A collaborative approach to the treatment of the Norwegian exotic HEU-materials

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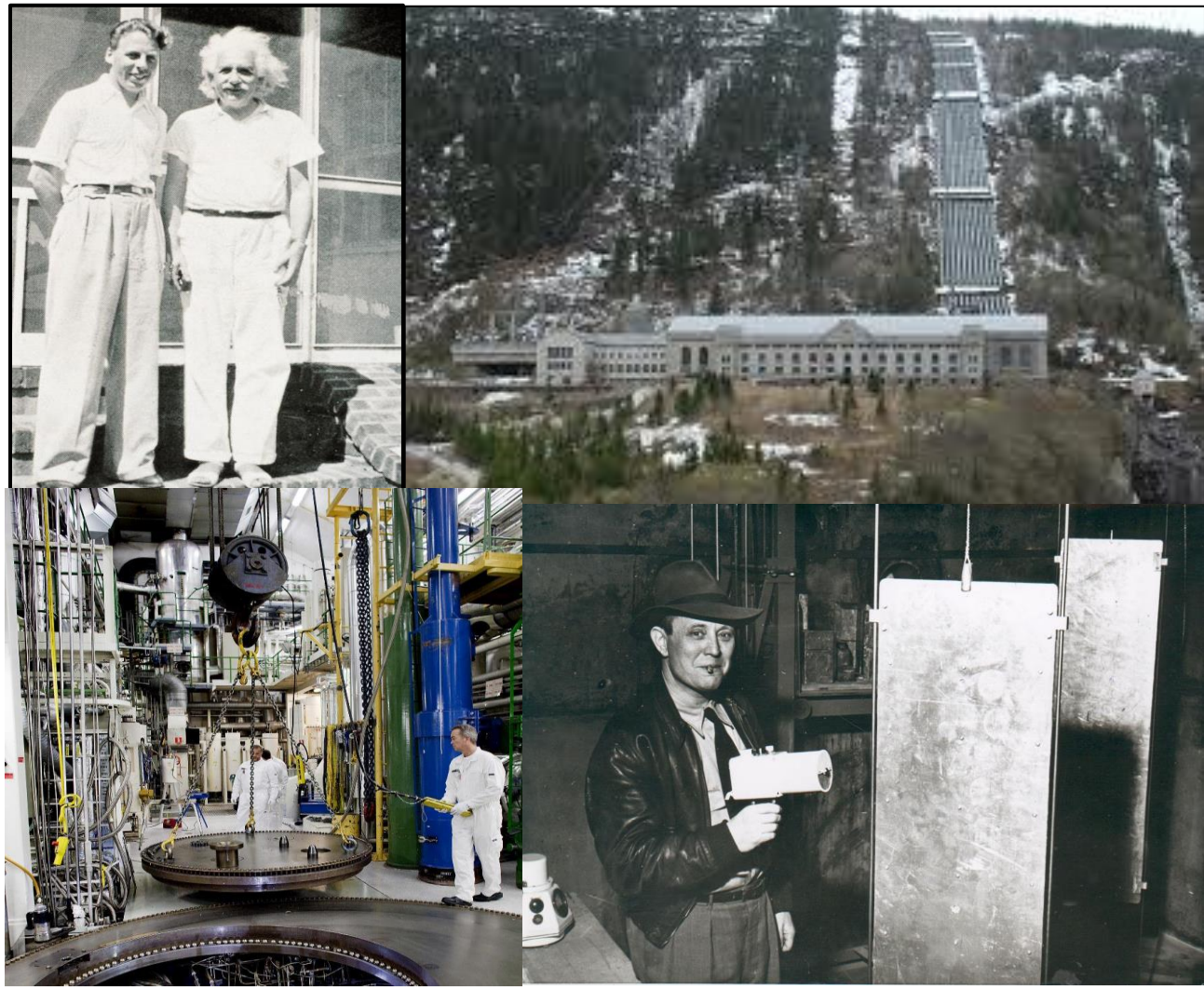
Norwegian Radiation and Nuclear Safety Authority

Outline

- Norwegian Nuclear History
- National and international collaboration
- Pilot Project
- MMC

Norwegian Nuclear History

- → 1934-1988: Heavy water plant at Vemork
- → 1946: Norwegian nuclear research activities started at the Norwegian Defence Research Establishment (FFI)
- → 1948 IFA (later IFE) was founded
  - → 1951-1967: JEEP I
  - → **1959-2018: HBWR**
  - → 1961-1968: N0RA
  - → **1966-2019: JEEP II**



