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Framatome *VVER-440 Fuel* Product Line Development

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1.

Introduction

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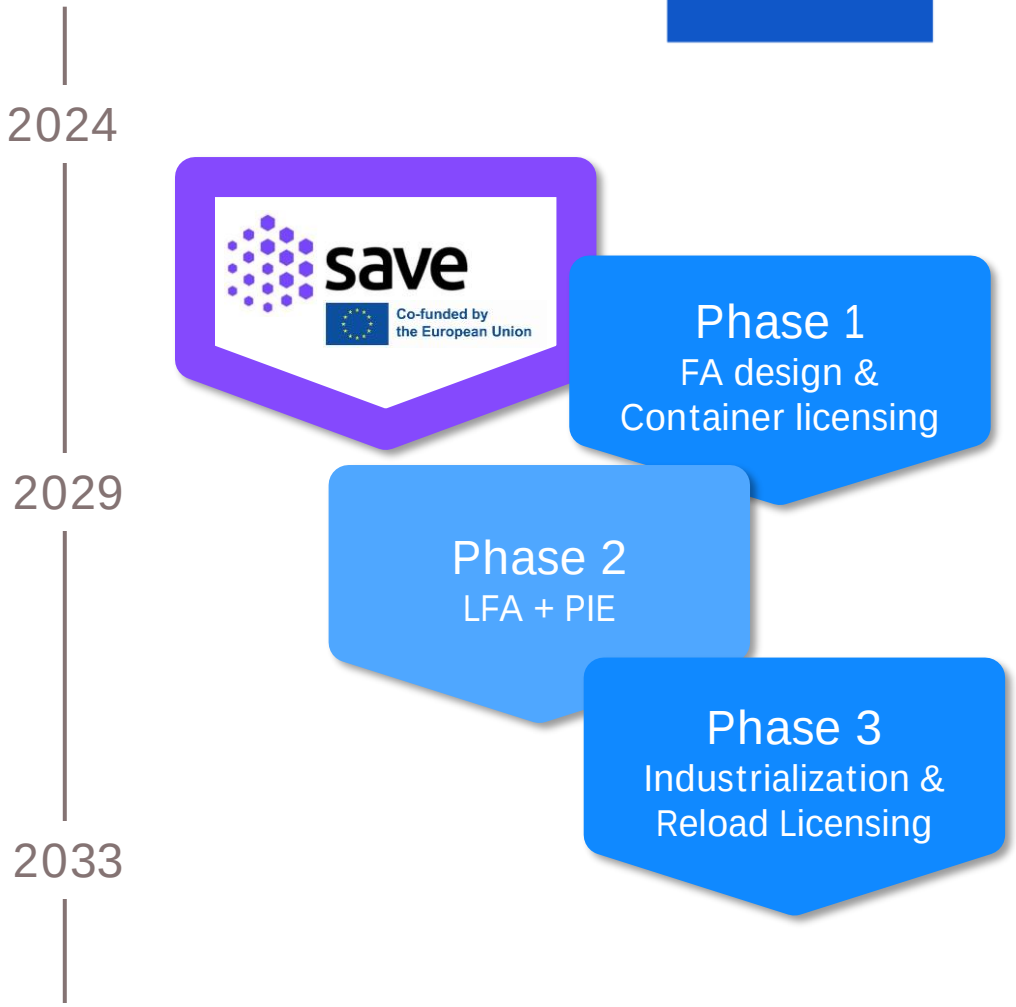
VERA-440 development roadmap & goals

4 utilities, 1 supplier

- ČEZ (CZE), Fortum (FIN), MVM Paks (HUN), SE (SVK)
- Framatome SAS and subsidiaries

Common goals

- Security of supply through diversification
- A modern VVER-440 fuel and transport container
- Safe, performant, and 100% European-sovereign
- LFA introduction by 2029
- Reload readiness by the early 2030's



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2.

