ALLEGRO gas cooled fast reactor demonstrator and SafeG H2020/Euratom project

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Janusz Malesa

NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

Content

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- V4G4 role
- SafeG project
- NCBJ / UZ3 involvemet
- Summary

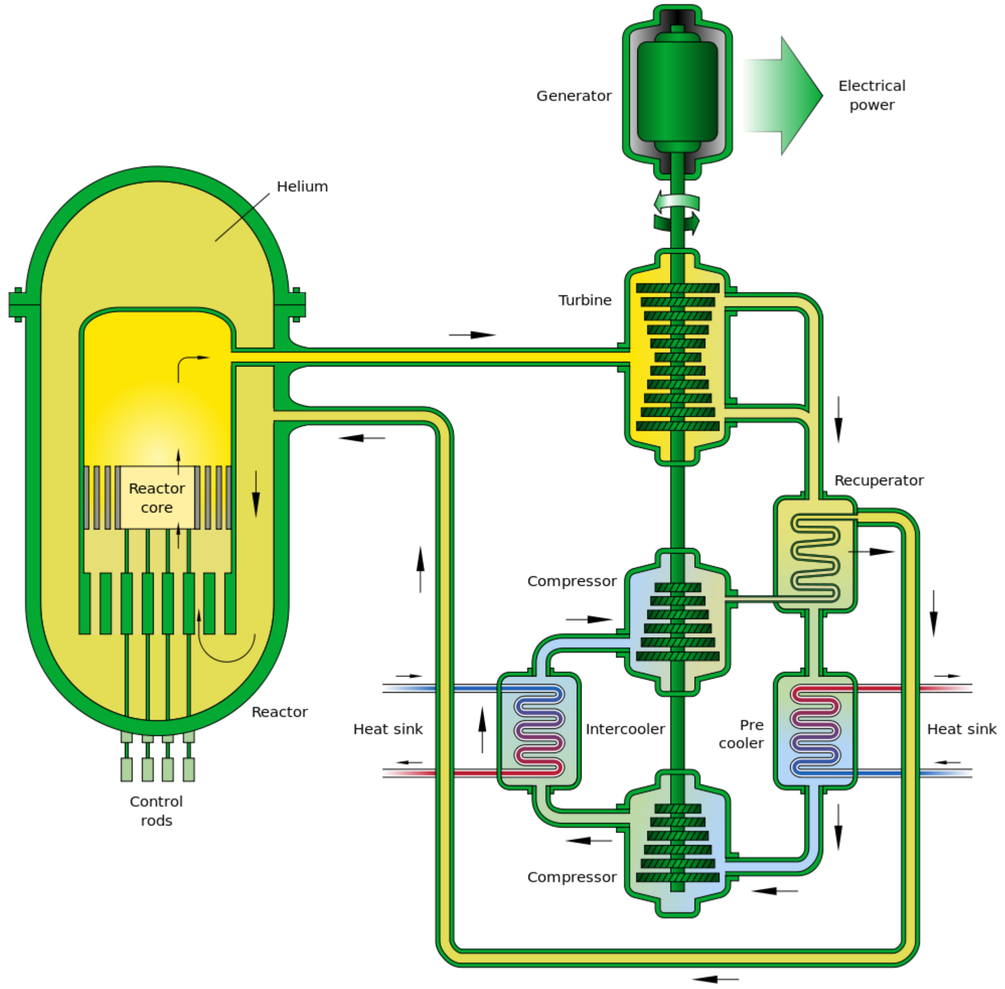
The presentation is based on a papers, presentations and other materials prepared by members of the V4G4 Centre of Excellence and ALLEGRO project .

GFR – Gass-cooled Fast Reactor

- GIF selection (1 of 6 technologies)
- Fast neutron spectrum
- Inherent coolant
- High outlet temperature

- High conversion factor (1.4)
- Closed fuel cycle
- Power conversion – various possibilities with high efficiency

- The quite old concept (80’)
- Requires development
  - Material technology
  - Robust cooling systems
  - Turbomachinery