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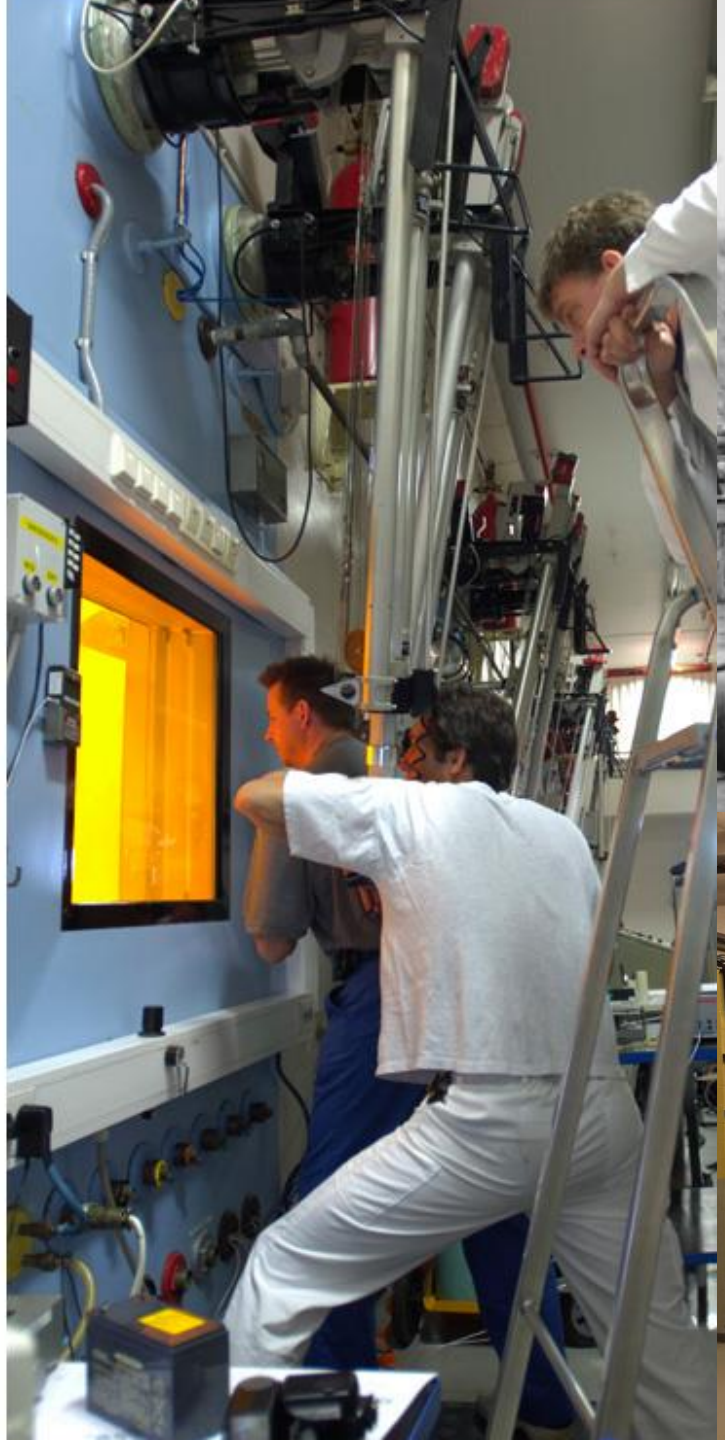
Norwegian Nuclear History

- → Fuel production facilities
- → Post irradiation examinations
- → A pilot reprocessing plant
- → Storages for fresh and spent fuel
- → National radiation waste handling facility
- → *Only national hotcell facility*



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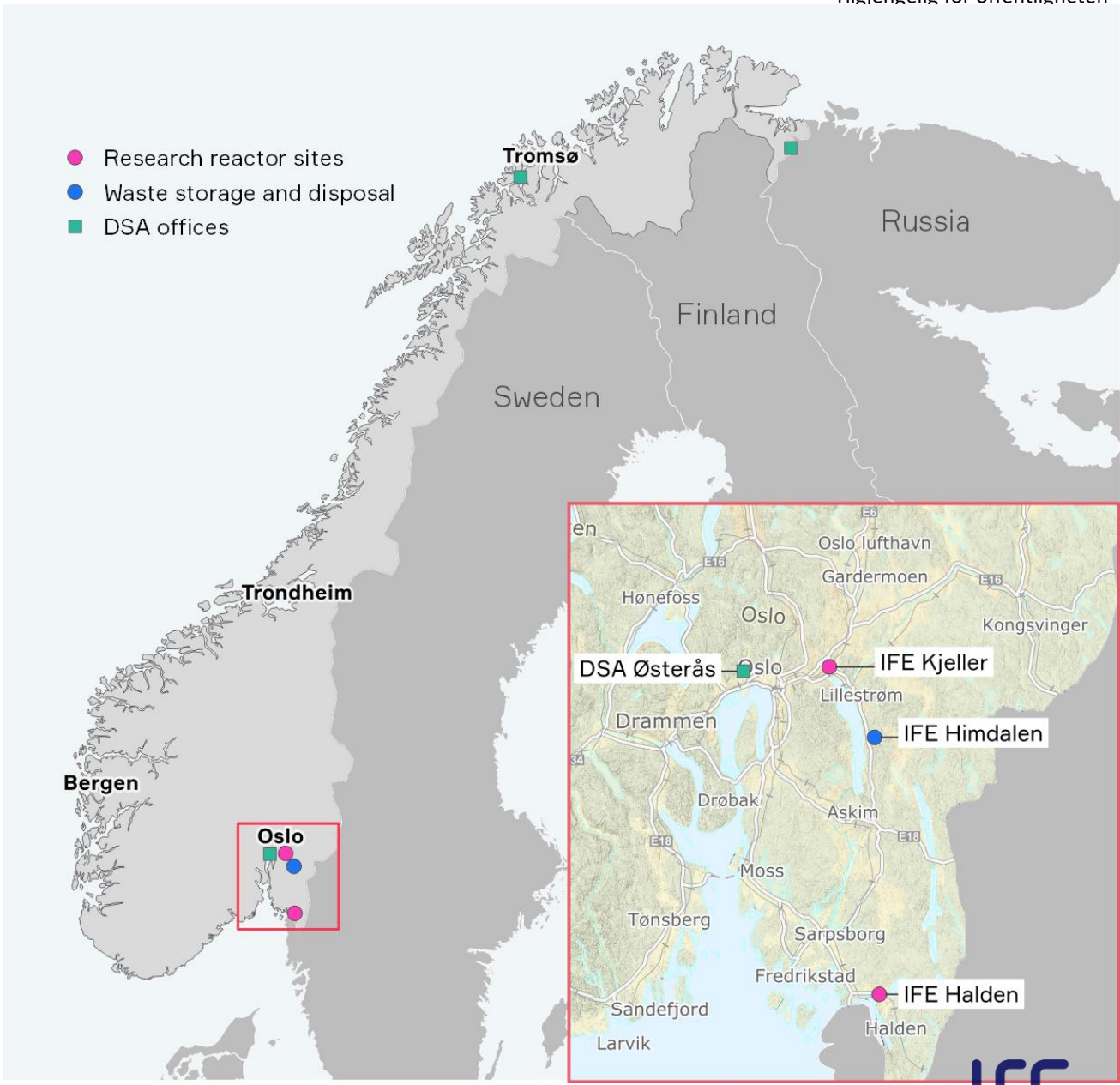
Nuclear facilities and regulators in Norway

