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DISPOSAL CONCEPT AND LLW-ILW CANISTER DESIGN FOR THE KONRAD DGR (GERMANY)

Technical Meeting of the Underground Research Facilities Network for Geological Disposal on Member State Updates and Global Progress in Developing Geological Disposal Solutions (Part II), 10-13 June, 2025

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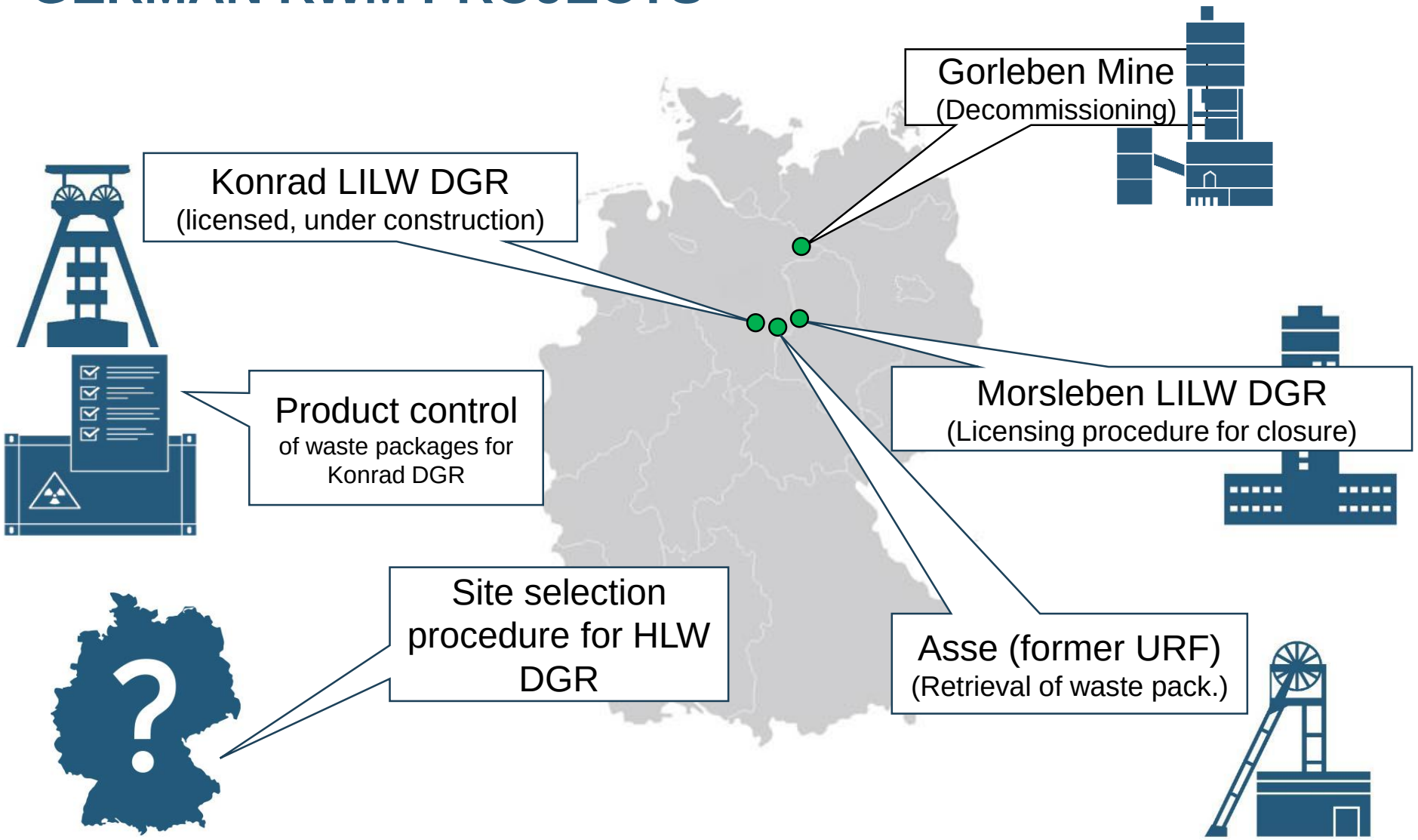
Key commitments on radioactive waste disposal

In Germany, all kinds of radioactive waste have to be disposed in a deep geological repository (DGR) in salt, clay or crystalline formations:

- For LILW disposal: former, adequate production mines can be converted into a repository mine
- For HLW disposal: the most suitable site will be selected in the course of a science-based, transparent and participative site selection procedure

- DGR site must be located in Germany
- DGR must provide the best possible safety for a period of 1 million years (HLW disposal)
- Retrievability of waste packages during operation, and recoverability for 500 years after closure have to be demonstrated (HLW disposal)

GERMAN RWM PROJECTS



RADIOACTIVE WASTE VOLUMES IN GERMANY

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High-level radioactive waste

- Forecast: approx. 1,900 CASTOR containers
- Approx. 10,500 tons heavy metal from spent fuel elements
- Waste from reprocessing (3.836 glass canisters)
- 99% of radioactivity