A new grid design

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Spacer grid development

Concept Design

- 13 grid concepts over 3 concept “families”
- Comparative analyses and tests, basic tool development
- Promotion of 2 concepts into the Basic Design phase

Basic Design

- Elimination of 1 concept
- Retained concept: Creation of 12 variants, tool improvement
- 1 variant retained, new features added

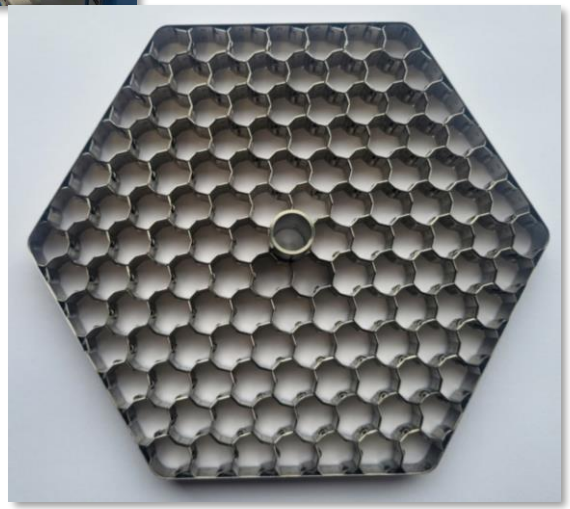
Detailed Design

- Fine tuning (rod support), testing, and manufacturing scale-up



CNC welding machine

Retained concept



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Decision & elimination process

Mechanical behavior

- Additive manufacturing (AM) of concepts
- Repetition on (simplified) conventional prototypes