ALLEGRO – the GFR demonstrator

Low power and limited operational parameters

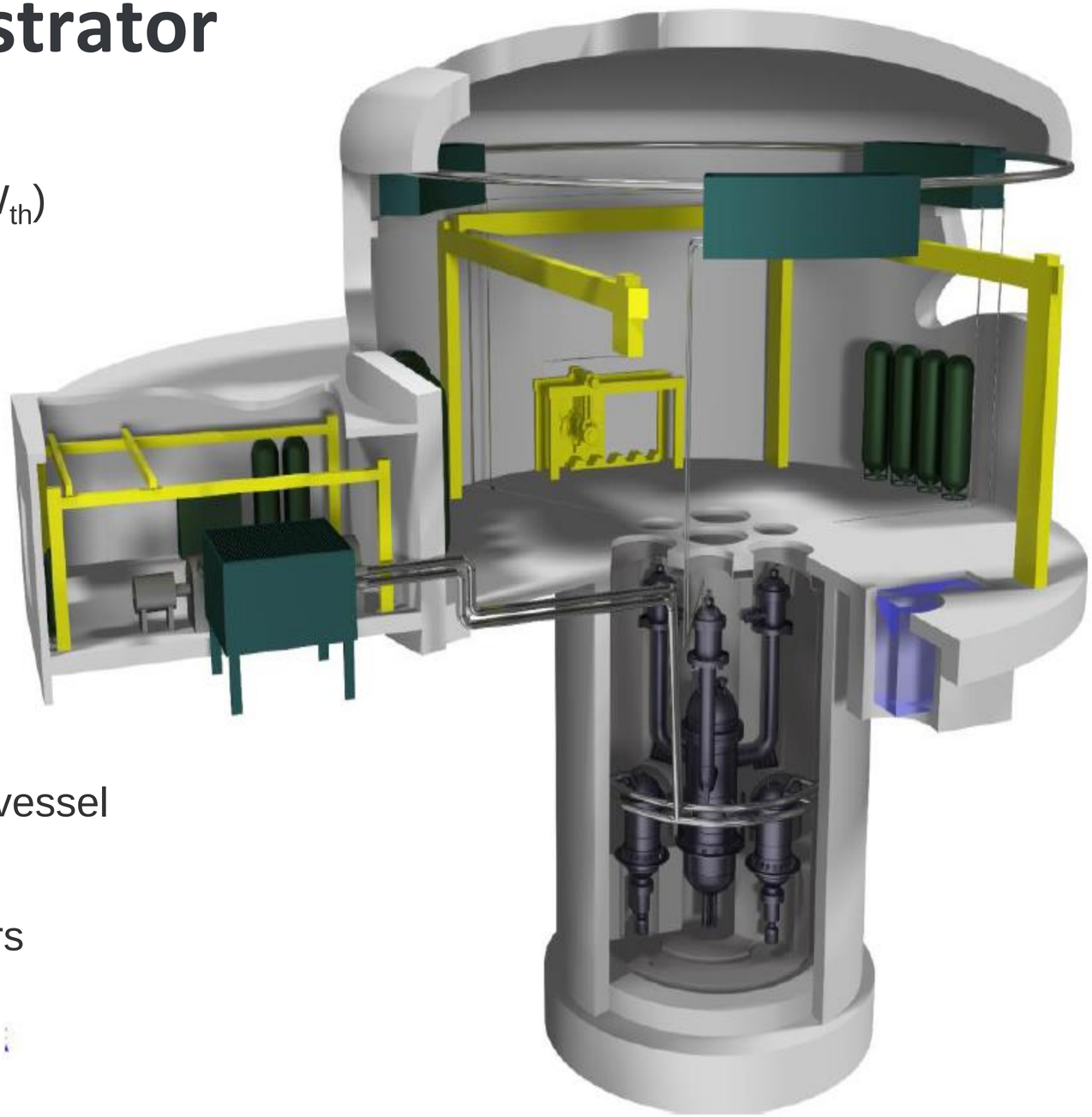
- P = 50 to 100MW_{th} (curently proposed 75MW_{th})
- Tcoolant = 260 / 516 ºC

The goal – demonstration of technology and

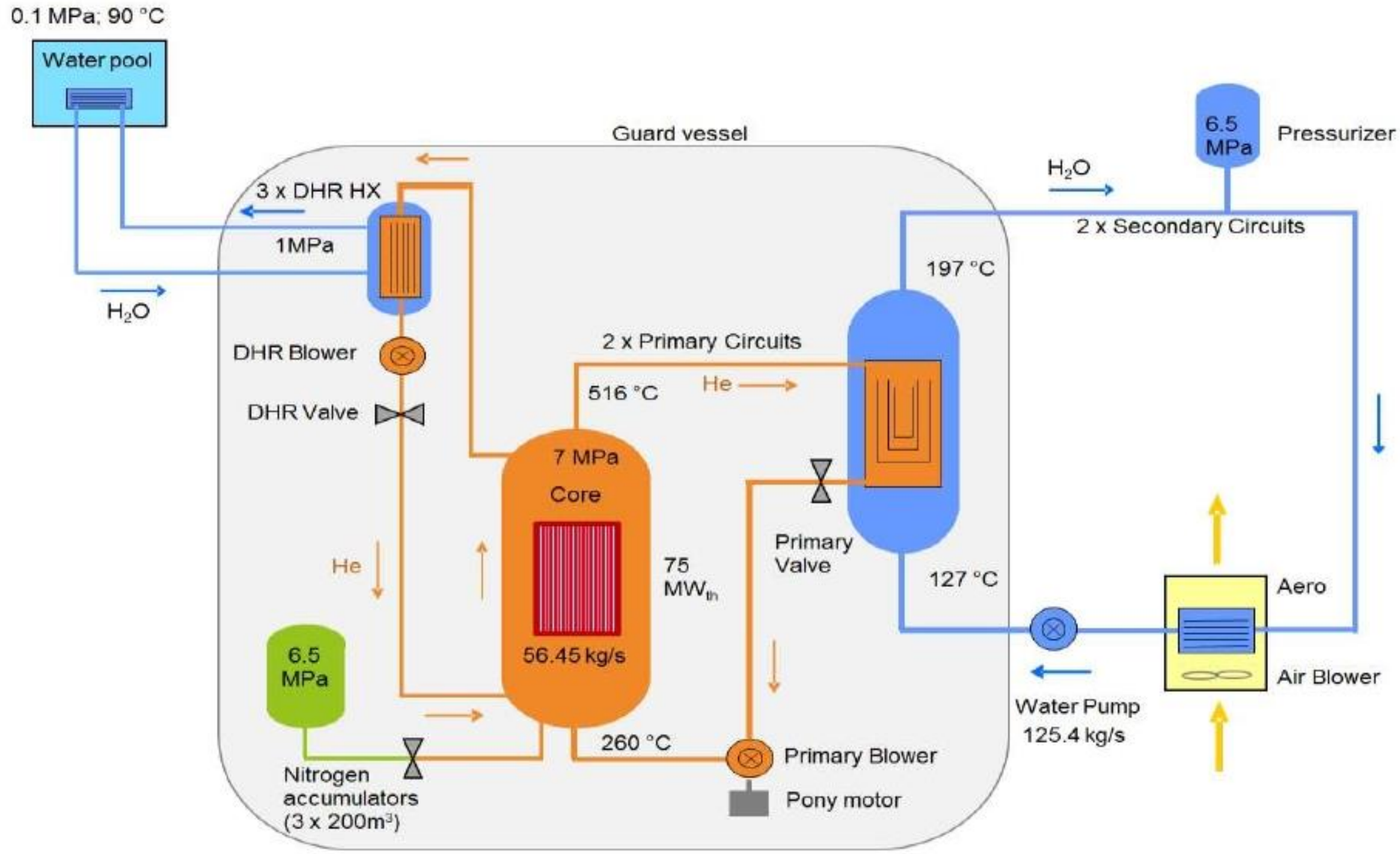
- Refractory Fuel development
- Helium technology development
- Safety systems and standarts development
- Feasibility and viability

