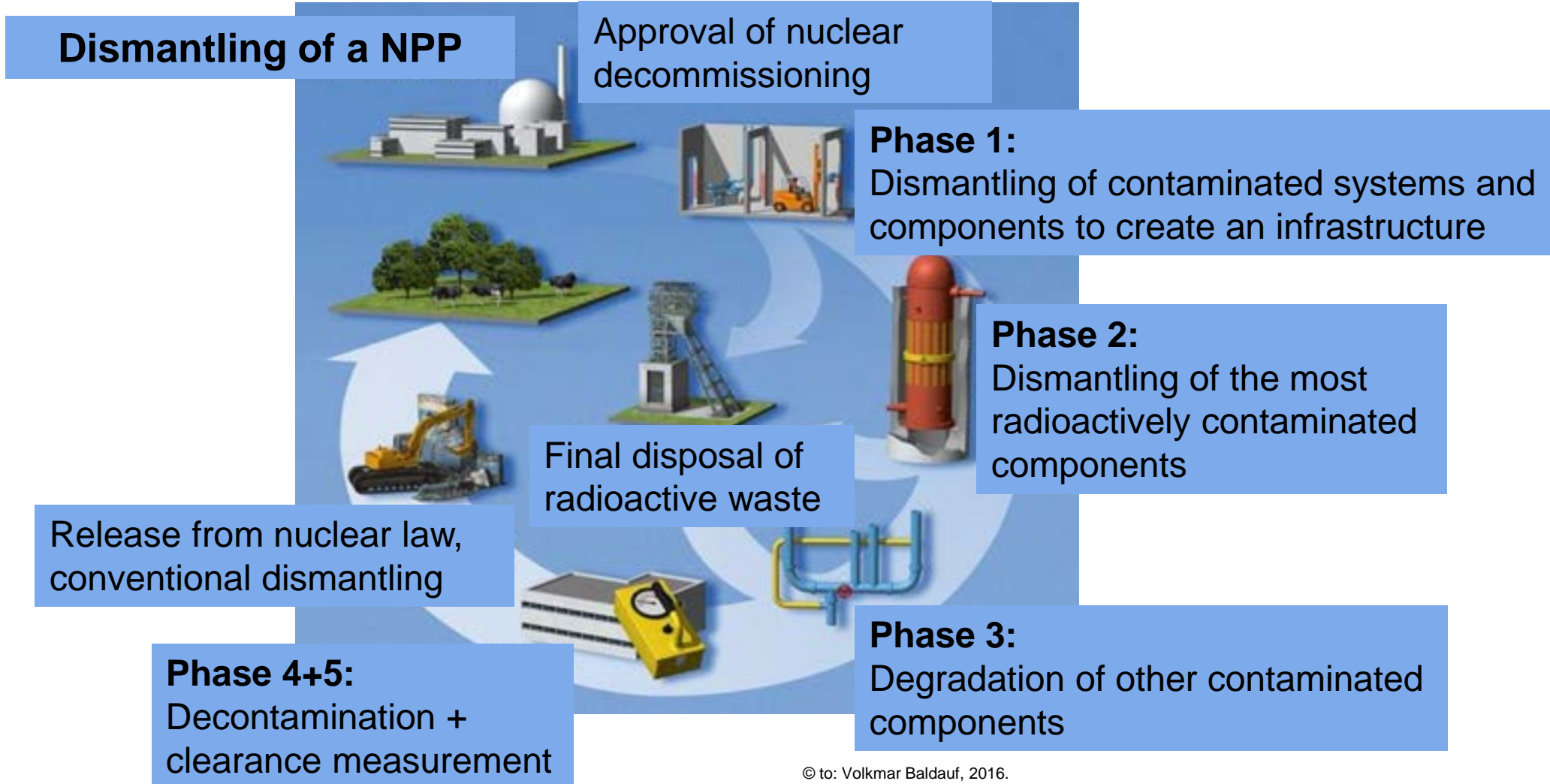


Working principle of a nuclear reactor



© whatisnuclear.com

Decommissioning of nuclear facilities



© to: Volkmar Baldauf, 2016.

Decommissioning of nuclear facilities

Decontamination



© BGE

Dismantling the turbine



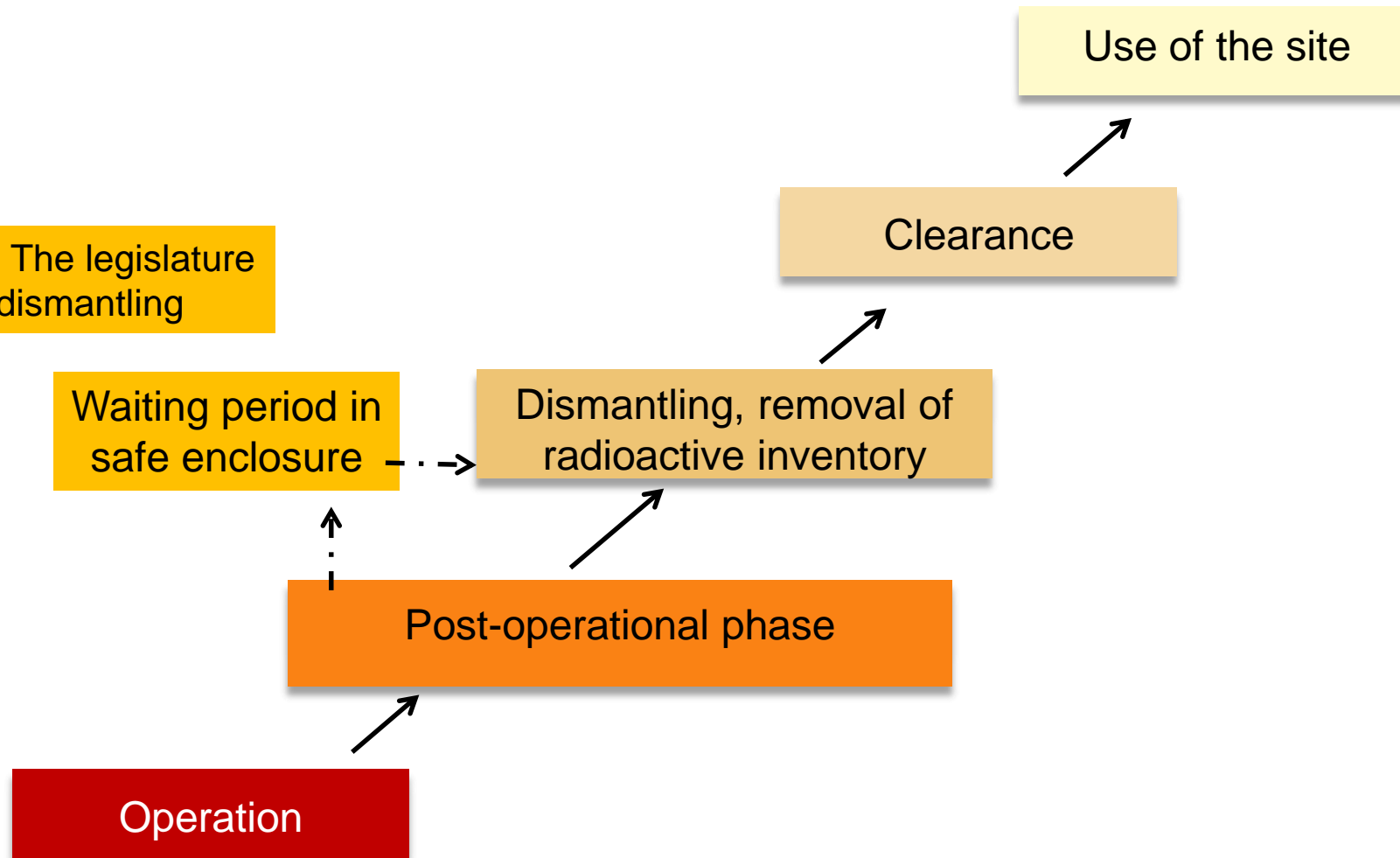
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Clearance measurement