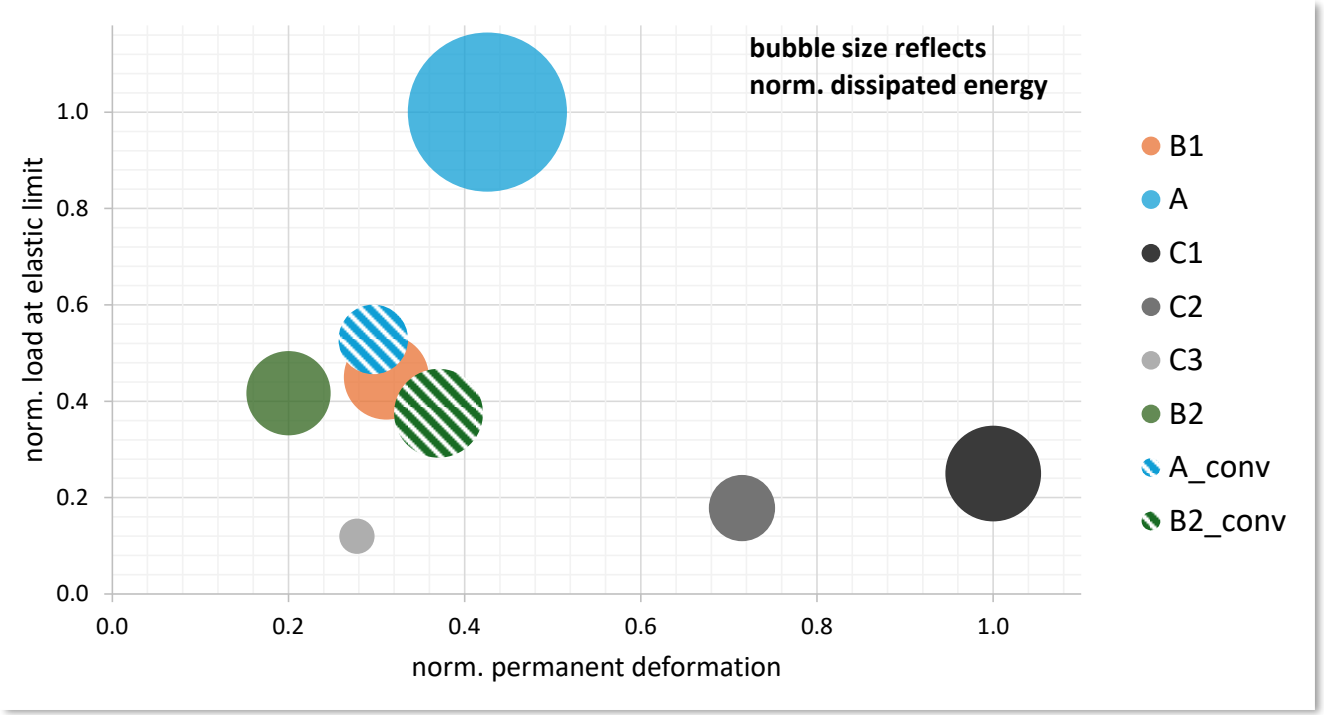
Lead time / iteration speed

- Materials and availability
- New vs. mastered technologies
- Tooling needs

(Thermal-) hydraulic behavior

- Pressure losses
- Expected CHF performance

Tested mechanical behavior of different grid concepts (AM and conventional prototypes)



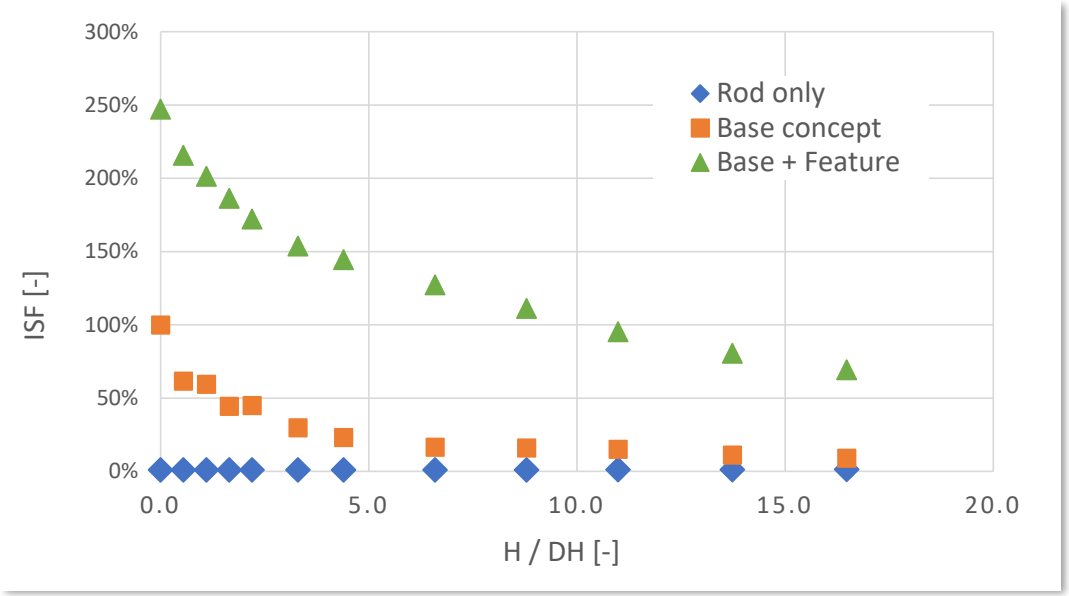
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Unlocking new possibilities

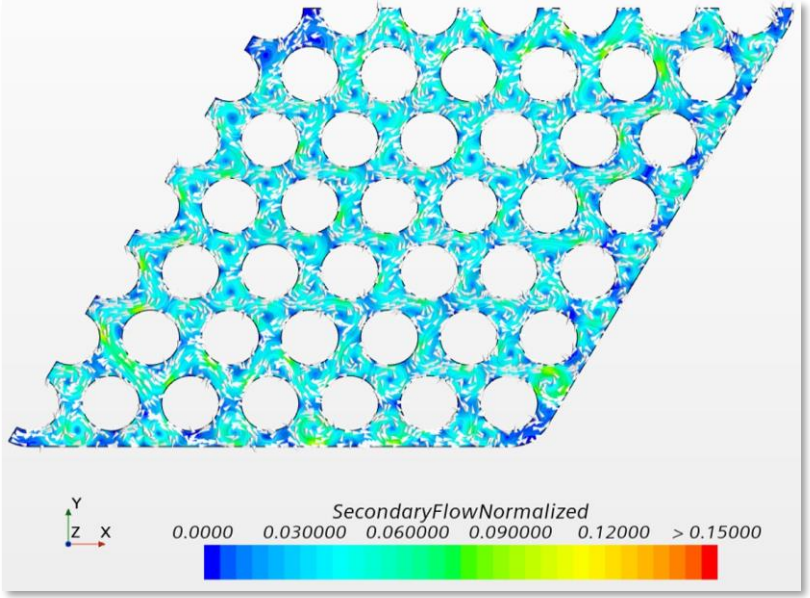
New feature built into retained spacer concept giving