99% radioactivity

1% volume

Low- and intermediate-level waste

- Approx. 363,000 m³ from operation und decommissioning of nuclear plants (commercial or research), and other nuclear installations, (303,000 m³ will be disposed in the Konrad repository)
- + Approx. 200,000 m³ from the Asse II mine
- + Up to 100,000 m³ from uranium enrichment
- 1% of radioactivity

1% radioactivity

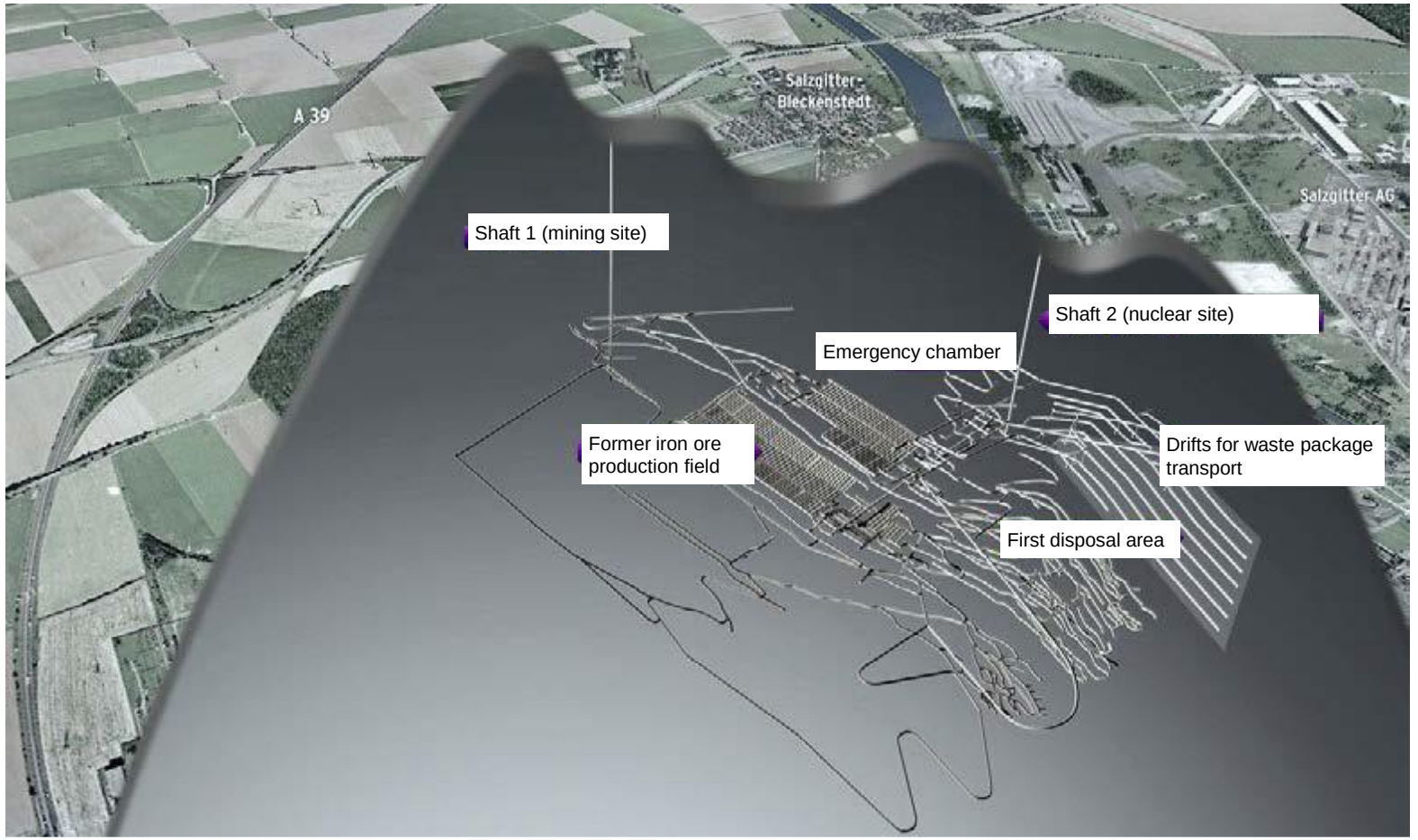
99% volume

KONRAD DGR (FORMER IRON-ORE MINE)

Shaft sinking: *1957/1960*
6 production levels 800 - 1300 m
Iron ore production: *1960-1978*
Site investigations: *to evaluate the suitability as a repository site: until 1982*
Licensing procedure: *1982-2007*
Conversion into a DGR: *since 2007 (commissioning expected in the early 2030th)*

Geosphere

Host rock: *Jurassic oolithic lime-stone*
Containment providing rock zone: *jurassic and lower Cretaceous* marls and claystones (> 400 m)



3 D model of the Konrad repository and former mine workings

FUNDAMENTALS OF SAFETY STRATEGY

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Main safety objective

protection of people and environment from ionising radiation and chemotoxic substances during the operational and post-closure periods (*Atomic Energy Act, Radiation Protection Ordinance, Safety Requirements for Disposal of Radioactive Waste*).