© Wiederaufarbeitungsanlage Karlsruhe
Betriebsgesellschaft mbH

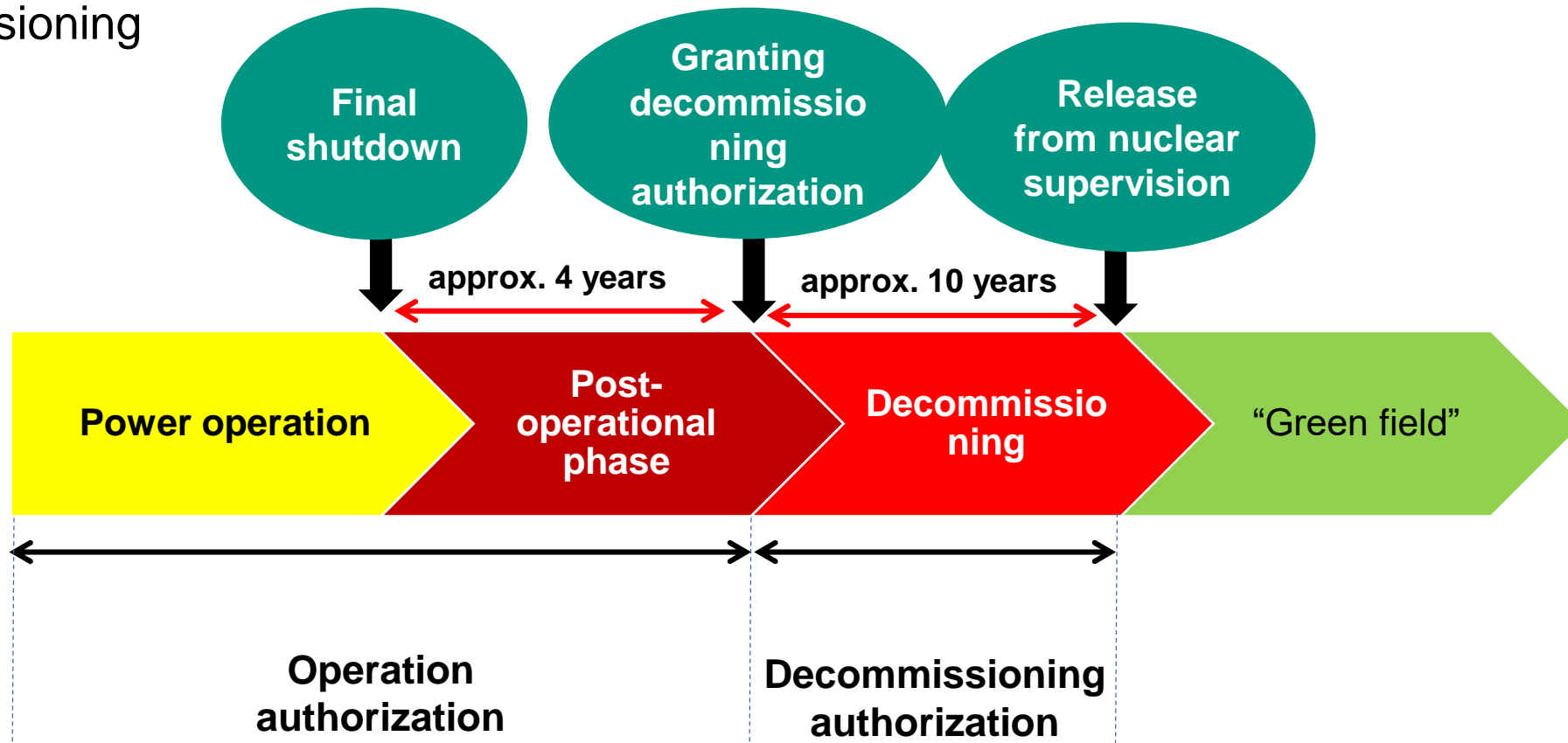
Decommissioning of nuclear facilities



© BrenkSystemplanung

Decommissioning of nuclear facilities

- Time schedule for the transitions between power operation, post-operational phase and decommissioning

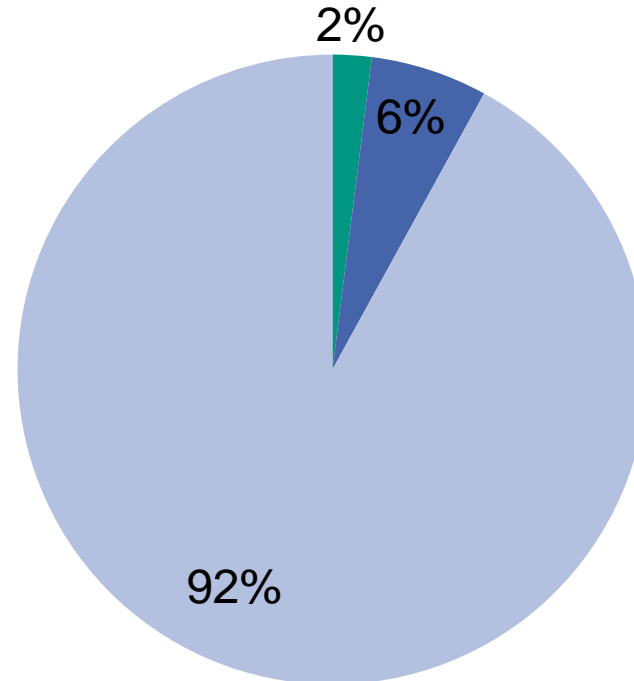


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Decommissioning of nuclear facilities: waste

Radioactive waste from the dismantling of a NPP

Typical distribution



- Radioactive waste for final disposal
- Reusable after treatment
- Directly releasable

© S. Thierfeldt, F. Schartmann

Radioactive waste

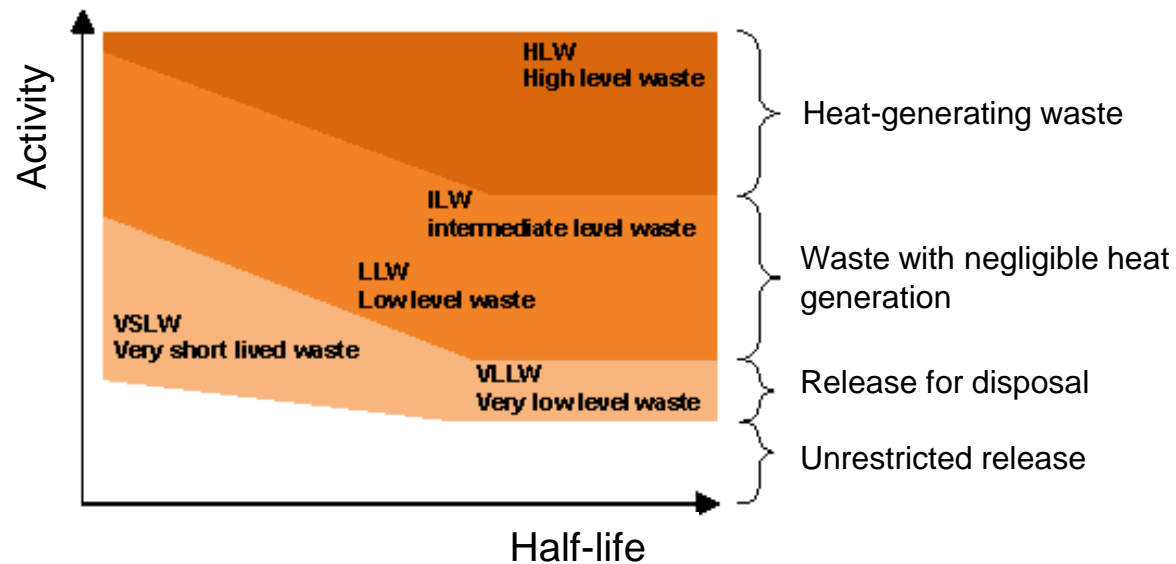
■ Classification of radioactive waste

■ In Germany

- Waste with low heat generation
- Heat-generating waste

■ International

- Dependency with activity content and half-life of radionuclides



© S. Thierfeldt, F. Schartmann

Conditioning/Packaging

- Packaging of low and medium-level waste:
 - Filling into 200 or 400 liter drums/standard containers
 - Mixed with concrete after pre-treatment