- 30% lower pressure losses
- 250% higher mixing

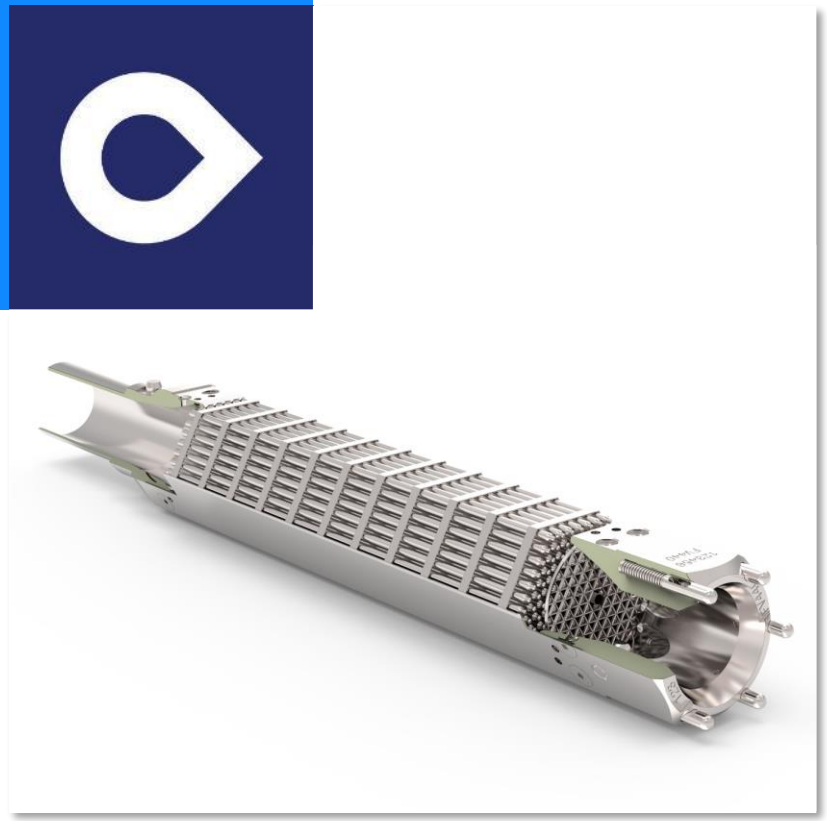
Secondary Flow Intensity vs. Hydraulic Diameter



Mid-span Secondary Flow Intensity



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3.