- Norwegian Radiation and Nuclear Safety Authority (DSA)
- One reactor operator in Norway – Institute for Energy Technology (IFE)
- New State owned company, Norwegian Nuclear Decommissioning (NND) established in 2018 will in the future be responsible for the nuclear sites and the materials on-site.



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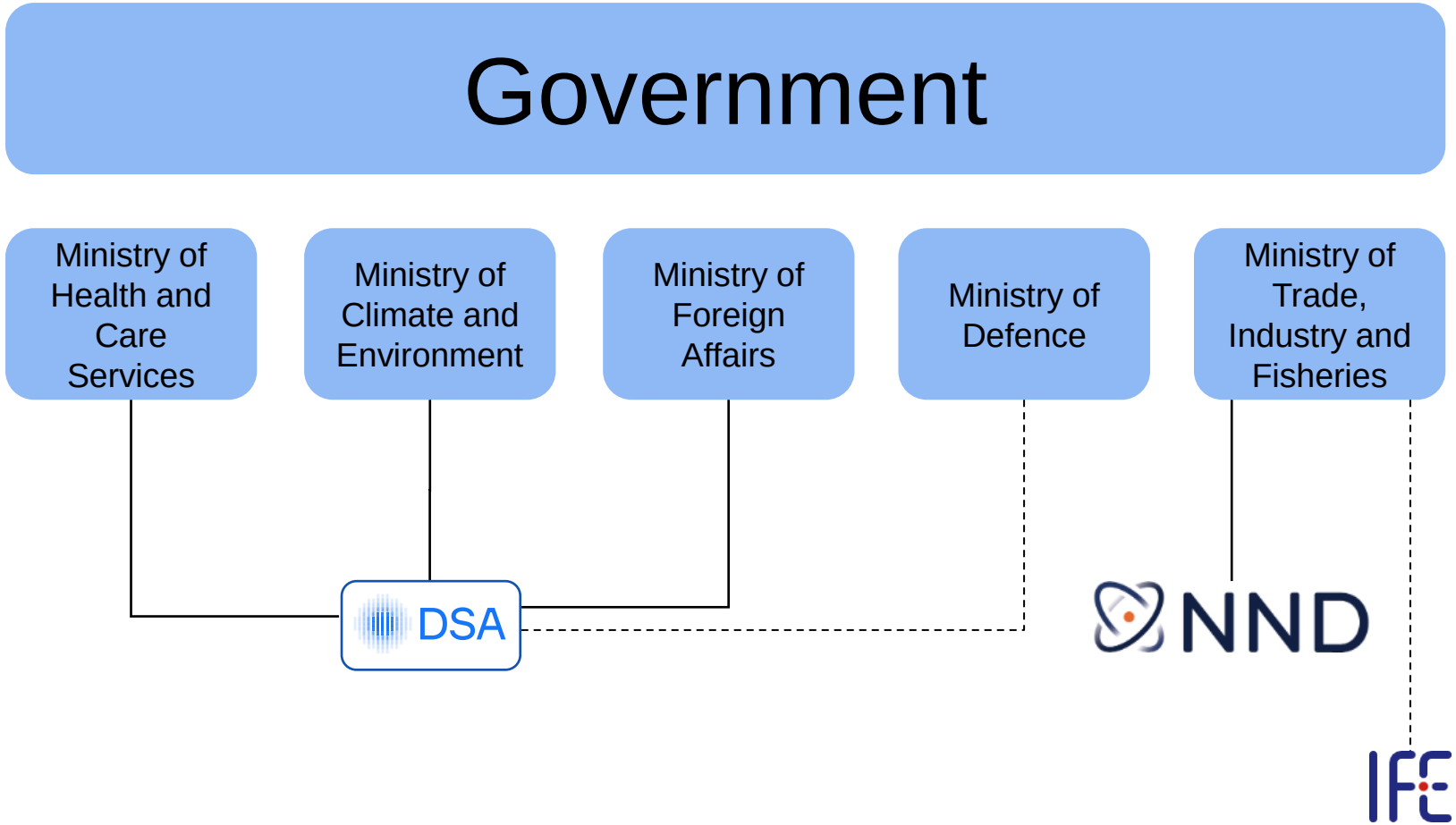
Government
Ministry of Health and Care Services
Ministry of Climate and Environment
Ministry of Foreign Affairs
Ministry of Defence
Ministry of Trade, Industry and Fisheries
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NND
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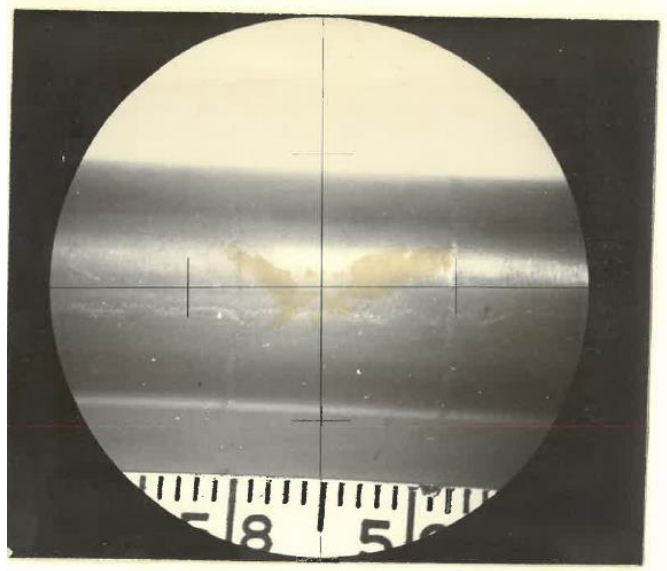
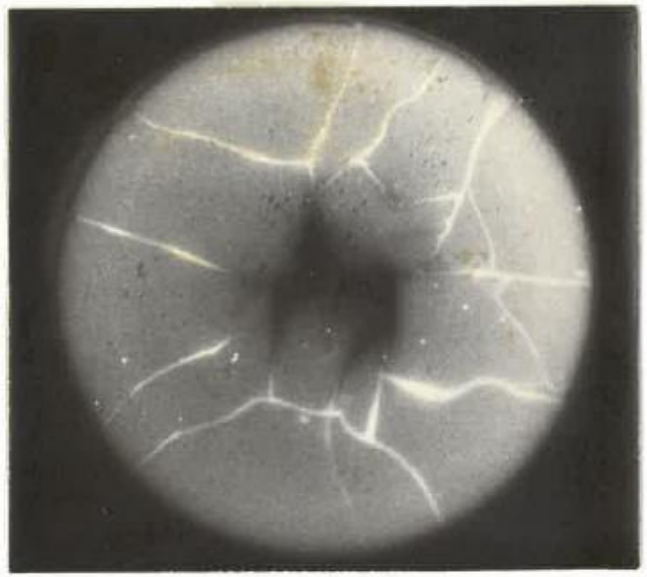
HEU in Norway