EB1-A200 standard



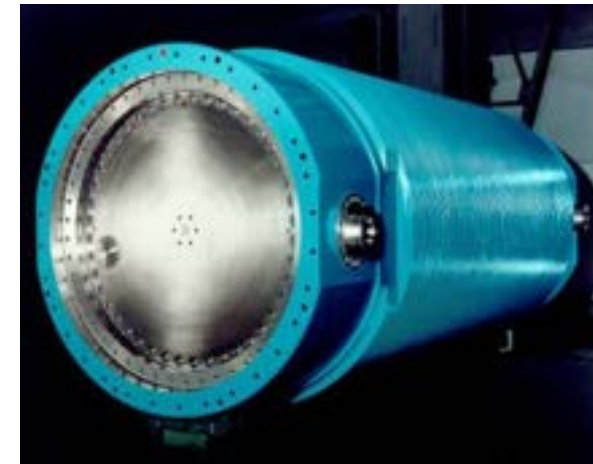
EB3-A400

© www.eisenwerk-bassum.de



Square barrel

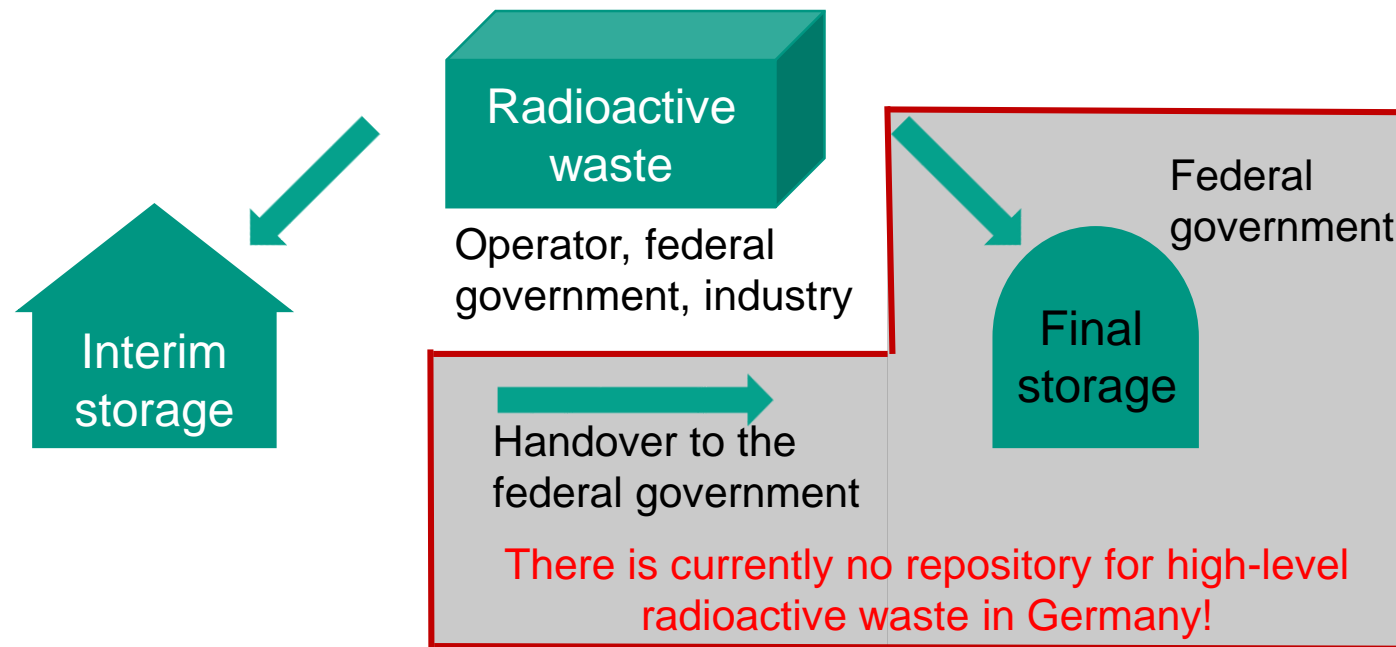
- Packaging of high-level waste
 - Castor stands for “Cask for Storage and Transport of radioactive Materials”
 - Four main requirements for the containers:
 - Safe containment of the radioactive contents, Shielding of the radiation, Dissipation of the heat generated by the radioactive materials, Ensuring subcriticality (impossibility of a chain reaction)



© www.gns.de

Storage in Germany

■ Storage types



Final storage in Germany

■ Final storage

- Disposal of waste by placing it in a specially designed facility
- Differentiation from interim storage
 - The need for monitoring, inspection and repair of any damage that may occur
- Differentiation into repositories for:
 - Low heat-generating waste
 - > Konrad mine repository, storage probably from 2030
 - Heat-generating waste
 - > No repository available, currently: site selection procedure



Konrad mine

Research projects in decommissioning of nuclear facilities

Research projects

Reasons for researching dismantling technologies:

- Radioactive waste minimization
- Supporting staff (improved safety and ergonomics in the workplace)
- Reducing radiation exposure for workers
- Increasing the efficiency of decommissioning procedures

Our research-projects

■ Current research projects:

- Validation of a continuous magnetic filter and sieving system for the treatment of particulate mixtures (KoMaSi)
- Development of a sampling system including quality assured sampling procedure for non-accessible area (Bero)
- Automated non-destructive internal corrosion detection on radioactive drums (ZIKA)
- Advancement of a demonstrator for dry-mechanical decontamination of corners and inner edge in nuclear facilities (EKONT-2)
- Decommissioning Management and Leadership for Safety Education (DMaLSE)
- Robotic Systems for Decontamination in Hazardous Environments Phase II (ROBDEKON II)
- Visualization of trouble spots for Decontamination Work and Decision Measurements with the help of BIM (ViSDeMe)
- Wet sieving and magnetic separation of grain mixtures to minimize secondary waste in the decommissioning of nuclear facilities Subproject: Experiments with non-radioactive materials (NaMaSK)
- Research work on the decommissioning of nuclear facilities within the scope of the program-oriented funding IV of the Helmholtz Association

Our research-projects

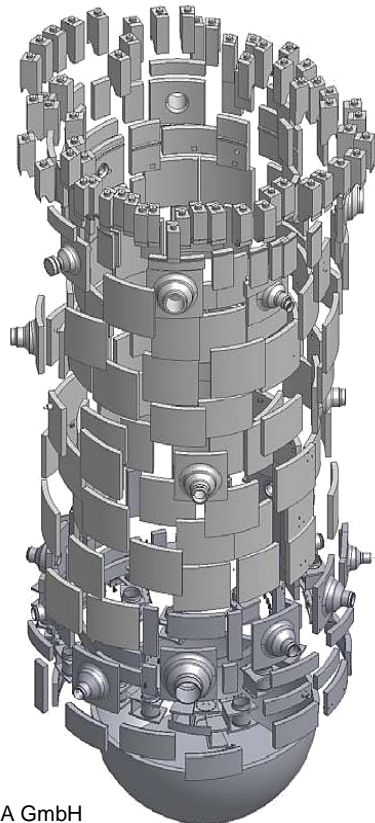


■ Our Partners:

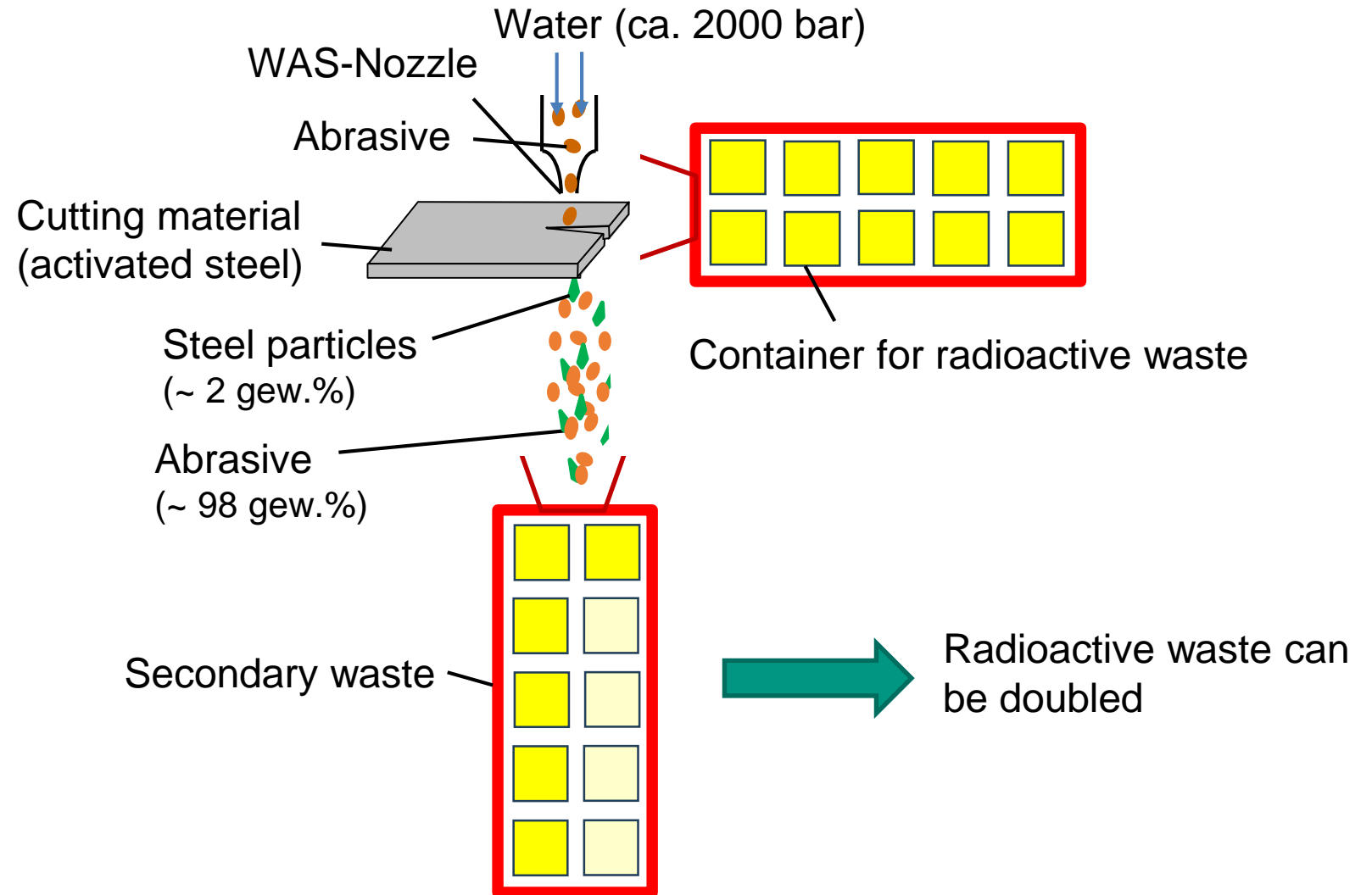
- IBASS GmbH & Co. KG
- Bundesanstalt für Materialforschung und -prüfung (BAM)
- Kraftanlagen Heidelberg GmbH (KAH)
- Zentralstelle für radioaktiven Abfall (ZRA)
- Labor für Maschinenkonstruktion und Produktentwicklung der Hochschule Konstanz - Technik Wirtschaft und Gestaltung
- CONTEC Maschinenbau & Entwicklungstechnik GmbH
- sat. Kerntechnik GmbH
- Université Côte d'Azur (UCA)
- SKEMA Business School (SKEMA)
- J Repussard Conseil (JRC)
- Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (IOSB)
- Deutsche Forschungszentrum für Künstliche Intelligenz (DFKI)
- Hochperformante Humanoide Technologien (KIT-H2T)
- Intelligente Sensor-Aktor-Systeme (KIT-ISAS)
- HKA Hochschule Karlsruhe
- Forschungszentrum Informatik (FZI)
- Götting KG
- ICP Ingenieurgesellschaft Prof. Czurda und Partner mbH (ICP)
- RWE Nuclear GmbH
- Institute for Nuclear Waste Disposal (INE) of Karlsruhe Institute of Technology (KIT)
- PreussenElektra

