# Development of Lead-Cooled Reactor Technology

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# Blykalla is the Swedish SMR vendor building Europe's first advanced SMR: the SEALER reactor

# Blykalla follows a three-step roadmap to commercialization

## Phase 1: Prototype to de-risk

- Located at OKG site in Oskarshamn
- Supported with 99M sek from Swedish Energy Authority
- Partnership with ABB

## Tests + commercial proof

- Simulation of station black-out to validate passive safety calculations
- De-risked engineering and system validations, incl. integrated test
- PoC on commercial electrolysis

Design started

Construction started

## Phase 2: Build first reactor

- Developed together with industry consortium in Sweden
- Licensing of technology with Swedish regulator
- Integrate with steam / process heat application to build commercial business case for e.g. hydrogen production, electrolysis and pyrolysis

Commissioni

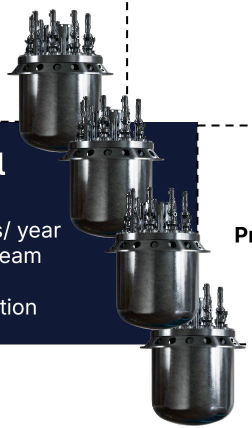
Operations

Licensing work starts

Decision-in-principle expected

## Phase 3: Scale-up with serial production

- Production ability 10 reactors/ year
- 55 MW reactors with 530° steam for industrial use cases
- 2 years from order to installation



Production

# SEALER-One: Sweden's First Advanced Reactor

## KEY DATA

| Item | Value |
|---|---|
| Power | 70 MWt |
| Lead coolant mass flow | 3170 kg/s |
| Lead inventory | 800 tons |
| Core inlet/outlet T | 400°C/550°C |
| Secondary side inlet/outlet T | 340°C/530°C |
| Fuel | Uranium Nitride (UN) |
| Maximum fuel residence time | 5000 days |
| Peak fuel burn-up | 18 GWd/ton |
| Peak damage dose | 35 dpa |

**SEALER is a compact nuclear power unit**

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# Potential Applications for SEALER extend beyond electrical power generation

## Mining

- Compact size, long lifetime and no refueling are ideal for installation in off-grid locations
- Stable power supply facilitates the electrification of many operations

## Chemicals

- Supply direct superheated steam
- Provide power for decarbonisation through electrification
- Link with pyrolysis and HT electrolysis for H2 and biogenic CO2 supply

## Steel

- Achieves smelters' electrification
- 530°C steam is ideal for production of high quality biochar to decarbonise iron ore sintering

## Maritime

- Heat & Power supply enables E-Fuels production
- Compact design is ideal for Floating NPP barges to power terminals
- Possible nuclear propulsion of ships

## Cement

- 530°C heat is ideal for production of high quality biochar to replace traditional SCMs like fly ash, acting as carbon sequestration
- Enables alternative fuel use like hydrogen

## Aviation

- Decarbonise ground operations by providing the electric power needed for production of SAF
- Supply stable energy supply to airports

## Refineries

- Use of superheated steam directly in reforming processes
- Link with pyrolysis and HT electrolysis for H2 and biogenic CO2 supply

## Data Centers

- Scalable in 55MW increments to match DC growth on the same site
- 55MW unit based clusters ensures high reliability and redundancy via optimally scheduled maintenance