- US-origin high enriched uranium (HEU), received in the 1960's
- Enrichment of around 90% U-235
- Research on HEU/Th-fuels for various projects
- Portions of the material have been used/analysed in Great Britain (Dounray), Denmark (Risø) and Italy (CNEN)
- HEU-Th fuels were irradiated in IFEs Halden Boiling Water Reactor (HBWR)
- Underwent post-irradiation examinations at the IFE Kjeller site

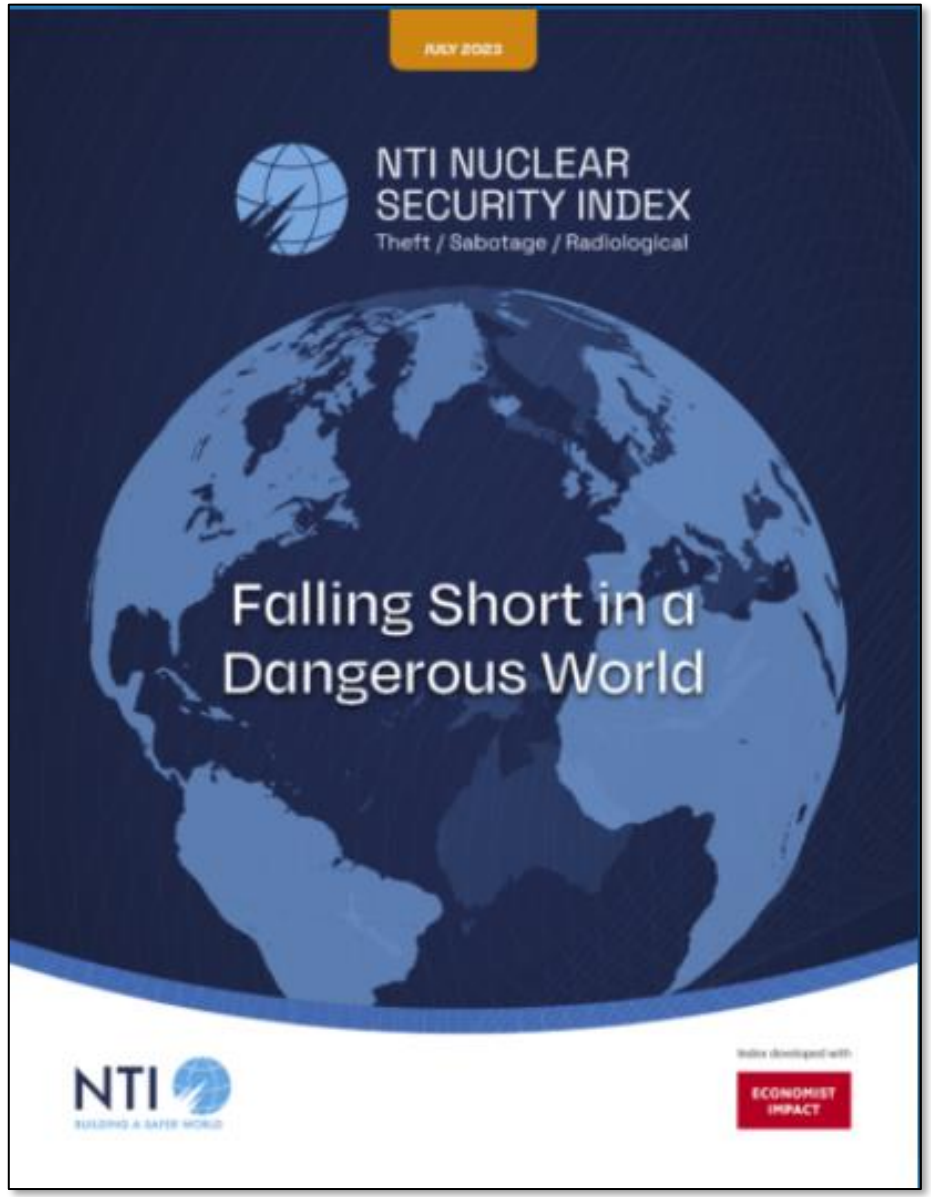




NTI Security Index

- Norway is one of 22 countries with civilian HEU or separated plutonium over 1 kg, according to the Nuclear Threat Initiative (NTI) Security Index 2023

- Norway has prioritised the elimination of its HEU stocks



Nuclear Security Summits

- Several Nuclear Security Summits (2010, 2012, 2014 and 2016) have discussed minimizing stocks of HEU

- At the Nuclear Security Summit in 2016 Norway offered a joint statement on minimization of HEU (InfCirc 912)
  - committing to fulfilling the statement goals and voluntary reporting
  - committed to organizing a symposium on HEU minimization in 2018

International meetings and symposiums on HEU minimizations

- The MFA, DSA and IFE have organized several international meetings and symposiums in cooperation with the International Atomic Energy Agency (IAEA), in 2006, 2012 and 2018 where minimization of HEU was discussed

- In 2019 Norway took initiative to organize a technical meeting together with other countries that have similar types of material, as well as the expertise and equipment to handle this type of material

International support

- Norway has taken an active role in supporting the IAEA in minimization of HEU in developing countries, by replacing HEU with LEU in research reactors and enabling repatriation of weapon usable material back to its origin State

- As Norway has had a focus on elimination of HEU internationally, it was natural to start discussions with the USA about return of HEU in Norway. This was in 2014 and was the starting point for the work with the Mobile Melt Consolidation (MMC) plant

Return to origin country?

- Considered if the material could be returned through the US Global Threat Reduction Initiative (GTRI) and their Gap Materials Program
- US facilities are unable to receive thorium-bearing fuels
  - separation of the Th from the HEU would be necessary
- As an alternative, the USDOE have proposed the Mobile-Melt Consolidate (MMC) system.
  - In this treatment option, the HEU will be down-blended using natural or depleted uranium to achieve low enrichments (<20 % U-235), reduced to metallic fuel and melted together with stainless steel