Waterjet abrasive suspension cutting (WAS)

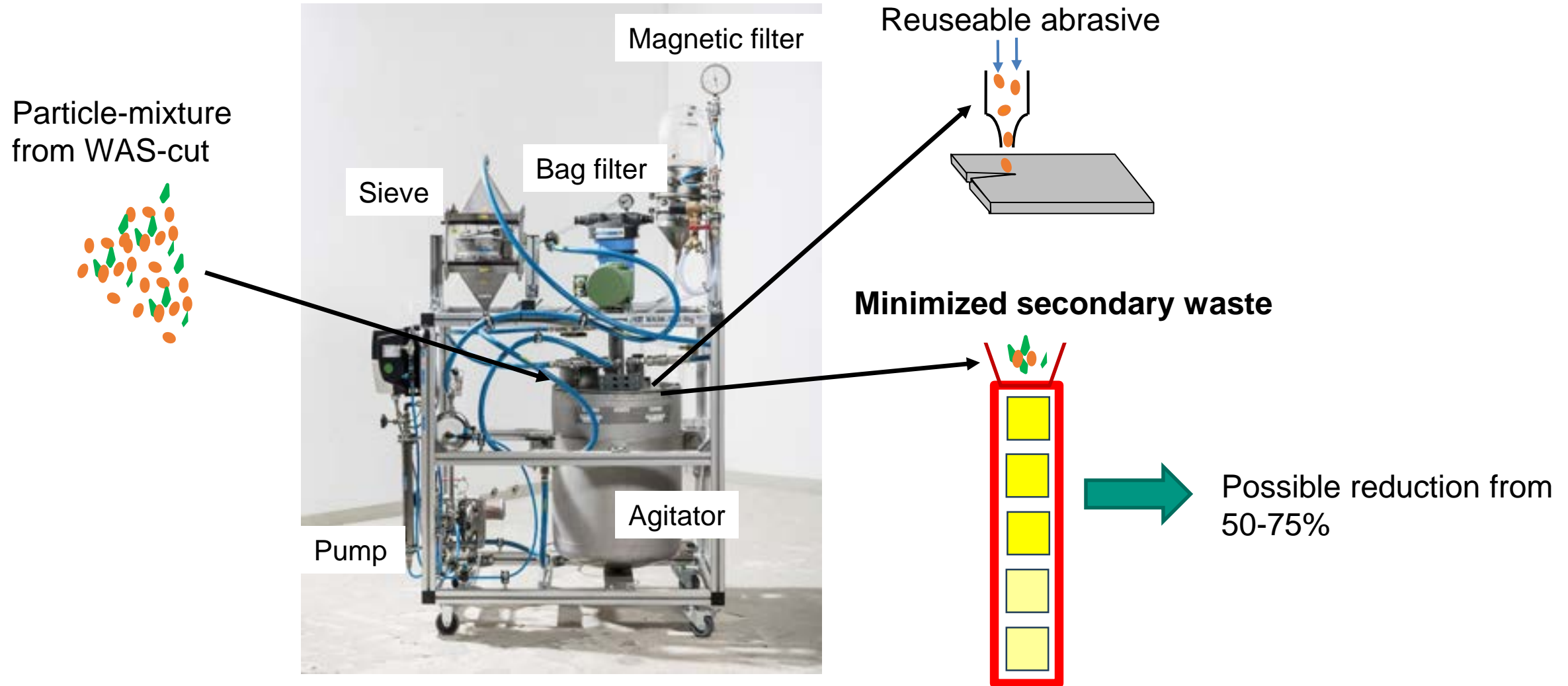
Dismantling of the reactor pressure vessel and its internals