General View

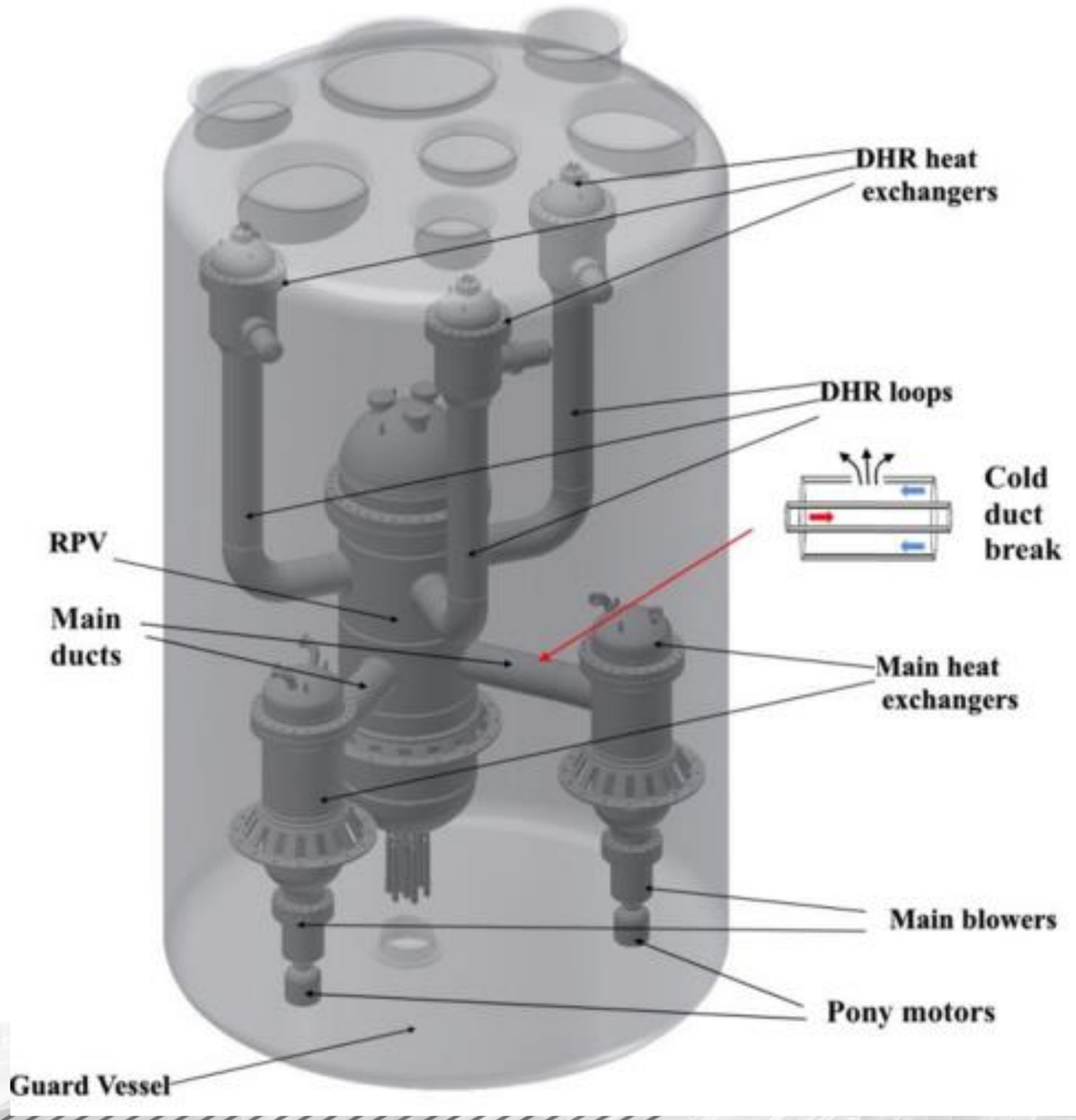
- The containment and auxiliary building(s)
- Underground concrete cavity and Steel guard vessel
- RPV and primary circuit equipment
  - 2x primary cooling HX integrated with blowers
  - 3x DHR loops