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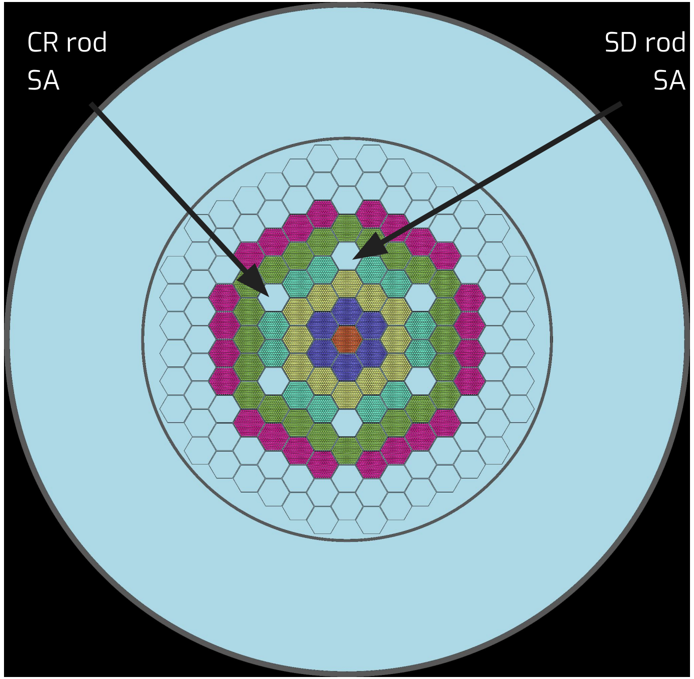
**SEALER-ONE to be fuelled with 9.9% enriched uranium nitride fuel, fuel of choice for reaching criticality with low as low enrichment as possible.**

## PRELIMINARY CORE DESIGN




| Item | Value |
|---|---|
| Power | 70 MWth |
| Fuel | $U^{15}N$ |
| $^{235}U$ enrichment | 9.9 wt% |
| Fuel mass (uranium) | 27 tons |
| No of fuel assemblies | 79 |
| Hex-can pitch | 204.4 mm |
| Full power life | 5000 days |
| Peak fuel burn-up | 18 GWd/ton (~2% FIMA) |
| Peak clad damage | 35 dpa |

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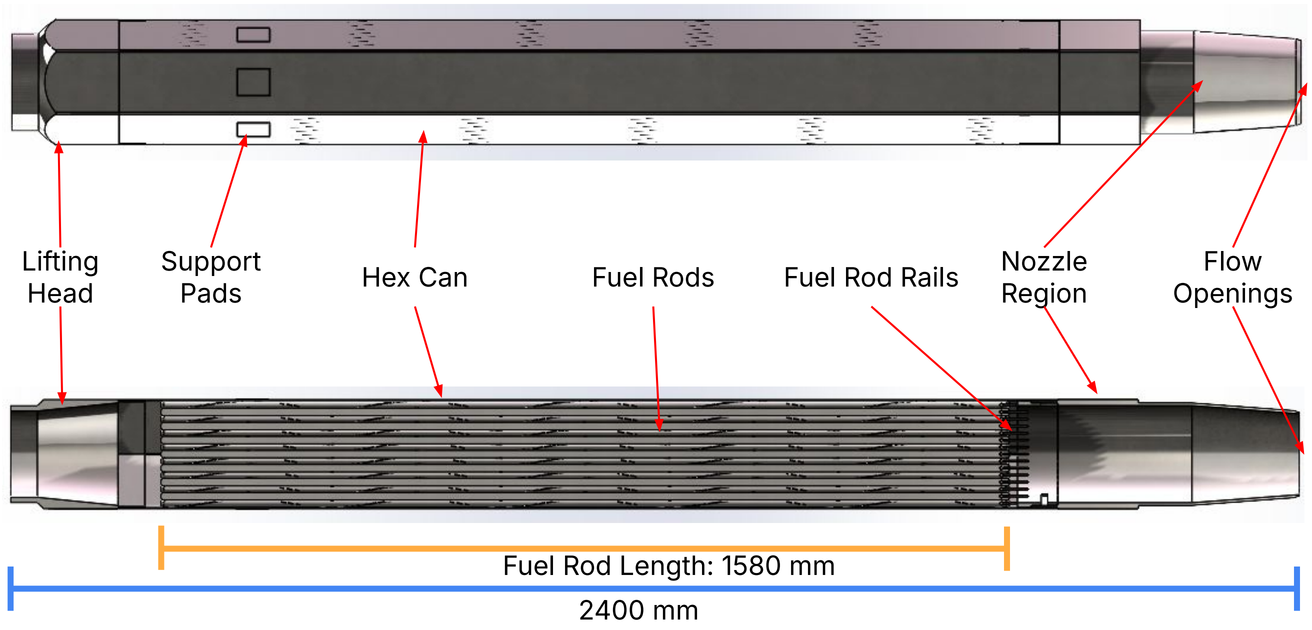
Hexagonal SEALER fuel assemblies are inspired by established fast reactor fuel design