Quelle: AREVA GmbH

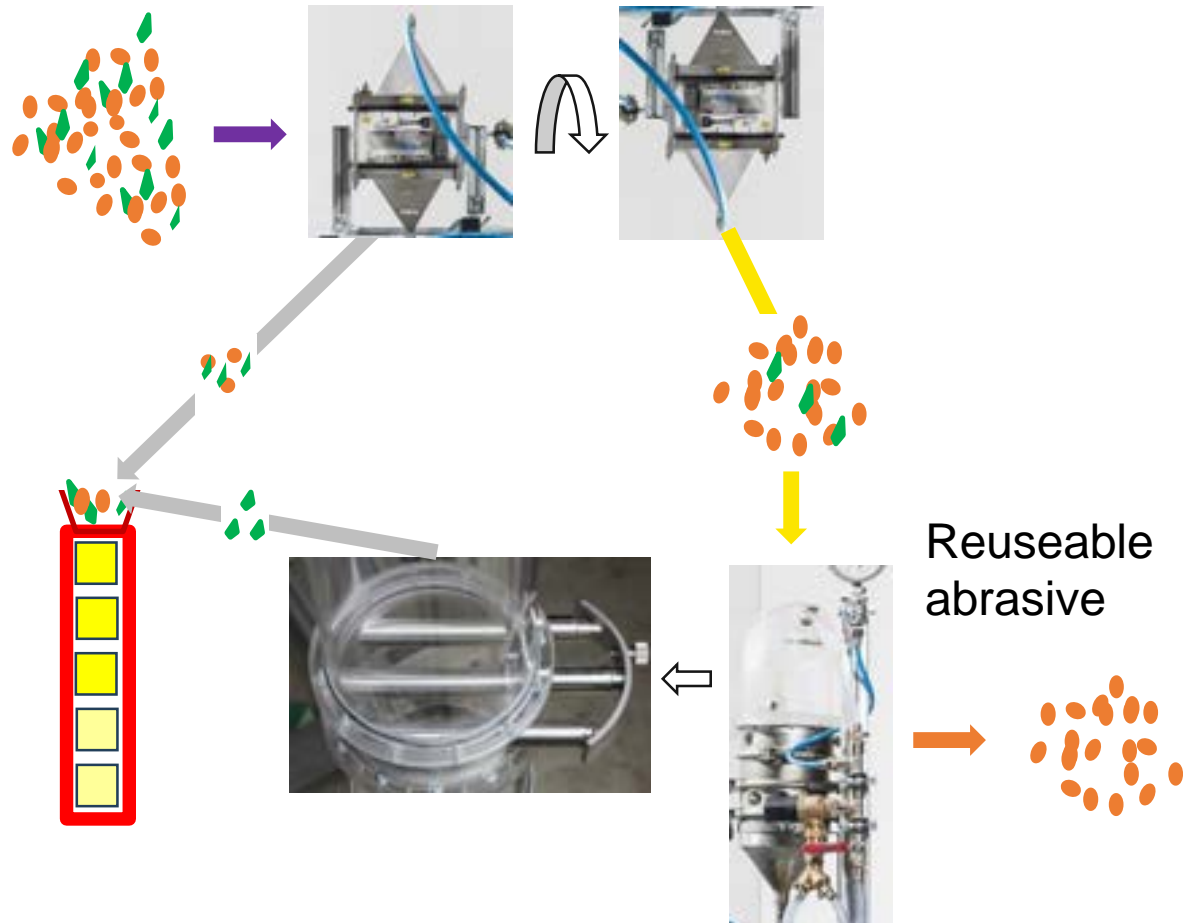


Separation-rig

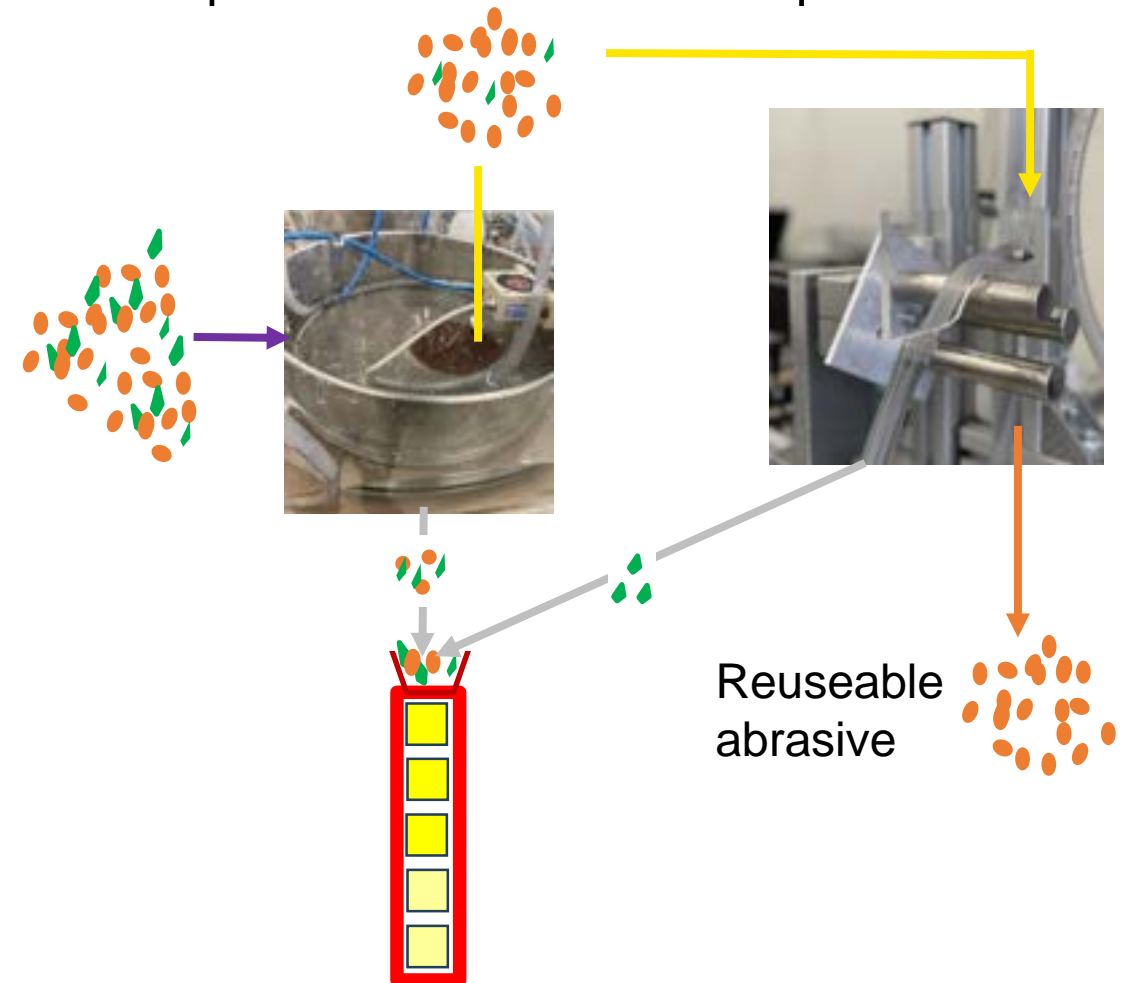


Transformation from batch to continuous process

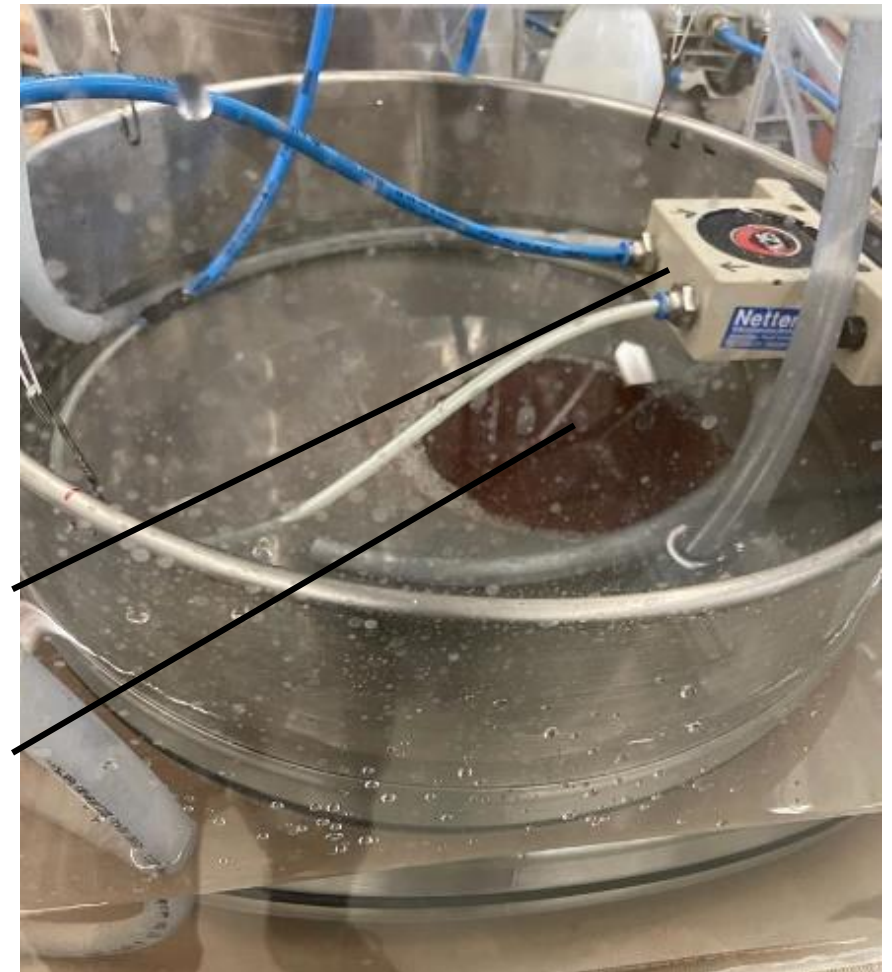
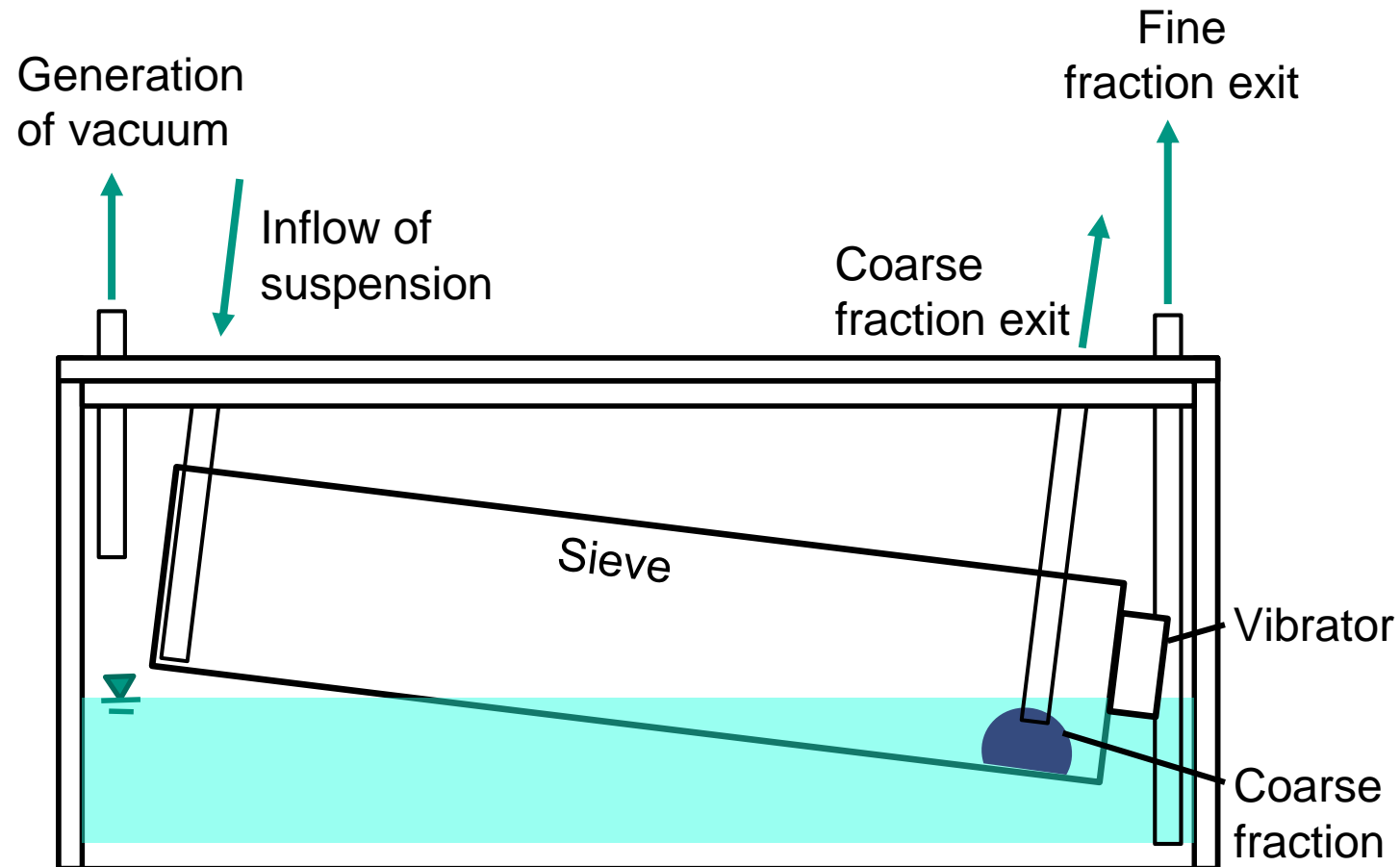
Separation with batch process