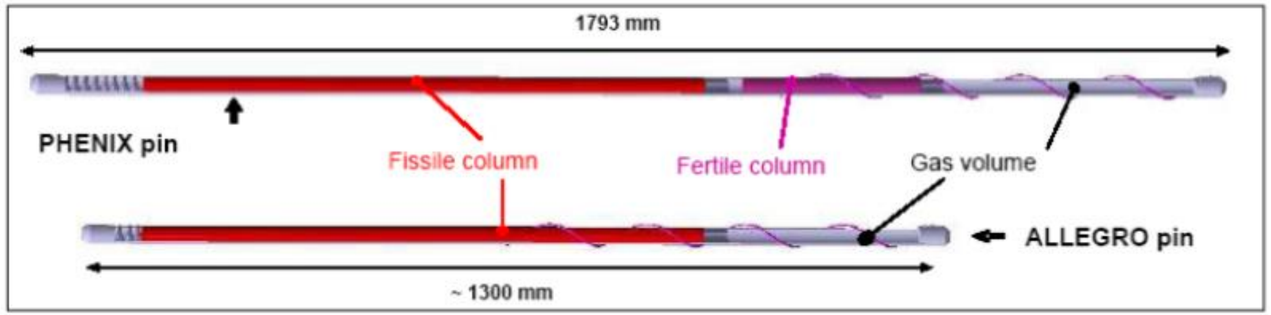
ALLEGRO Cooling Systems Concept

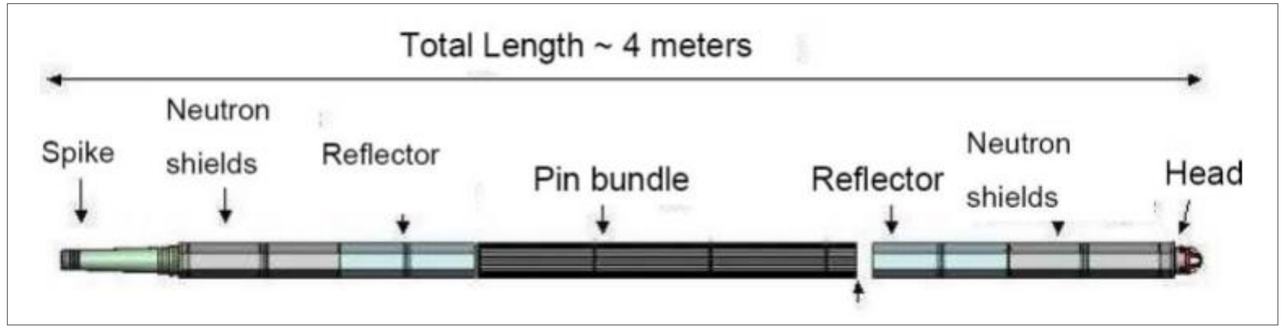


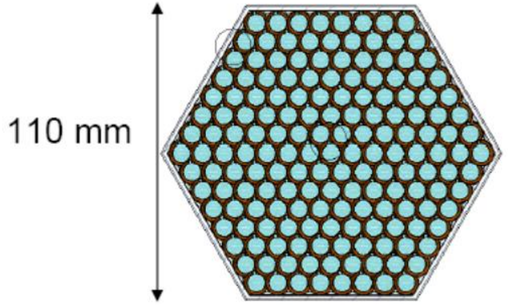
ALLEGRO Cooling Systems Concept of arrangement