Memorandum of understanding between Norway and USA

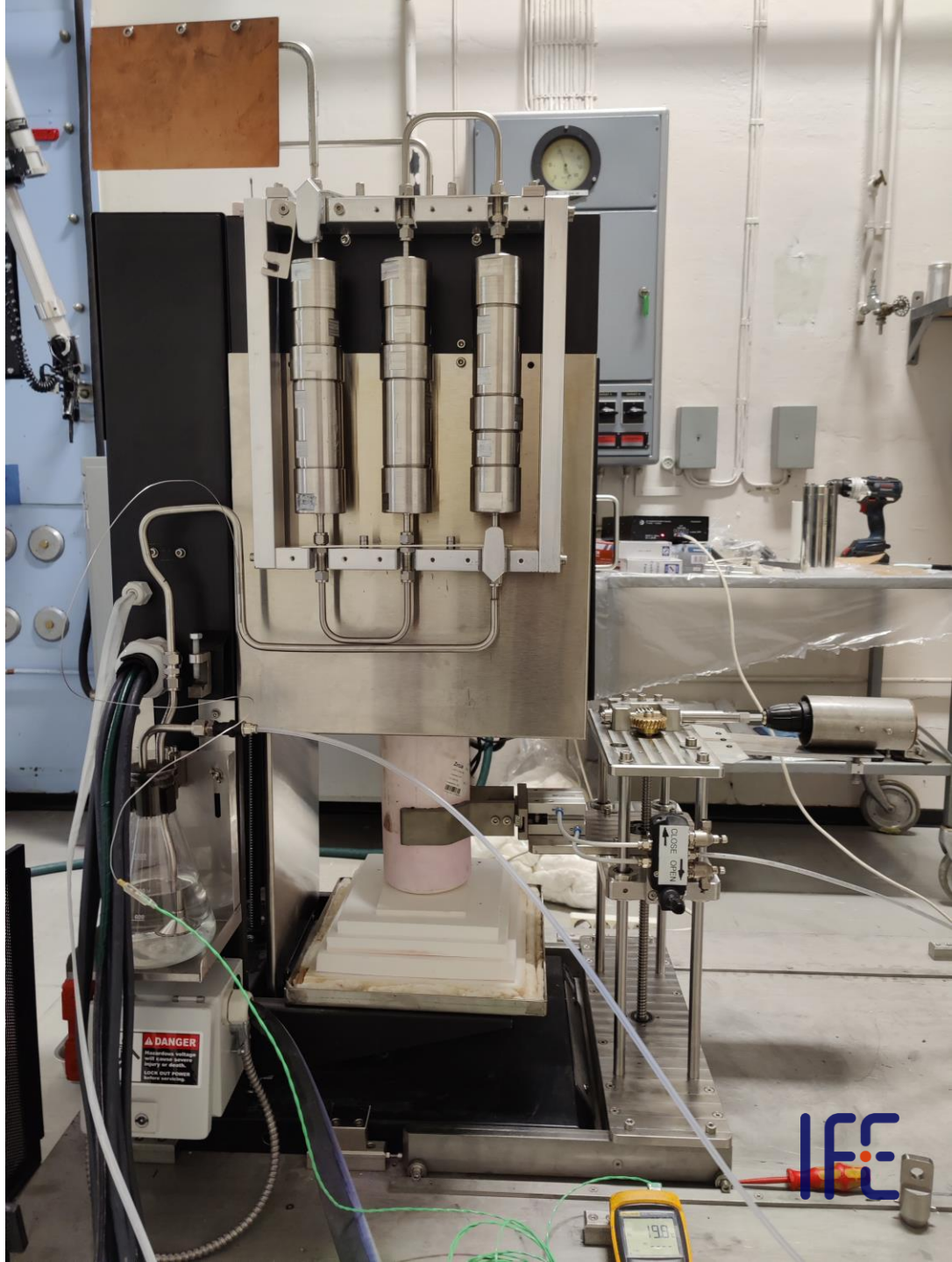
- In 2021, the Norwegian government signed a memorandum of understanding with USDOE to, in effect, employ the MMC for treatment and immobilising the Norwegian civilian HEU

- The national mission of achieving HEU elimination was given jointly to IFE and DSA:
  - IFE to implement and operate the MMC technology in Norway
  - DSA to regulate the technology and facility

The Pilot Project

The pilot project: Small scale test of melting/downblending