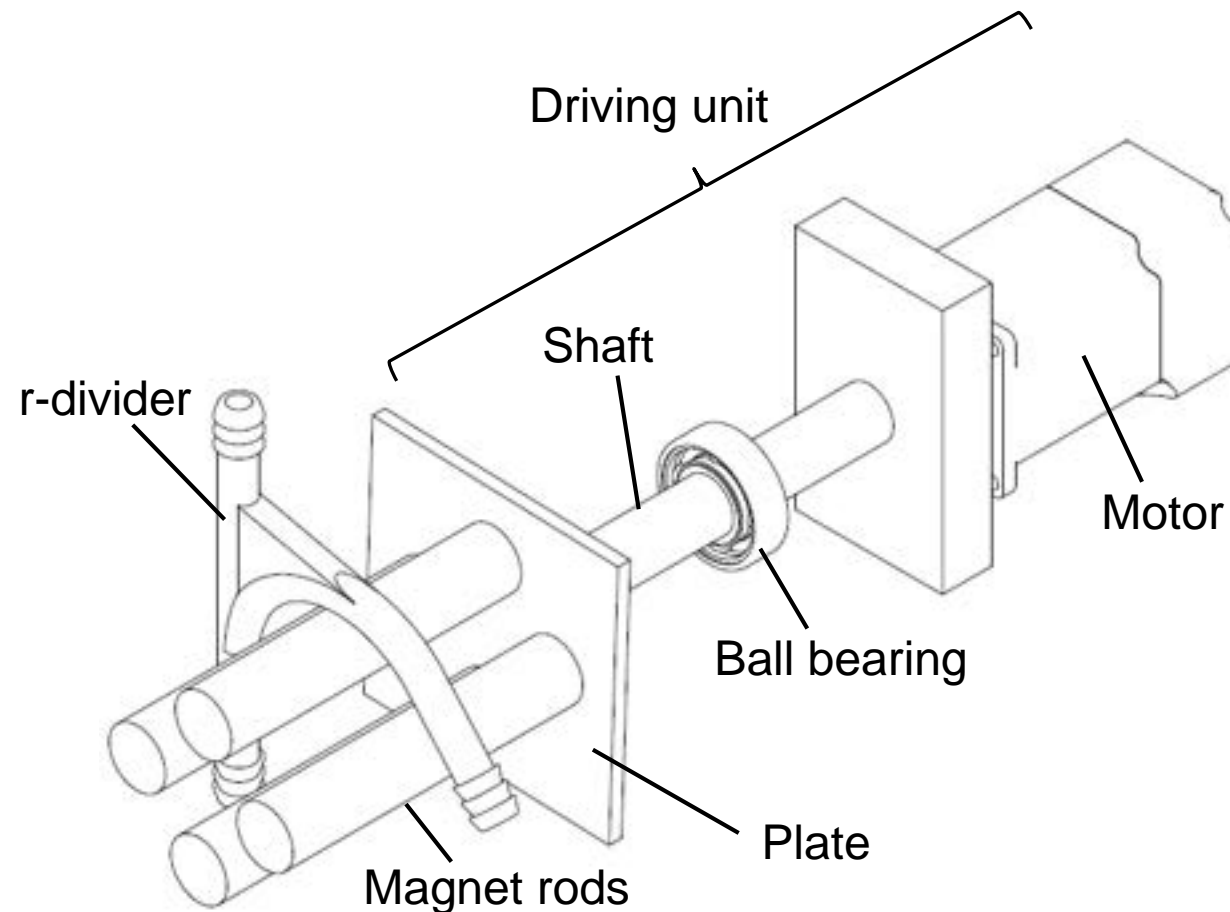
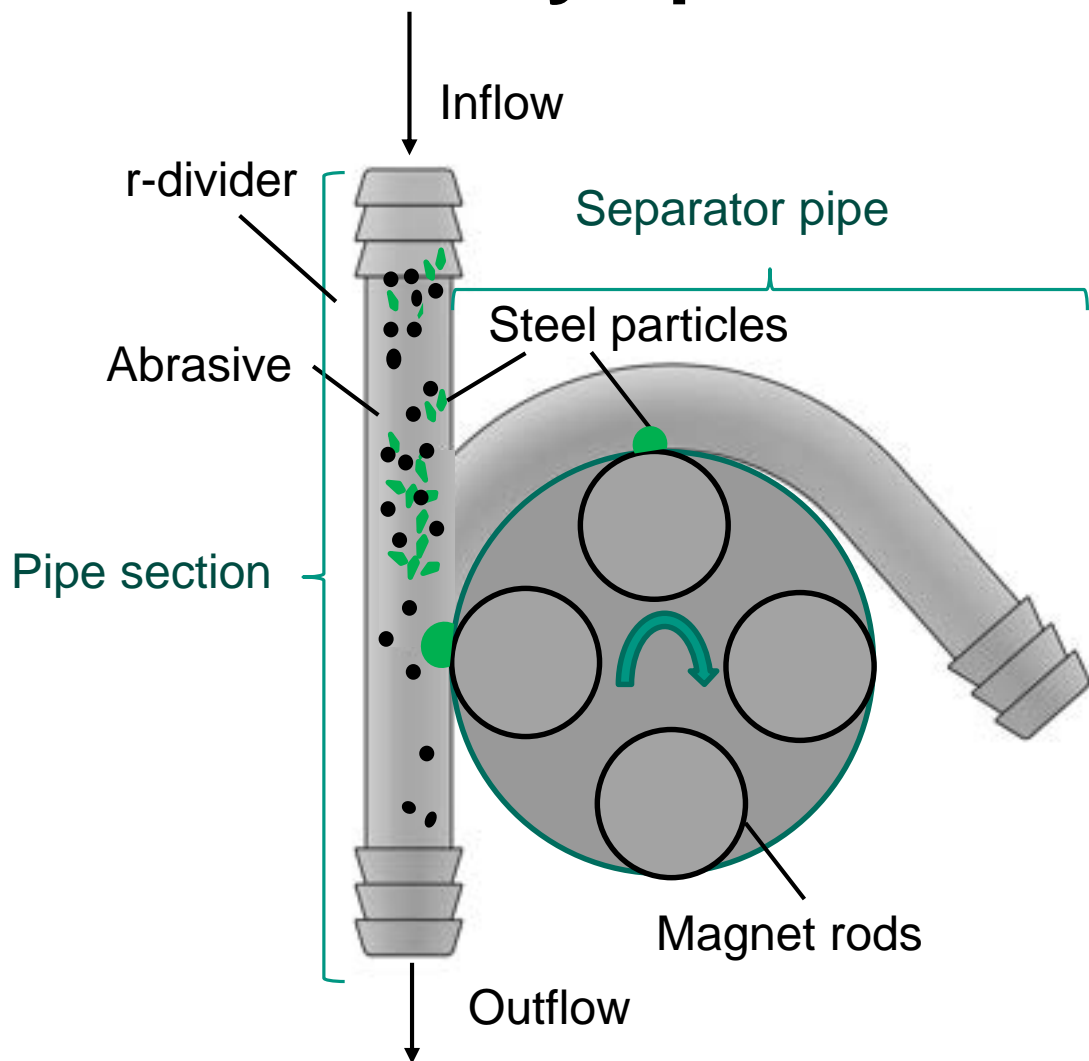
Separation with continuous process



Continuously operated sieve



Continuously operated magnetic filter

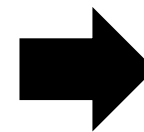
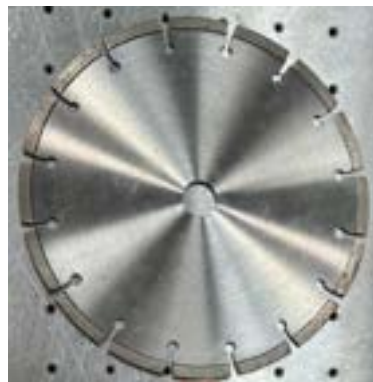


Decontamination of inner edges and impurities in NPP

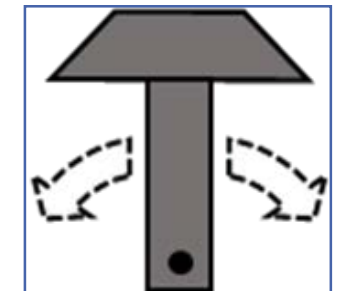
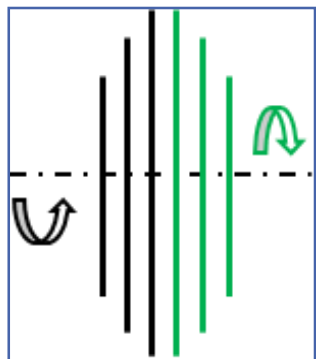
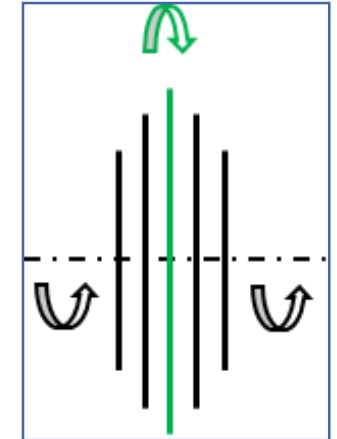
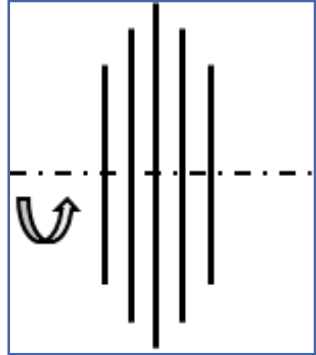


1. Cantilever plates
2. Consoles
3. Beams
4. Curved walls
5. Wells
6. Openings
7. Staggered walls
8. Parting joints
9. Recesses

Versatile need for inside edge decontamination tool, only universal tools from the conventional construction in use