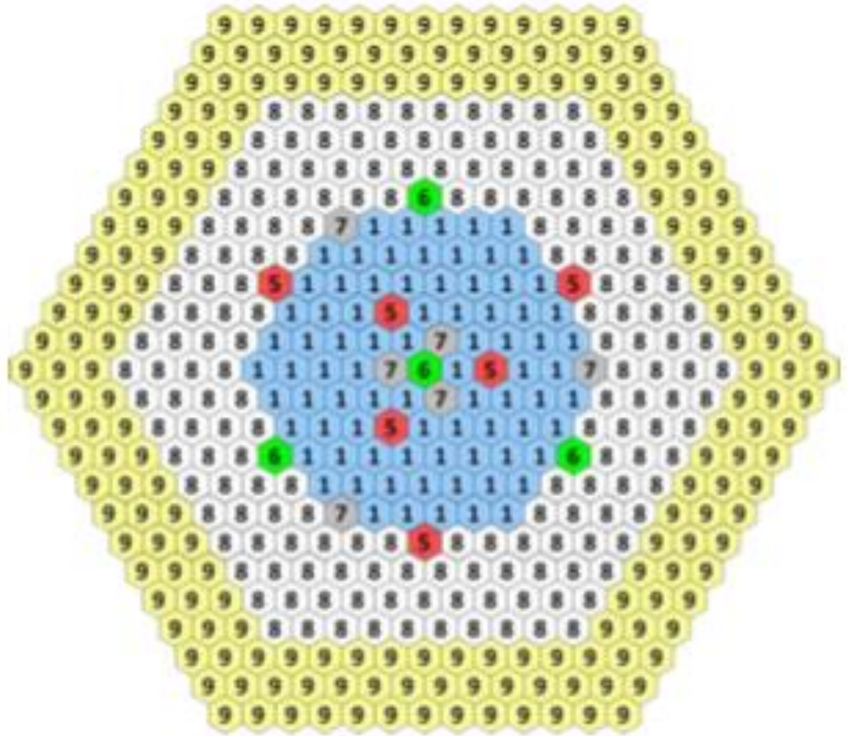


ALLEGRO Fuel and Core (MOX, UOX)









1: original fuel sub-assemblies
5: control sub-assemblies
6: diverse shutdowns devices
7: steel/dummy sub-assemblies
8: radial reflector sub-assemblies
9: radial shield sub-assemblies

V4G4

2010 Nuclear research institutes of the Visegrad-4 region, in cooperation with CEA started joint preparations aiming at the construction and operation of the GFR demonstrator ALLEGRO

2013 Creation of the “V4G4 Centre of Excellence”

2015 ALLEGRO Project – Preparatory Phase launched

2017 CEA joined to the project

2019 CVR joined to the project

- ❑ Steering Committee
- ❑ Project Coordination Team
- ❑ Financing: national and European projects

- ❑ Safety and Design Roadmap
- ❑ Databases, Design specifications, Design criteria

Reference Design

- ❑ An modern concept elaborated by CEA after 2000
- ❑ Experimental Technology Demonstration Reactor (ETDR) CEA presented in 2008; 50MWth; 560^{o}C
- ❑ new concept was presented by CEA in 2009 with the name ALLEGRO; 75 MWth; 530^{o}C
- ❑ **ALLEGRO CEA 2009** taken as reference design for V4G4 CoE

European Projects on GFR

- GCFR - The Gas Cooled Fast Reactor Project (FP6) – R&D 2005 – 2009
- GoFastR - European Gas Cooled Fast Reactor (FP7) – R&D 2010 – 2013
- ALLIANCE - ALLegro Implementing Advanced Nuclear Fuel Cycle (FP7) – CSA 2012 – 2015
- ESNII + Preparing ESNII for HORIZON 2020 (FP7) – CSA 2013 – 2017
- VINCO - Visegrad Initiative for Nuclear Cooperation (Horizon 2020) – CSA 2015 – 2018
- SafeG Safety of GFR through innovative materials, technologies and processes – R&D 2020 – 2024