## CONCEPTUAL FUEL DESIGN

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# SEALER design takes into account the needs of spent fuel on-site management

## FUNDAMENTALS

SEALER is a Gen-IV breeder reactor

Safeguards by design a must

No fuel reloading, single load

## FOCAL POINTS

Fuel failure

Fuel removal

SNF reprocessing

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## SEALER design takes into account the needs of spent fuel on-site management

### FOCAL POINTS

- Fuel failure
- Fuel removal
- SNF reprocessing

### AIM FOR ZERO FUEL FAILURE, PREPARE FOR THEM ANYWAY

- Preventing fuel failure through QA design & fabrication and operations
- Use global lessons learned
- Detecting fuel failure during operation
- Identifying assembly with fuel failure
- Managing failed fuel assembly in and ex-vessel
- Liquid lead filtering and systems decontamination

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# SEALER design takes into account the needs of spent fuel on-site management

## FOCAL POINTS

Fuel failure

Fuel removal

SNF reprocessing

## BALANCE INNOVATION, SAFETY, OPERATIONAL EFFICIENCY AND COST

- Locating fuel in liquid lead
- Removing fuel with high precision in complex operating conditions
- Developing reliable and intelligent fuel removal technology, at low cost
- Preparing for an interim storage, expecting not to use it

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## SEALER design takes into account the needs of spent fuel on-site management

### FOCAL POINTS

- Fuel failure
- Fuel removal
- SNF reprocessing

### BALANCE SAFETY, SAFEGUARDS AND SECURITY WITH THE INTENT OF GEN-IV

- Identifying pathways and obstacles to utilizing the potential of a breeder
- Designing reactor technology and processes ensuring non-proliferation
- Finding appropriate canisters for spent fuel removal and transportation
- Developing reliable gas-cooling systems for SNF

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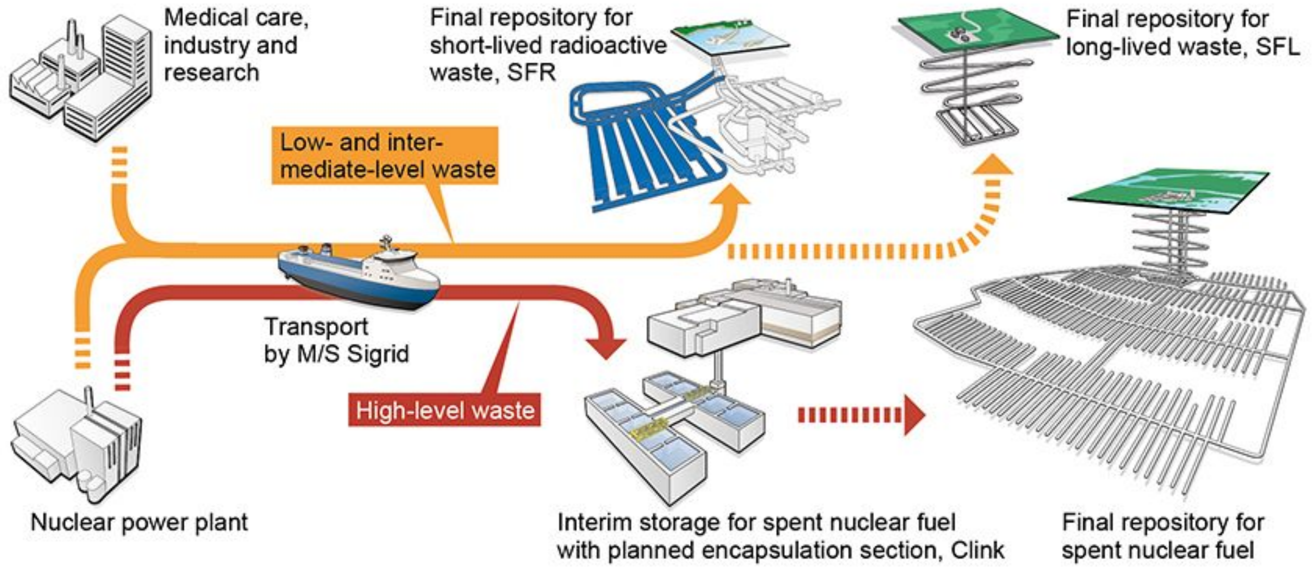
Licensee responsible for developing a credible SNF management plan, including compliance with the Swedish waste management framework