Resulting safety measures

- Safe containment of radionuclides by a multi-barrier system during operation and post-closure periods
- Avoidance of unnecessary radiation exposure during operation
- Limitation and control of radiation exposure of the staff and the public during operation

Multi-Barriersystem and safety functions

- Geological barrier (Containment providing rock-zone): long-time containment of radionuclides
- Geotechnical barriers (Shaft seals, backfilling of disposal chambers and connecting drifts, closing plugs at disposal chambers):
  - ➢ minimizing fluid flow from disposal area to biosphere and vice versa,
  - ➢ avoidance of cavities for accumulations of explosive gases
- Waste packages and waste matrices > containment of RN, radiation shielding and retardation of RN release esp. during operational period (for normal, abnormal and accident conditions)

WASTE ACCEPTANCE CRITERIA

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Development of waste acceptance criteria based on:

- **Safety assessments** for transport of waste packages, operation and post-closure phases to check compliance with the safety goals .
- Estimation of potential **radiation exposures** of staff and public resulting from waste handling in DGR > requirements for repository design, operation, waste form and waste packages.
- Definition of the acceptable types of waste, waste forms, container types and the activity limitations of the waste packages.

Basic requirements on waste products (conditioning)

- Properties of waste: Solid, neither ferment nor decay, no fluids or gases, not self-igniting or explosive
- Constituents of waste: limitations of concentrations and chemical/physical properties of neutron fissible materials (U, Pu, Th, Am, Cm, Cf), uncriticality
- Waste matrix: Requirements for chemical and mechanical stability; compatibility with waste, and container material. Minimization of release of Rn-220.

WASTE ACCEPTANCE CRITERIA

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6 Waste product groups

Criteria:

- mechanical and chemical properties of the waste matrices, restrictions for combustible materials,
- conditioning of materials of reactor core,
- homogeneous dispersion of radionuclides in matrices,
- compressive strength of waste products.

Requirements for containers

- **Basic requirements on geometry**: shape, volume, maximum weight
- **Mechanical properties**: stackable up to a height of at least 6 m, resistance to accident scenarios
- **Chemical properties:** corrosion resistance (steel containers), shielding etc.
- **Containment properties**:
  - Leakage rate, tightness ensured by container design (incl. internal packaging)
  - Faultless deliverance of containers

WASTE ACCEPTANCE CRITERIA

Container types

Cylindrical containers (MOSAIK type): concrete, or cast steel; lids screwed or welded, elastomer seals. Shielding lead inserts.
5 subtypes

Box-shaped containers: body and lids made of steel, reinforced concrete or cast materials. Wall thickness > 3 mm. 11 subtypes (different geometries, materials and weights)

Compliance with **traffic law requirements (type B(U)):**
resistance to accident scenarios, radiological requirements

Radiological requirements
Average dose rate at surface: $2 \cdot 10^{-3}$ Sv/h
Dose rate at 1 m (MOSAIK-type) / 2 m (box): $1 \cdot 10^{-4}$ Sv/h
Leakage rate (gas): 10^{-4} hPa*l/s
Contamination at surface: 0.5 Bq/cm² for alpha emitters
50 Bq/cm² for beta emitters , 5 Bq/cm² for other radionuclides