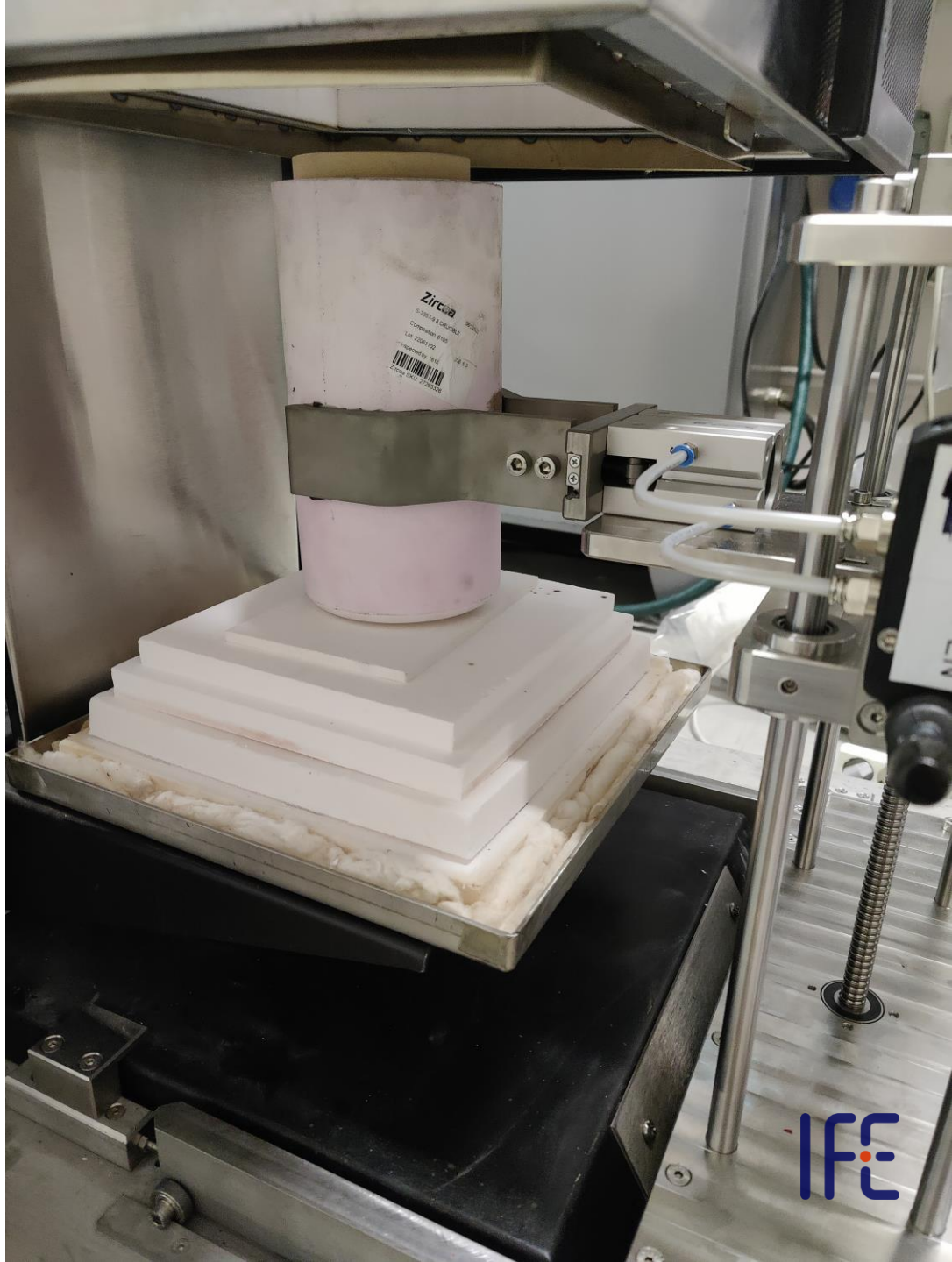
- **Purpose:**
  - Validate the melt technology
  - Confirm downblending – analysis of the end-product
  - Confirm OGE system efficiency
- **Pilot Phase 1 – Cold Melts**
  - Melting of stainless steel in nested crucibles.
  - Glass flux added to reduce oxidation
  - Stirring applied. Addition of Tungsten to confirm mixing efficiency
  - Equipment set-up in JEEP-I building
  - 8 Cold melts done so far
  - Issues with cracks in crucible resolved (geometry and thermal expansion)