## SNF MANAGEMENT IN SWEDEN

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## Investigating three solutions, since SNF management will have to be valid in other markets as well

**THREE BACK-END SCENARIOS**

| Direct disposal | Conversion & disposal | Reprocessing & vitrification |
| --- | --- | --- |
| Encapsulation of SNF, and direct disposal as nitride. | Coversion of nitride to oxide and sintering into waste pucks to assure chemical stability.<br><br>Disposal in some capsulated form. | Reprocessing to utilize all fissile materials in fresh nuclear fuel.<br><br>Vitrification of fission products and MA prior to disposal. |

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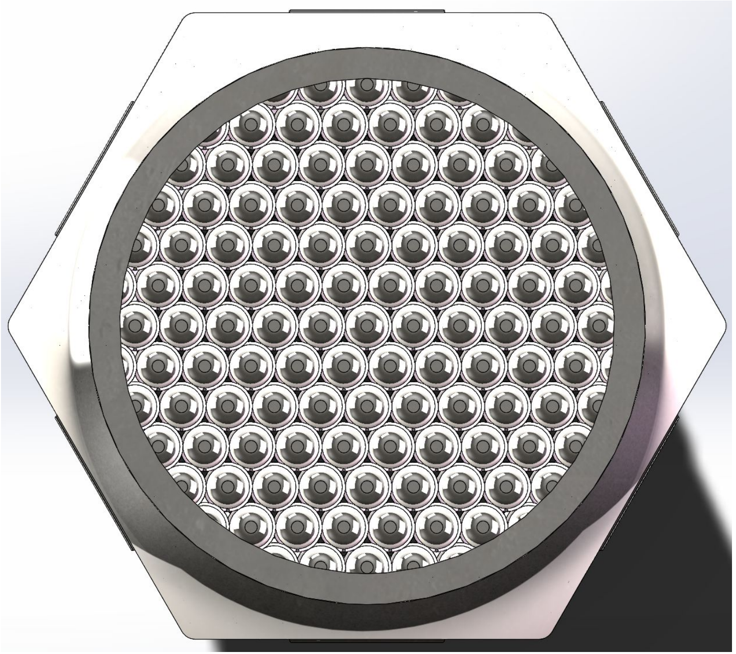
# Irradiated nitride fuel differs from irradiated LWR fuel, impacting back-end strategies



- Higher enrichment
- Higher density
- Increased criticality risk at equal volumes
- Spent fuel must be handled in smaller volumes and packages
- Higher solubility  at lower temperatures, i.e. easier to reprocess
- Multi-reprocessing possible
- Low TRU decay heat in long term storage, i.e. compact disposal

Active participation in international back-end RnD programmes is a valuable asset in the strategic planning of SNF management

BACK-END R&D WORK

**ASGARD**
**2012-2016**

Advanced fuels for Gen IV reactors: reprocessing, dissolution, fabrication, recyclability, and large-scale feasibility, with European collaboration and E&T focus.

**FREDMANS**
**2022-2026**

Fuel recycling and advanced UN fuel manufacturing for safe and efficient nuclear power generation

**WISARD**
**2025-2028**

Assessing advanced reactor fuel cycle impacts on back-end solutions, led by OECD/NEA and with active participation from national nuclear organizations and industry

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# Thank you!