WASTE ACCEPTANCE CRITERIA

Classification of waste containers

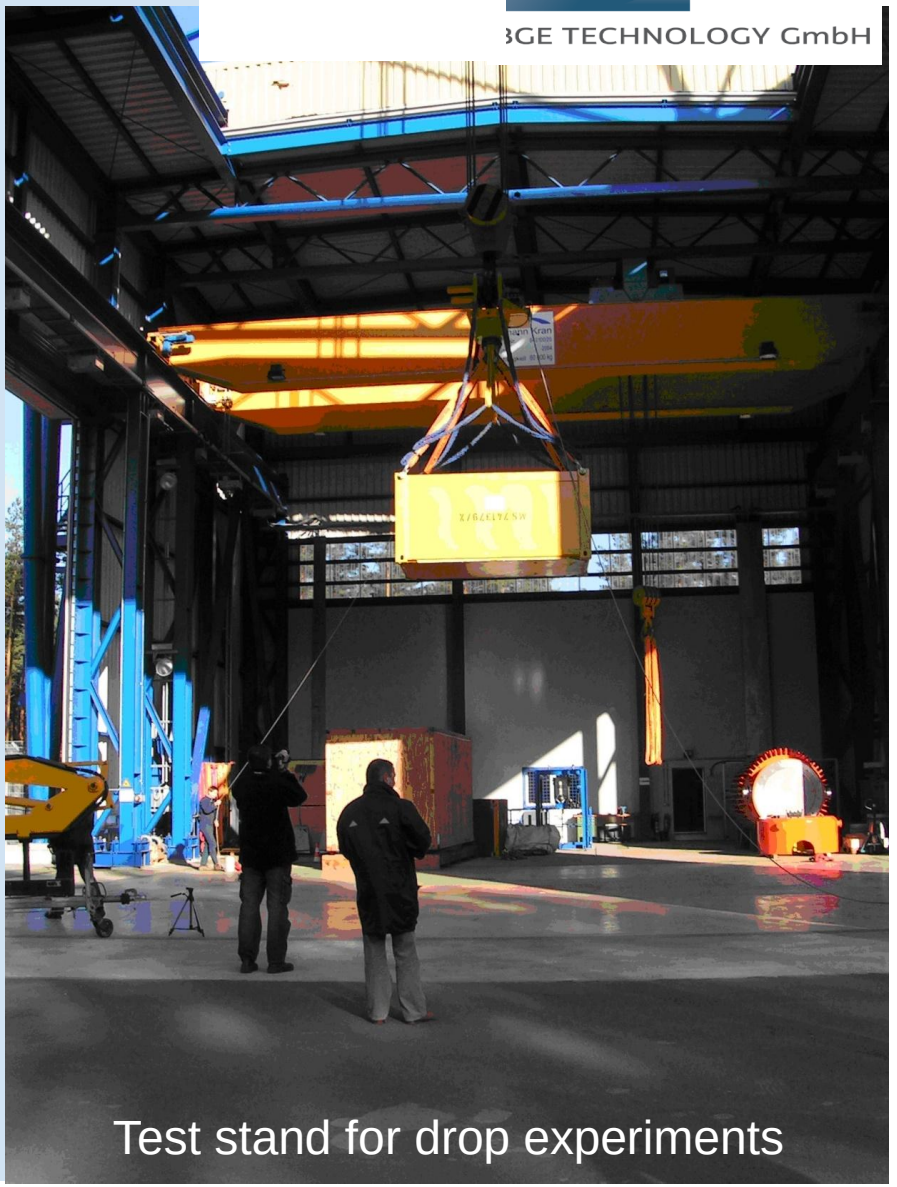
Waste container class I (for ILW)

- Resistance to accidents scenarios:
  - collision velocity 4 m/s > no impairment of container
  - 5 m drop on floor: integrity not affected
  - thermal resistance at least 0.1 $m^2 \cdot K/W$
  - Fire of 800°C for one hour: no ignition of combustible waste

Waste container class II (for LLW)

- Resistance to accidents scenarios:
  - 5 m drop on floor: total leakage rate $<10^{-4}$ $Pa \cdot m^3/s$, integrity of containers / inner containers not affected
  - Fire of 800°C for one hour:
    - total leakage rate $< 10^{-5}$ $Pa \cdot m^3/s$
    - release of gases from container < 1 mol
    - release of radionuclides below radiological constraints

Primary (inner) containers (e.g. 200 l or 400 l drums): for packaging of waste products, no specific requirements, but considered together with container properties (e.g. for tightness)



Test stand for drop experiments

WASTE ACCEPTANCE CRITERIA

Inventory and activity limitations

Maximum total **activity of the most relevant radionuclides in the repository**

Radionuclide / Group of radionuclides	Activity [Bq]
H-3	6.0E+17
C-14	4.0E+14
I-129	7.0E+11
Ra-226	4.0E+12
Th-232	5.0E+11
U-235	2.0E+11
U-236	1.0E+12
U-238	1.9E+12
Pu-239	2.0E+15
Pu-241	2.0E+17
Total – Alpha emitters	1.5+E17
Total – Beta / Gamma emitters	5.0+E18

Permitted **activities of radionuclides and groups of radionuclides per waste package**: derived from operational and long-term safety analyses (for normal / abnormal operation, accidents, long-term safety) > **limitations for 108 radionuclides**

Mass limitations on non-radioactive, potentially **harmful materials to groundwater** > threshold values defined in **Groundwater Ordinance**

QUALIFICATION PROCESS AND PRODUCT CONTROL

Objective:

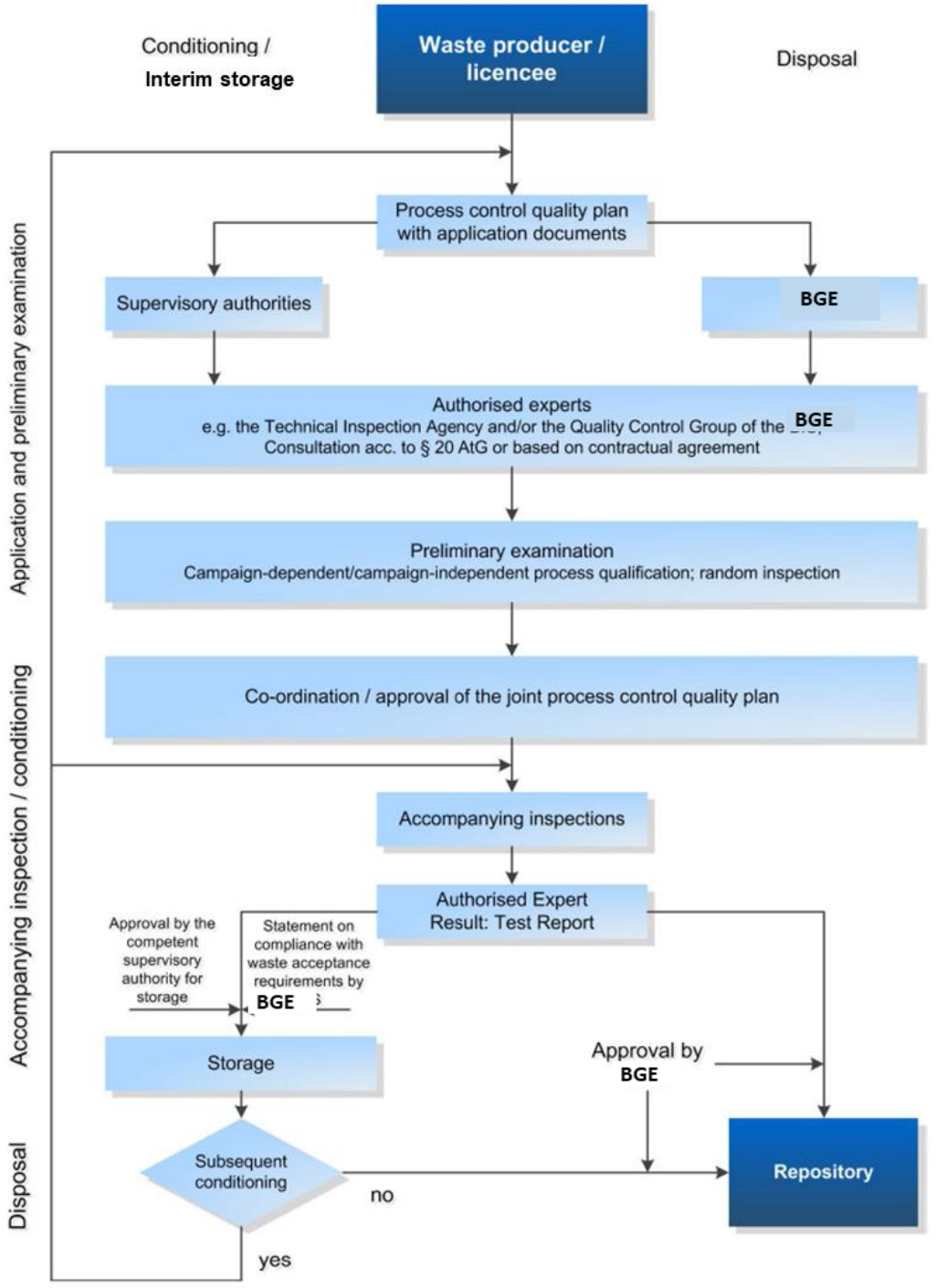
compliance of waste conditioning and packaging with waste acceptance criteria (WAC)

Procedure:

- waste packages evaluated by diverse validation processes
  - combination of nondestructive test of conditioning and destructive random sample tests
  - For packaging, the waste producer can rely on a procedure qualified by BGE. Otherwise, compliance with WAC has to be checked.
- Application management of product control is digitalized, Nuclear Waste Logistics-Platform

Responsibility for control procedure:

- Federal Company for Waste disposal (BGE),
- On behalf of BGE, independant experts supervise the procedure, the waste containers and the corresponding documentation.