VERA-440

Framatome’s VVER-440 fuel

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VERA-440 fuel assemblies

126 x 8.9 mm fuel rod ❶

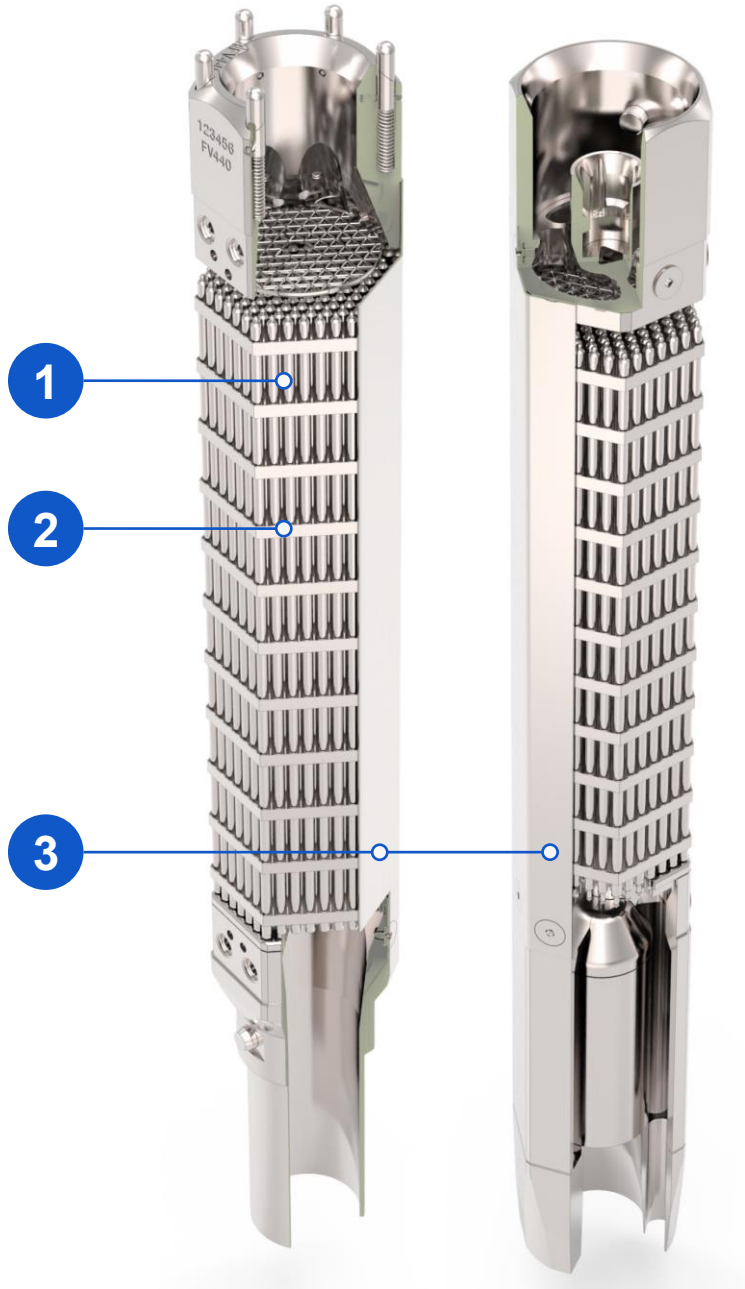
- 148 (141) kg UO_2 and cycles up to 18 months
- M5 cladding

11 x Q12 spacer grid ❷

- Good mechanical performance regarding impact and fretting
- Excellent hydraulic performance
- 12.3 mm fuel rod pitch

Detachable Q12 shroud ❸

- Every VERA-440 assembly is serviceable



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4.

VERA-440 container

Framatome’s VVER-440 container

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VERA-440 transport container

Concept Design

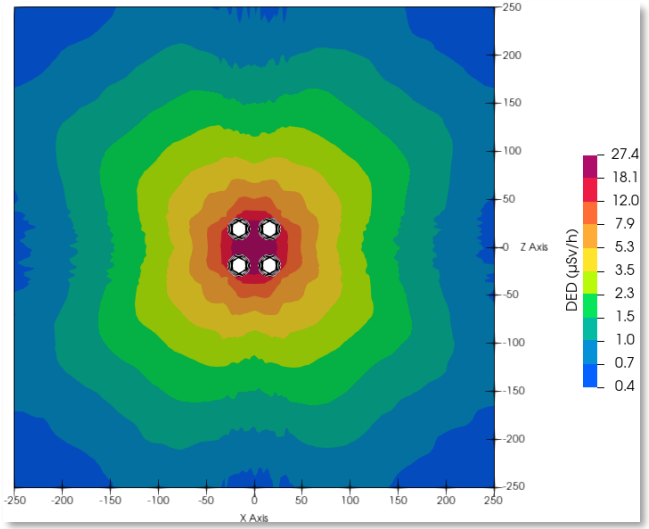
- Boundaries set by criticality, radioprotection, thermal, mechanical analyses
- 3 concepts proposed, 1 promoted into Basic Design phase