Project objectives

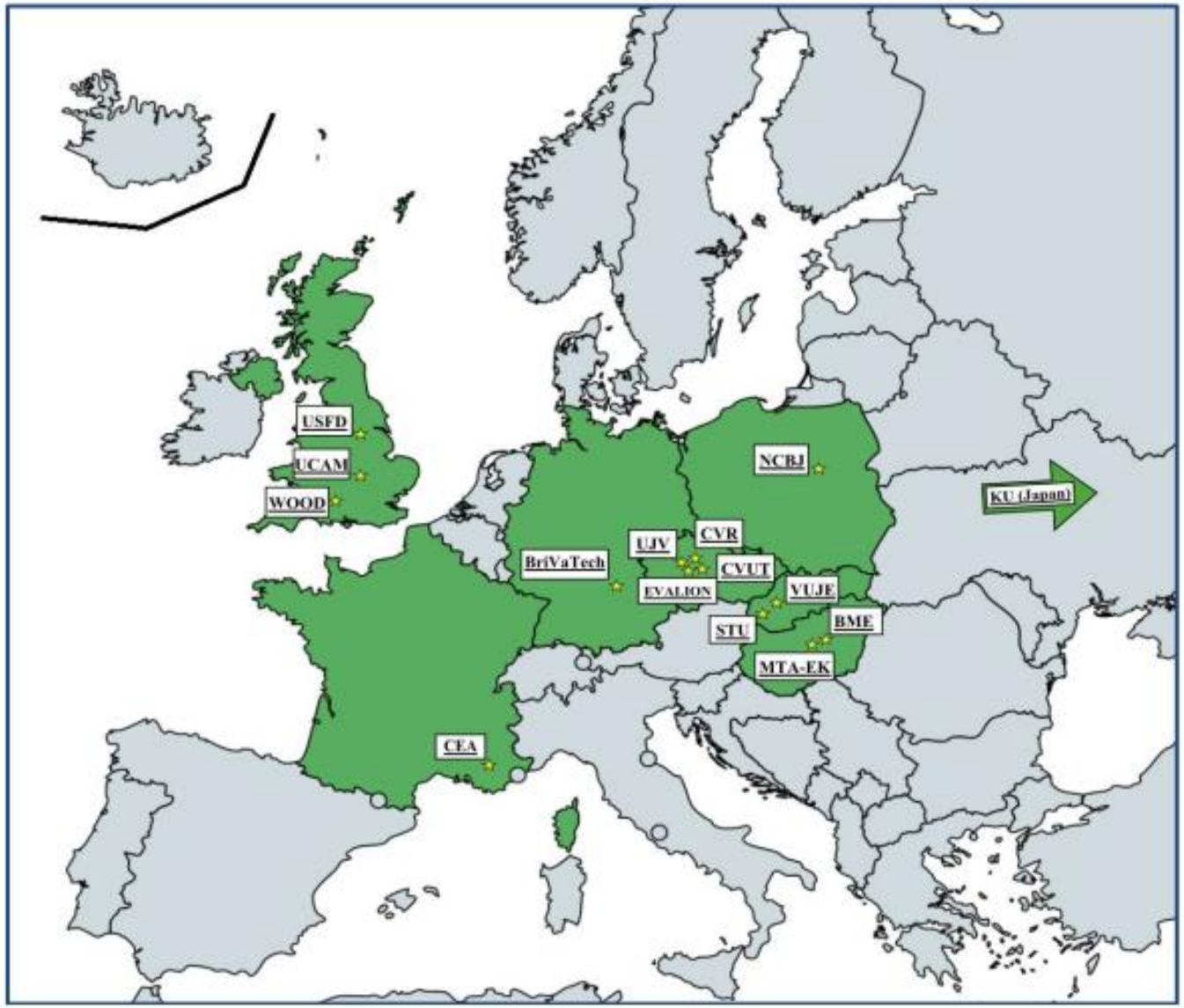
In general:

- ❑ GFR technology demonstrator ALLEGRO
- ❑ Update the safety status
- ❑ Research for safety improvements

Specifically

- ❑ Improvement of safety
  - ➢ Through the use of innovative technologies, materials and systems
  - ➢ To solve remaining open questions in residual heat removal in accident conditions
  - ➢ To strengthen the inherent safety of the key reactor components
- ❑ Review of the GFR reference options in materials and technologies
- ❑ Adaptation of GFR safety to changing needs in electricity production worldwide
  - ➢ Studies of various fuel cycles and their suitability from the safety and proliferation resistance points of view
- ❑ Boosting interest in GFR research by wide involvement of universities and students
- ❑ Deep collaboration with international non-EU research teams

Partners


USFD
UCAM
WOOD
NCBJ
KU (Japan)
UJV
CVR
BriVaTech
CVUT
EVALION
VUJE
BME
STU
MTA-EK
CEA

	Participant organisation name	Short name	Country
1	VUJE, a. s. (Coordinator)	VUJE	Slovakia
2	ÚJV ŘEŽ, a. s.	UJV	Czech Republic
3	ENERGIATUDOMANYI KUTATOKOZPONT	EK	Hungary
4	NARODOWE CENTRUM BADAN JADROWYCH	NCBJ	Poland
5	CENTRUM VÝZKUMU ŘEZ S.R.O.	CVR	Czech Republic
6	THE COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	France
7	JACOBS CLEAN ENERGY LIMITED	JACOBS	United Kingdom
8	BRINKMANN GERD FRIEDRICH	BRIVATECH	Germany
9	NATIONAL UNIVERSITY CORPORATION, KYOTO UNIVERSITY	KU	Japan
10	ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE	CVUT	Czech Republic
11	BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM	BME	Hungary
12	SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE	STUBA	Slovakia
13	THE CHANCELLOR MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	UCAM	United Kingdom
14	THE UNIVERSITY OF SHEFFIELD	USFD	United Kingdom
15	EVALION s.r.o.	EVALION	Czech Republic