KONRAD REPOSITORY: NUCLEAR SITE

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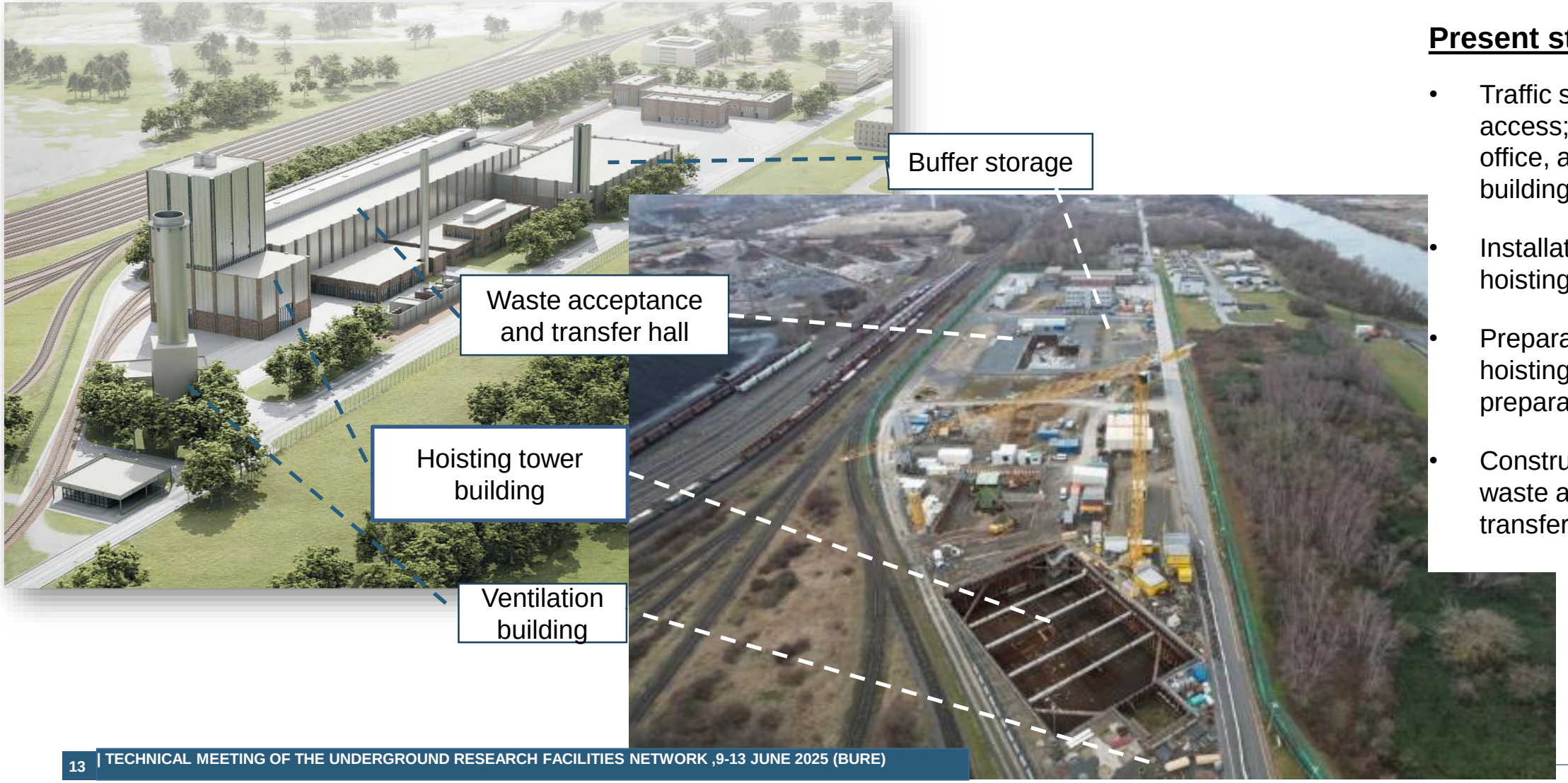

Present status (12/2024)

- Traffic system and road access; workshops; social, office, and security buildings are completed
- Installation of temporary hoisting tower
- Preparatory work for final hoisting tower running, e.g. preparation of base plate
- Construction work for waste acceptance and transfer hall started

KONRAD REPOSITORY – WASTE ARRIVAL

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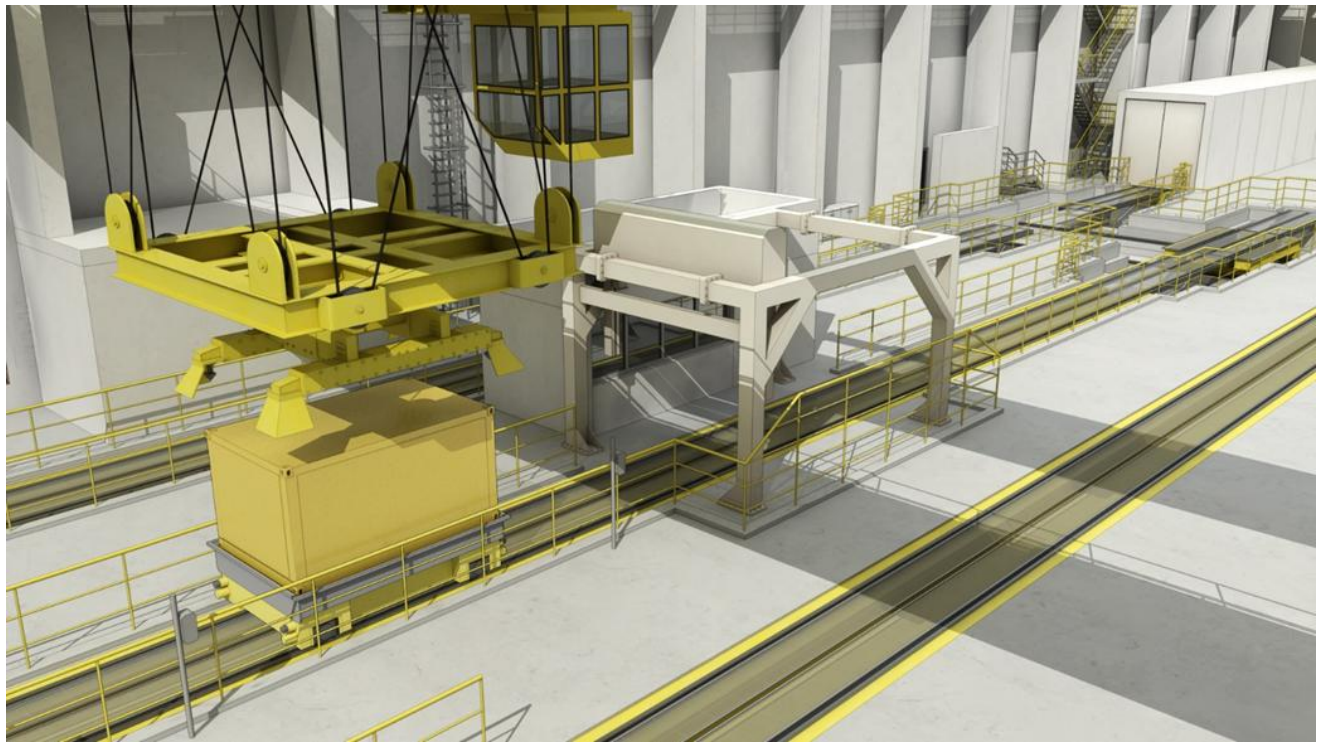
Entrance to waste acceptance and transfer hall