The Pilot Project

→ **Pilot Phase 2 – Hot melts**

- Melt 1-4 uses non-irradiated HEU-Th
- Melt 5 with irradiated materiale (part of fuel rod)
- Facility modification license granted by DSA
- Melt 1 planned Q1 2025
- IAEA and DSA will be invited



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The Pilot Project

	1	2	3	4	5
HEU-Th	2.7 g	83.66 g	83.66 g	654.25	
	Al-foil	pellets	pellets	powder	Part of rod
U-nat	13 g	45 g	45 g	520 g	
Master alloy (SS 316)	7000 g	6800 g	6800 g	5100 g	
YFe	0	150 g	150 g	1200 g	
Cs, I, Tc	x	x	x	x	
Target date	Q1 20215	Q2 2025	Q2 2025	Q2 2025	

Cold melt experiences

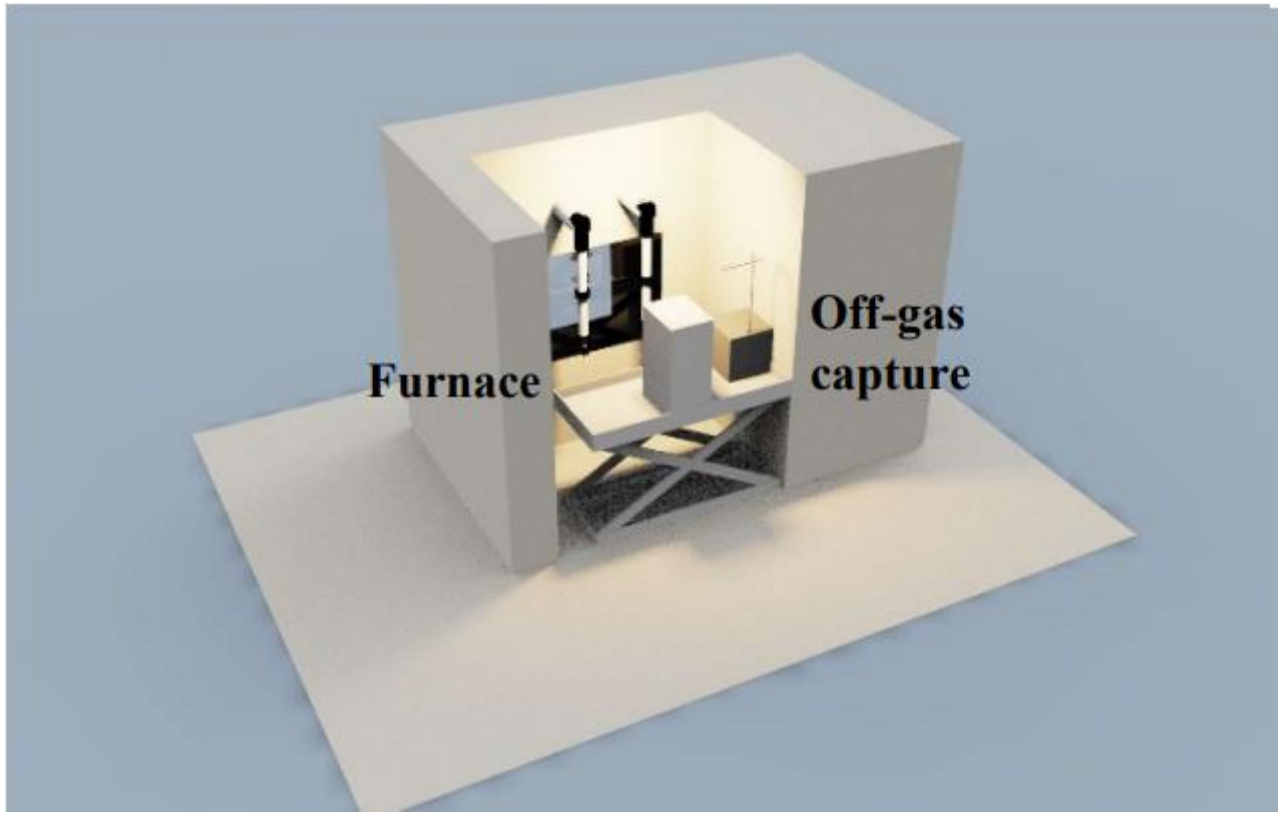
- → Melt 2: 11 December 2023, steel cylinder modified
- → The TC installed to measure temperature in the melt failed when reaching 1300 C
- → Probable cause: Insulation on wire melted
- → Both inner and outer crucible exhibited cracks
- → Probable cause: The steel cylinder applied pressure to crucible wall due to thermal expansion. The rounding off made to avoid this effect was not sufficient.
- → Cracking in later tests due to thermal shock upon rapid cooling