SafeG

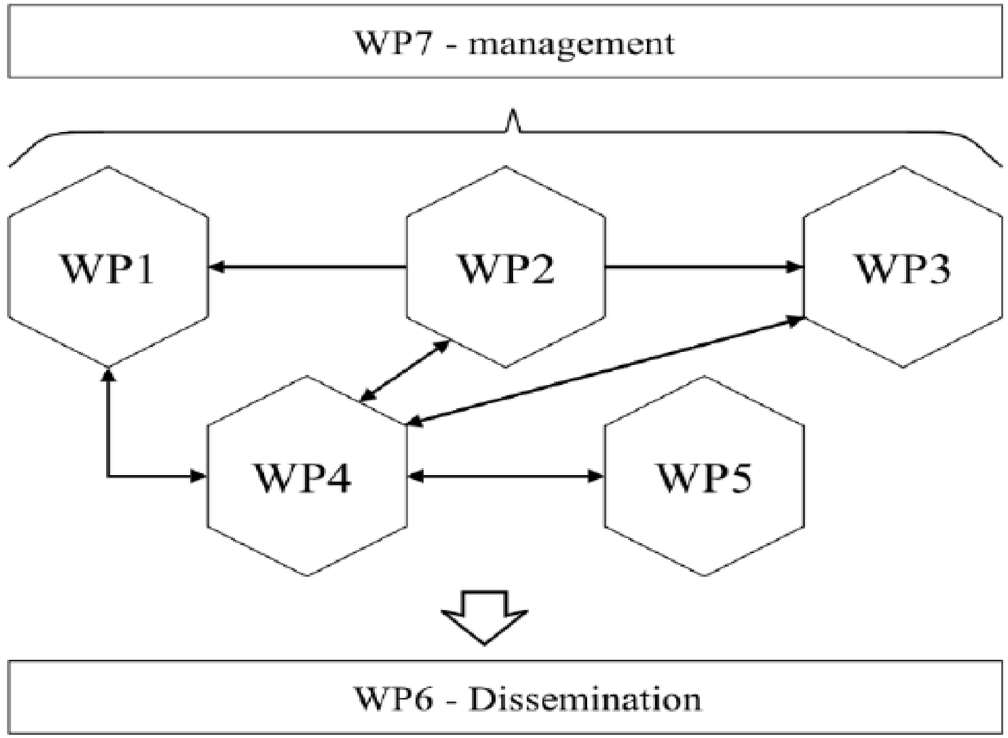
Partners

Work Packages

- WP1 Core safety – EK
- WP2 Materials and technologies – CVR
- WP3 Decay heat removal – VUJE
- WP4 Integration of results and standardization – UJV

- WP5 Education and training – UCAM

- WP6 Dissemination and outreach – Evalion
- WP7 Project management – VUJE
- WP8 Ethics requirements – VUJE



WP1 - Core safety, proliferation resistance

- **WP leader: EK – Gusztav Mayer (initially Andras Kereszturi)**
  - Core safety, through optimized neutronic, thermal-hydraulic and thermomechanics design of the core
  - Proliferation resistance
  - Safe core shutdown – by design of passive, reliable core control and shutdown system

- **Tasks**
  - 1.1 ALLEGRO core designs
  - 1.2 Proliferation resistance
  - 1.3 Diversified shutdown system
  - 1.4 Core and reflector features, radiation shielding of the reactor vessel and internals

WP2 - Innovative Materials and Technologies for Enhancing Safety of GFRs

- **WP leader: CVR – Jana Kalivodova**
  - To solve the weak points of selected key components with respect to materials
  - To test compatibility of selected materials and components with GFR coolant
  - To propose and assess adequate innovative materials with better performance as well as the advanced manufacturing processes and technologies

- **Tasks**
  - 2.1 Innovative solutions for the core and the primary circuit
  - 2.2 Compatibility of materials with media in GFR conditions
  - 2.3 Advanced manufacturing processes

WP3 - Innovative solutions for decay heat removal

- **WP leader: VUJE – Boris Kvizda**
  - Understanding of complex phenomena related to DHR in GFRs
  - Optimization of reference concepts
  - Design of innovative solutions of key safety systems related to DHR in GFRs

- **Tasks**
  - 3.1 Innovative DHR solutions including experimental verification of the DHR system function
  - 3.2 Instrumentation
  - 3.3 Isolated DHR loop operation and “conditioning” options
  - 3.4 Emergency coolant injection system of ALLEGRO
  - 3.5 Isolation and check valves
  - 3.6 CFD study of LOFA

WP4 - Integration of the results, standardization, codes

- **WP leader: UJV – Petr Vacha**
  - Integration of results of the project
  - Identification of R&D needed in future projects, to build on results of SafeG

- **Tasks**
  - 4.1 Results integration
  - 4.2 Assessment of timescales and R&D needed to implement solutions identified in WP1 and WP2
  - 4.3 Standardization and codes
  - 4.4 Fuel qualification options

WP5 - Education and training

- **WP leader: UCAM – Eugene Shwageraus**
  - The goal is to involve new students
    in solving of actual cutting-edge research problems,
    by offering interesting Ph. D. and masters theses
    with a clear connection to application of their results
  - Organization of several events
    thermal-hydraulics benchmark
    workshops

- **Tasks**
  - 5.1 Direct involvement of students in the project
  - 5.2 Benchmarking exercise on gas-cooled reactors
  - 5.3 GFR summer school and seminars

WP6 - Dissemination and outreach

- **WP leader: EVALION – Jana Peroutkova**
  - Dissemination of project results to targeted professional audiences
  - Communication with relevant stakeholders and decision makers

WP7 - Project management

- **WP leader: VUJE – Slavomir Bebjak**
  - To assure efficient management of SafeG project activities including overall project steering
  - To ensure cooperative research on technical tasks with quality control;
  - To assure internal and external (to the EC) reporting, communication, risk management and knowledge management within the partnership
  - To organize project meetings and steering of the project management bodies