Reloading in the waste acceptance and transfer hall

KONRAD REPOSITORY – ENTRANCE CONTROL

- Registration of container, product control and waste package documentation
- Automatic radiation measurements (contamination control: α- und β- activity; dose rate measurements in 1 m and 2 m distance, control of neutron dose rate (if expected)
- location tracking during the transport in the repository



Possible reasons for transfer of waste containers to maintenance / repair shop

- damage of waste package / transport equipment
- exceedance of permitted dose rate
- exceedance of permitted contamination

KONRAD REPOSITORY - KEY STEPS OF DISPOSAL PROCEDURE

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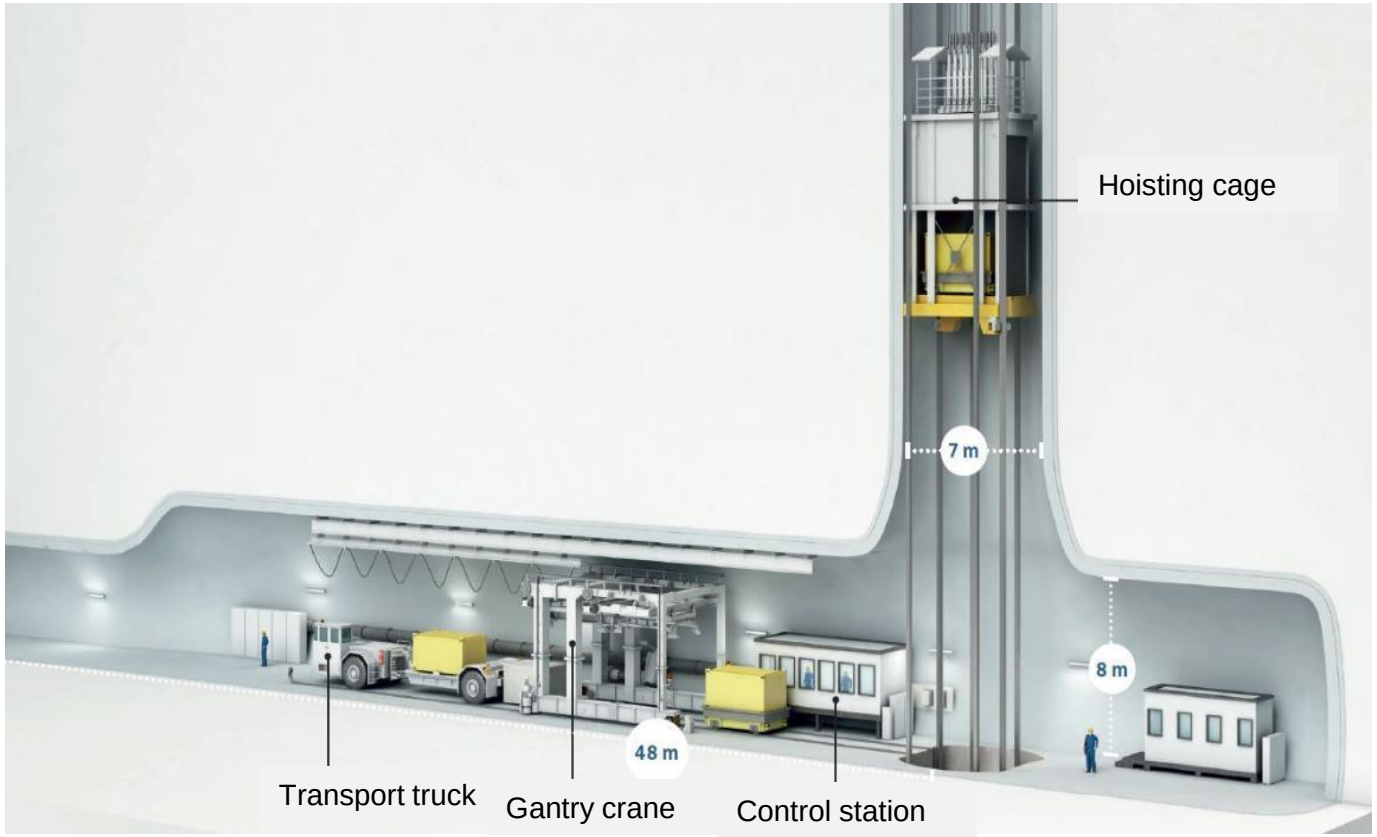
Construction underground