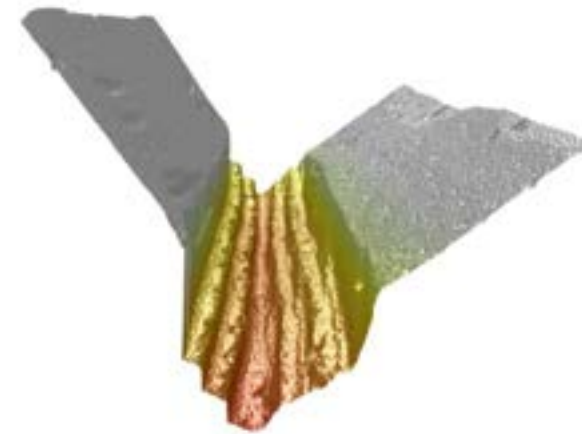
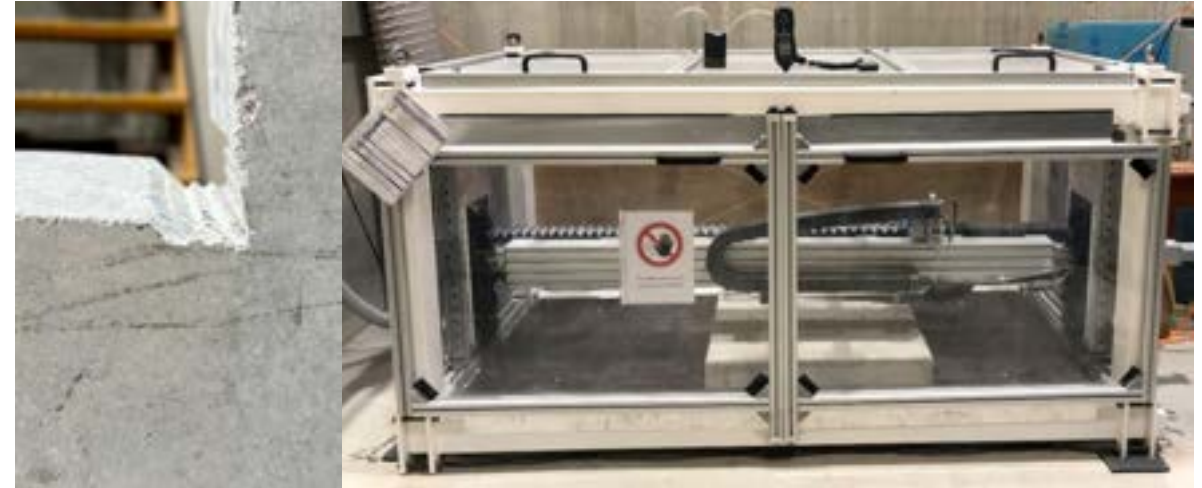


Developed cutting tools (Ekont-1)



Test bench and experiments

- Central suction
- Feed rate and removal depth operation
- Research of external factors
 - Forces for the user
 - Vibrations
 - Sound level
 - Amount of dust
 - Particulate matter
 - Surface roughness





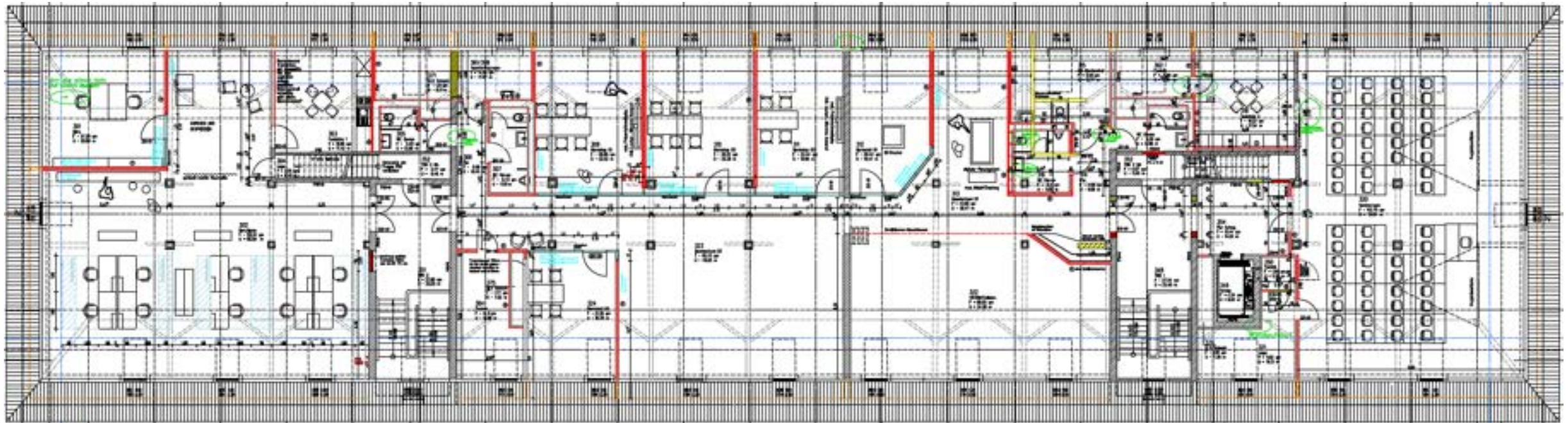
Digitalization lab & Building Information Modeling (BIM)

Digitalization lab

- New lab for Digitalization of Decommissioning & Deconstruction
- Located at Campus East
- Named BIM D²:
Building Information Modeling Decommissioning & Deconstruction
- Completion in early 2025



Digitalization lab



Offices



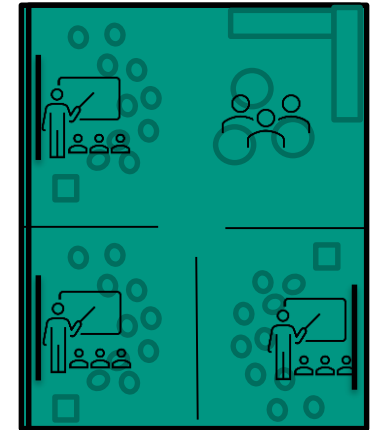
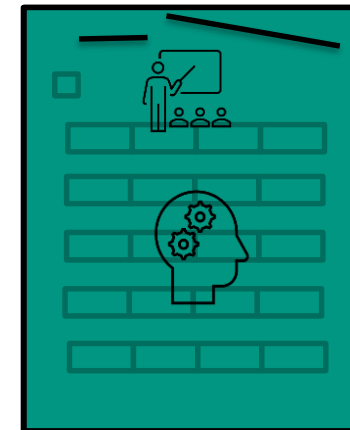
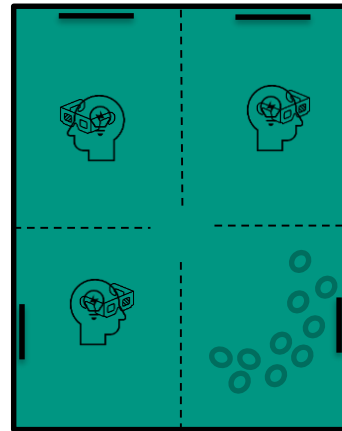
Open Area/Workshop rooms



Seminar room

Digitalization lab: Purposes

- Teaching
- Workshops
- Exchange
- Office workplaces
- Software training
- Simulations
- Visualization with virtual reality (VR) or augmented reality (AR)

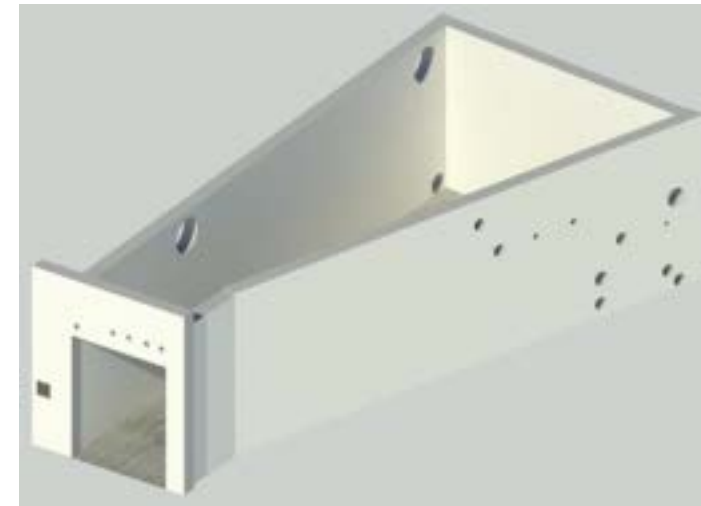
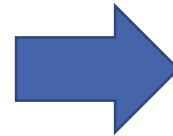


Short introduction to BIM

- Building information modeling (BIM) is a process involving the generation and management of digital representations of the physical and functional characteristics of buildings and other physical assets



3D-model



BIM
(3D-model+metadata)