Basic Design

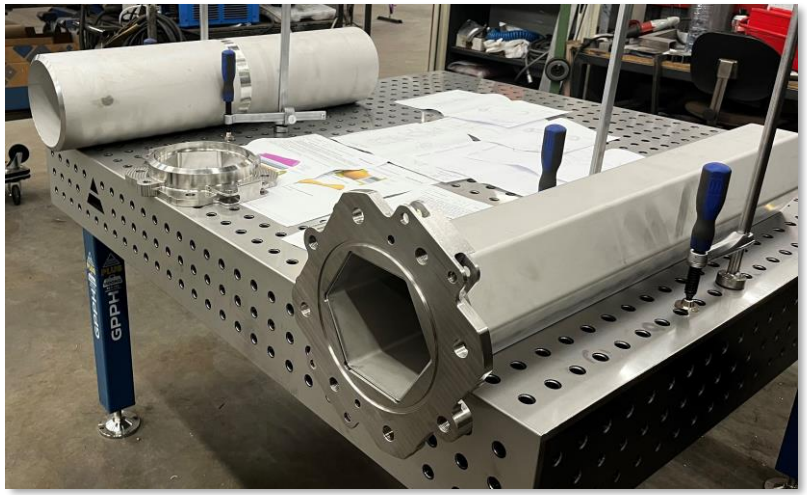
- Prototyping phase to demonstrate manufacturing feasibility
- Refined analyses performed on Basic Design
- Insertion tests performed with Fuel Assembly prototype

Detailed Design

- ASNR assessment report on Safety Options File received
- IAEA tests (cf. next slide)



Radioprotection analyses



Early prototypes

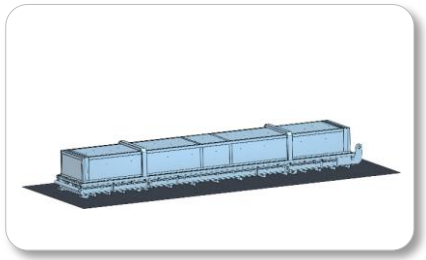
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VERA-440 transport container

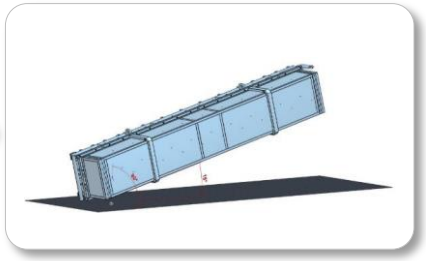
IAEA test sequence

- Manufacturing of container drop test specimen
- FEM calculations to identify penalizing test configurations

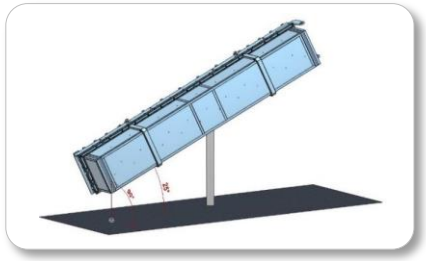
1.2 m drop



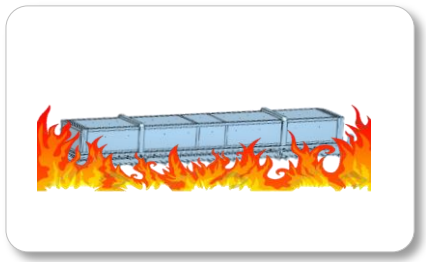
9 m drop



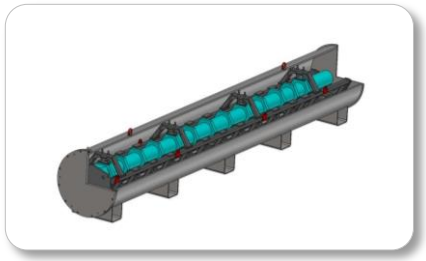
Spike drop



Fire testing



Helium leakage test



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5.