Cold melt experiences

- → Melt test #7 and #8 (Dec'24)
- → Improvement of operating procedure after input from HF team
- → Seal of air intake improved
- → Extension of cables

The Pilot Project – way forward

- → Installation in IFE hotcell
- → Cold tests
- → Notification to DSA and IAEA
- → Hot melt 1
- → Characterisation and analysis



Mobile Melt Consolidate (MMC)

MMC Modules

- CCM: Control Module
- UTL1: Power
- UTL2: Furnace power
- CpM: Cooling liquid pump
- CfM: Cooling fan
- +: Diesel back-up power, Diesel storage tank

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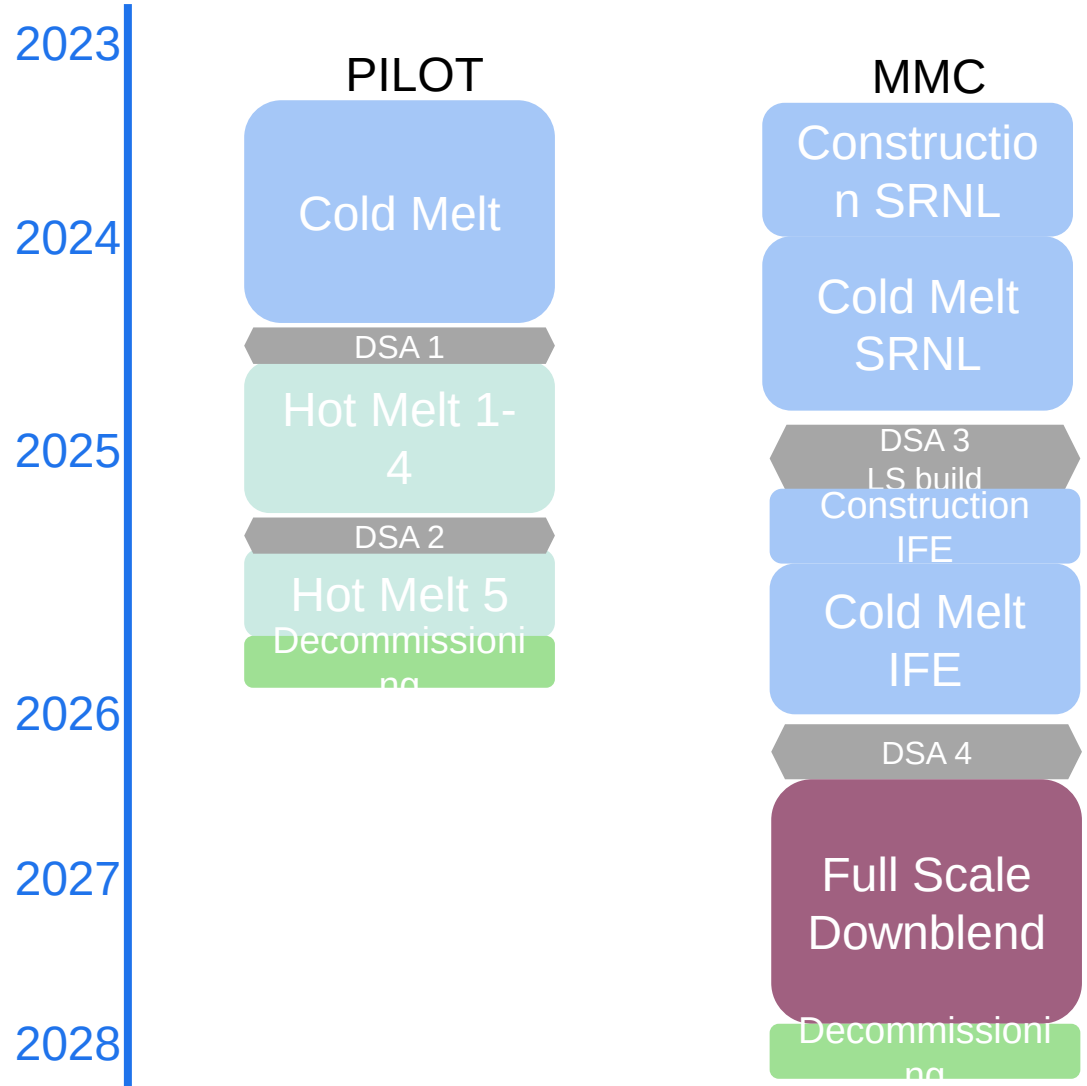
Process modules



Dependencies:

- DSA 1 – Facility mod. non-irr. HEU
- DSA 2 – Facility mod. irr. HEU
- DSA 3 – Concession mod. - Installation and testing
- DSA 4 – Concession mod. - Operation
- LS build – Permit to set-up MMC on site (Lillestrøm)

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Thank you for your attention!