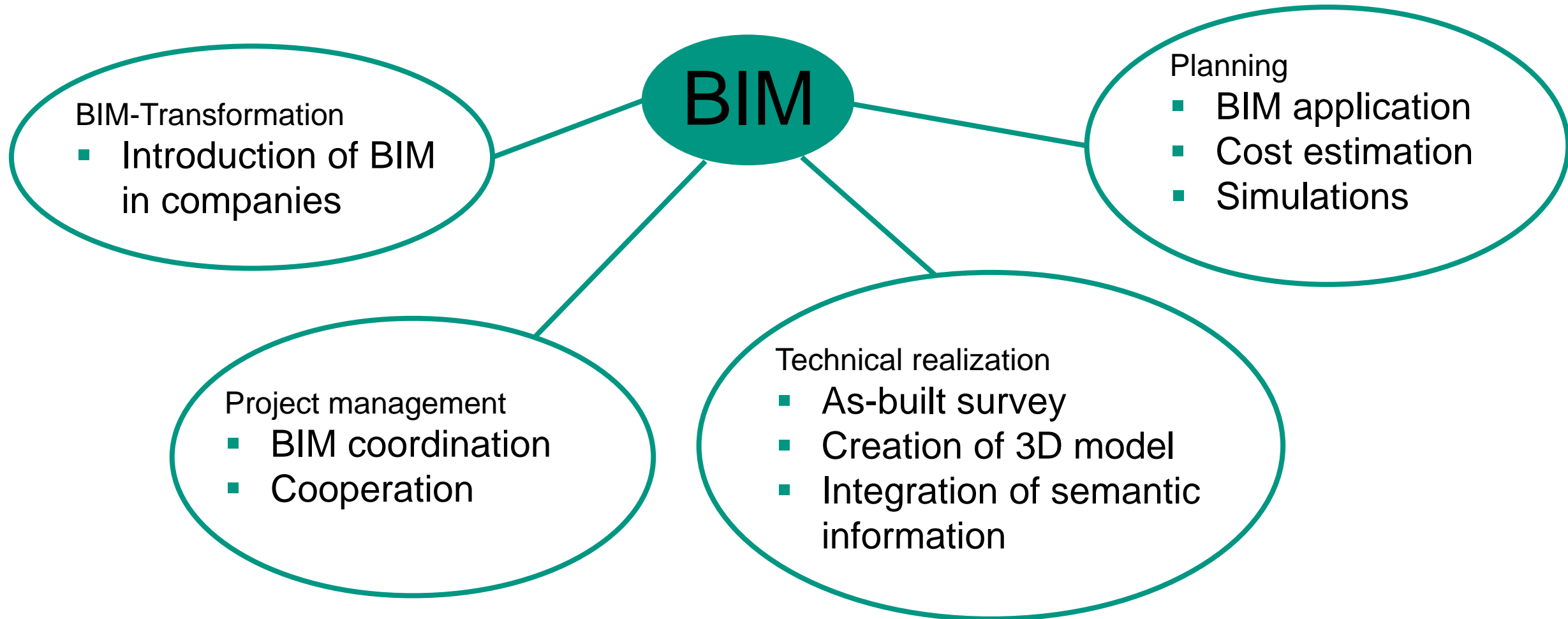
Included information
e.g.:
Materials,
Costs,
Scheduling,
...

Advantages of digitalization/BIM

- Integration of information about the radioactivity into the digital building model
 - Overview of the presence of radioactivity
 - Facilitated planning of the targeted and controlled removal and dismantling of components that are radioactive
- Digital technologies such as VR can compliment or possibly replace hot cell mock-ups
- Enabling virtual simulations

Advantages:

- Less time spent in the control area required due to digitalization of processes
 - Reduction of radiation exposure for staff

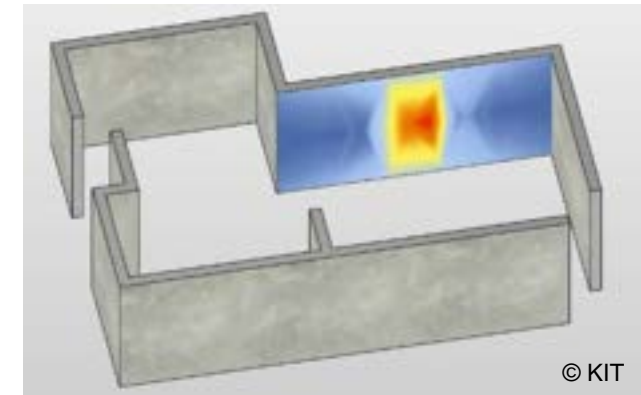


Current projects

- 3 projects:
 - Robotic Systems for Decontamination in Hazardous Environments Phase II (ROBDEKON II)
 - Visualization of trouble spots for Decontamination Work and Decision Measurements with the help of BIM (ViSDeMe)
 - Platform based on Emerging and Interoperable Applications for enhanced Decommissioning processes (PLEIADES)
- 6 Employees



Measurement of surface activity



Digitization and modeling using BIM

Presentation of the project ROBDEKON II

Robotic Systems for Decontamination in Hazardous Environments Phase II

- Automation of hazardous decontamination work
- Transferring modern robot technologies into practical systems
- Bundling the scientific and technological expertise of the Federal Republic of Germany in a competence network
- **Closed chain for the automation of decommissioning processes**

Current decontamination process

- **Challenges in dismantling**
- Many process steps:
 - Inventory, gutting, treatment of plant components, decontamination and measuring of concrete surfaces
- No standardized procedure
- Lack of automation
- Labor-intensive and monotonous
- Accumulation of secondary waste



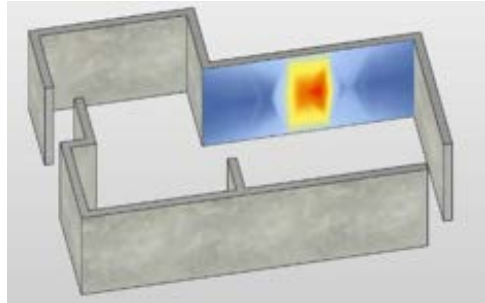
- **Automation of the process steps**
- Relief for decontamination personnel
- Increase in repeat accuracy
- Reduction of secondary waste



Chain for the automation of dismantling processes



Autonomous environmental exploration and radiation measurement



Digitization and modeling using BIM



Decontamination



Measurement of surface activity



Removal of contaminated material



Presentation of the project ViSDeMe

Visualization of trouble sspots for decontamination work and decision measurements with the help of BIM



- Digitalization of spatial data acquisition for the clearance of buildings

Building clearance: current procedure

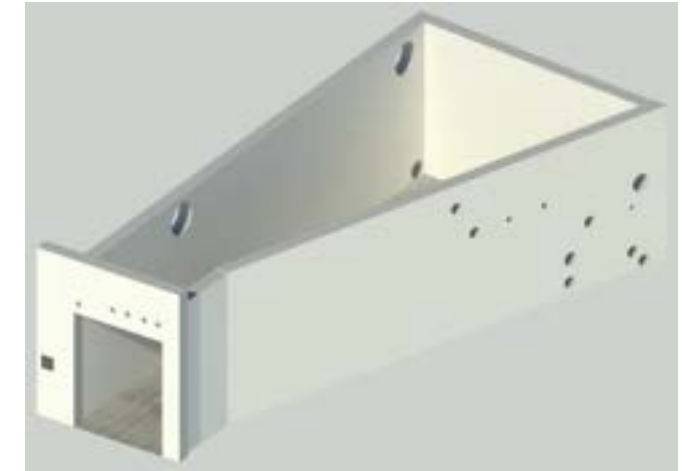
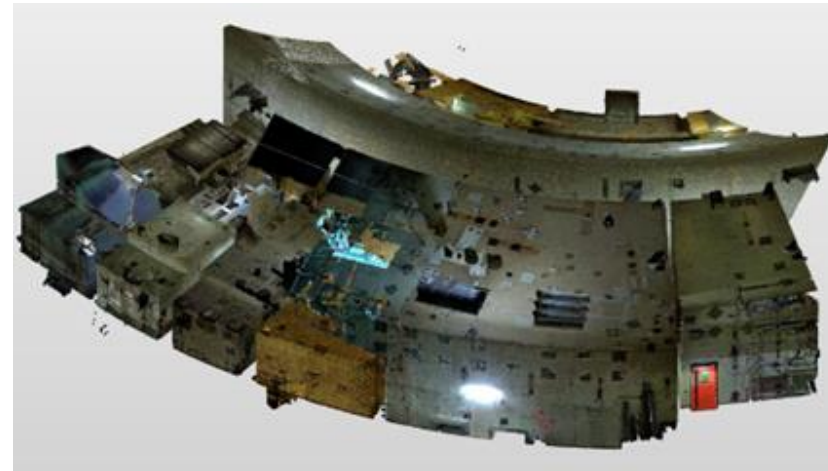
- Procedure for building clearance:
 1. Recording of all building areas to be released with all relevant information → Room data recording
 2. Free measurement of the areas (decision measurement)
 3. Documentation of the spatial data acquisition and measurements as proof for the authorities
- Typical NPPs in Germany have between 100.000 m² and 450.000 m² of concrete surfaces that need to be measured for building approval → Mülheim-Kärlich (MüK) plant: approx. 200.000 m²
- Room data is currently recorded manually for the most part:



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→ **No digital spatial models or similar are available for the further process steps.**

Digitization during building clearance



Laser scan



Point cloud



BIM-model
(including trouble spots)

Preprocessing

Registration
Outlier removal
...

Semi-automated
BIM modeling

Segmentation
Geometry extraction
BIM modeling

Conclusion

- Institute:
 - Department with a topic about Decommissioning of nuclear facilities

 - Decommissioning of nuclear facilities:
 - Relevant topic
 - Dismantling of NPPs
 - Packaging and storage of nuclear waste

 - Research projects:
 - Research is necessary
 - There are many research projects (national, international, cooperation between industry und universities, ...)

 - Digitalization:
 - Efficient documentation and knowledge about the radiation occurrence and the dismantling process
 - Standardization of processes
 - Less radiation exposure of staff
- ➔ Topics related to automization and digitalization will grow and empower research in the next few years

Thank you for your attention!

<https://www.tmb.kit.edu/english/941.php>