Summary

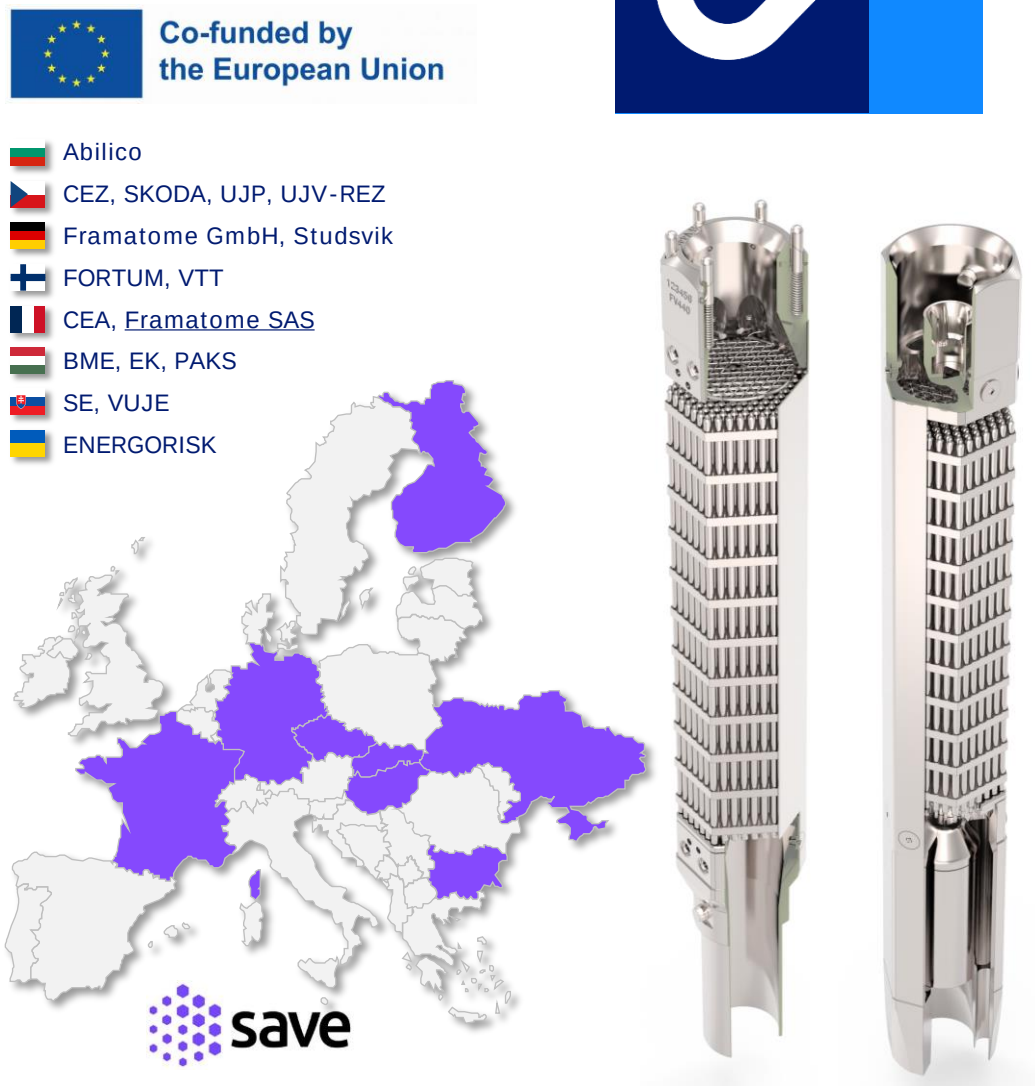
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Summary

Goal & Status

- Contribute to Europe's energy sovereignty
- Co-funded by the European Union (SAVE project EU)
- LFA in 2029, be qualified for reloads by early 2030's
- VERA-440 and container on track with goals

Framatome thanks all clients, partners, suppliers, and the European Commission for their contributions and support!



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Thank you

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