Lining at the shaft landing,
-900 m below surface

Shaft landing, equipment for waste reloading / transport



KONRAD REPOSITORY – DISPOSAL EQUIPMENT

Lift truck

Lateral lift truck

Platform wagon

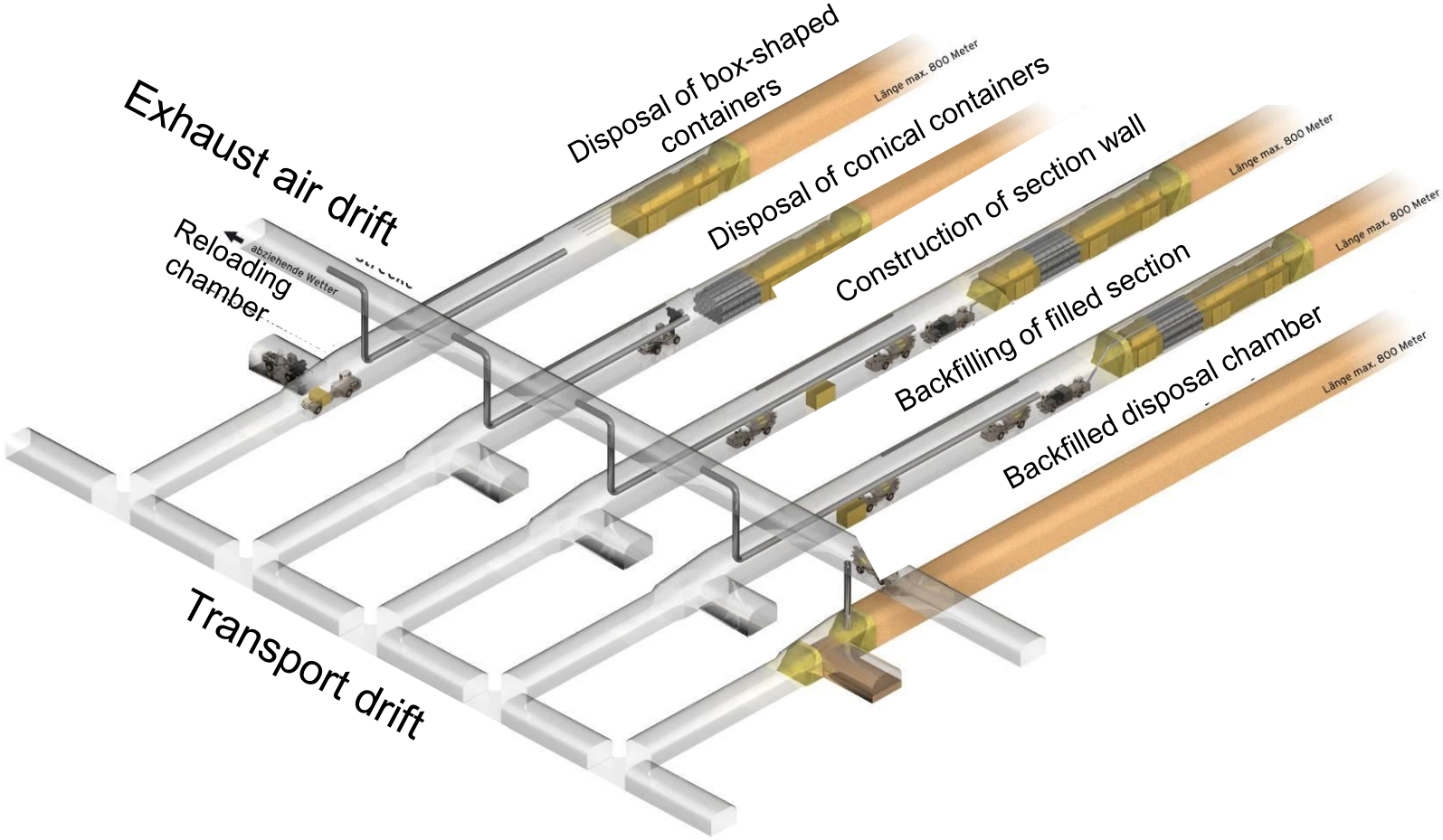
Gantry crane (at shaft landing)

Concrete transport truck

Concrete spraying truck

Low bed truck

KONRAD REPOSITORY - EMPLACEMENT PROCEDURE



Disposal drift

Width: 7 m

High: 6 m

Length: 800 m (subdivided in 15 **disposal sections**)

Length of disposal section: ca. 50 m

Thickness of section wall: 0,50 m – 1,00 m

Final concrete plug: 1,50 – 2,00 m


Thanks for your Attention!