Involvement of NCBJ

- **WP1: Core safety…**
  - Task 1.1 ALLEGRO core designs
- **WP2: Innovative Materials…**
  - Task 2.1 Innovative solutions for the core and the primary circuit
  - Task 2.3 Advanced manufacturing processes
- **WP3: Innovative solutions for DHR**
  - Task 3.1 Innovative DHR solutions including experimental verification of the DHR system function
- **WP4: Integration of the results, standardization, codes**
  - Task 4.1 Results integration
- **WP5: Education and training**
  - Task 5.1 Direct involvement of students in the project
  - Task 5.2 Benchmarking exercise on gas-cooled reactors

WP1 – Core safety

Task 1.1 ALLEGRO core designs (EK, VUJE, CEA, JACOBS, UJV, BME, UCAM,NCBJ)

❖ Subtask T1.1-a

❑ **Expected output from the task**

- ➢ Proposed optimized UOX core configuration(s)
- ➢ Performance characteristics of the UOX core(s)
- ➢ Justification of the safety criteria of the UOX core(s)

- ➢ Proposed MOX core configuration
- ➢ Performance characteristics of the MOX core(s)
- ➢ Justification of the safety criteria of the MOX core(s)

❑ **Reference**

- ➢ ALLEGRO core configuration from the ESNII+ project
- ➢ ALLEGRO demonstrator status from EU VINCO project

❑ **Codes/models available**

- ➢ CATHARE2(3), ALLEGRO TH model (VUJE, EK, NCBJ)
- ➢ RELAP5-3D, ALLEGRO TH model (VUJE)
- ➢ ATHLET3.2 (EK)
- ➢ TRACE (NCBJ) ?
- ➢ FFTBM (Fast Fourier Transformation Based Method) tool for accuracy evaluation of the TH tools and models

- ➢ SERPENT (EK, VUJE, NCBJ, BME)
- ➢ KIKO3DMG (EK, BME)
- ➢ WIMS (JACOBS, UCAM)
- ➢ MONK (JACOBS, UCAM)

WP1 – Core safety

Task 1.1 ALLEGRO core designs (EK, VUJE, CEA, JACOBS, UJV, BME, UCAM,NCBJ)

❖ Subtask T1.1-b

❑ **Expected output from the task**

- Thermal hydraulic design of the primary and the secondary loops resulting in high helium temperature at the core outlet of the refractory core.
- Generation and the parameterization of the group constants of the possible variants of the refractory fuel
- Generation of cross sections of ALLEGRO fuel for the code DYN3D

❑ **Reference**

- ALLEGRO core configuration from the GOFASTR project
- ALLEGRO demonstrator status from VINCO project

❑ **Codes/models available**

- CATHARE2(3), ALLEGRO TH model (VUJE, EK, NCBJ)
- RELAP5-3D, ALLEGRO TH model (VUJE)
- ATHLET3.2 (EK)
- TRACE (NCBJ) ?
- FFTBM (Fast Fourier Transformation Based Method) tool for accuracy evaluation of the TH tools and models

- SERPENT (EK, VUJE, NCBJ, BME)
- KIKO3DMG (EK, BME)
- DYN3D – FR data preparation (VUJE)
- WIMS (JACOBS, UCAM)
- MONK (JACOBS, UCAM)

WP1 – Core safety

Task 1.1 ALLEGRO core designs (EK, VUJE, CEA, JACOBS, UJV, BME, UCAM,NCBJ)

❖ Subtask T1.1-c

❑ **Expected output from the task**

- Proposed optimized refractory core configuration(s)
- Performance characteristics of the refractory core(s)
- Justification of the safety criteria of the proposed refractory core(s)

❑ **Reference**

- ALLEGRO core configuration from the GOFASTR project
- ALLEGRO demonstrator status from VINCO project

❑ **Codes/models available**

- CATHARE2(3), ALLEGRO TH model (VUJE, EK, NCBJ)
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- SERPENT (EK, VUJE, NCBJ, BME)
- KIKO3DMG (EK, BME)
- DYN3D – FR data preparation (VUJE)
- MCNP (BME)

Other planned activities

- **WP2 - Innovative Materials and Technologies for Enhancing Safety of GFRs**
  - NCBJ activities to be done **mostly by LBM**
    - Advanced manufacturing processes
  - UZ3 – update of TH models according to innovative solutions for core, primary circuit (Main Heat Exchanger and DHR heat exchanger)

- **WP3 - Task 3.1 Innovative DHR solutions**
  - S-ALLEGRO Loop model / codes validation
  - STU Loop model / codes validation
- **WP5 – Education and Training**
  - Involvement of MSc students
  - Benchmarking
  - Summer School

Summary

- ALLEGRO is the concept of low power GFR reactor
  - for development and demonstration of the technology
- V4G4 CoE runs the ALLEGRO project since 2015
  - Design, simulations, benchmarking, experimental facilities
- SafeG project is a great opportunity
  - Collaboration with very involved specialists
  - Getting experience in simulation, optimisation, safety philosophy
  - Publications and Conferences
- Coordination of tasks at UZ3
  - Soon / some actions started

References

- The ALLEGRO Experimental Gas Cooled Fast Reactor Project; L. Belovsky, J. Gado, B. Hatala, A. Vasile, G. Wrochna; IAEA-CN245-574
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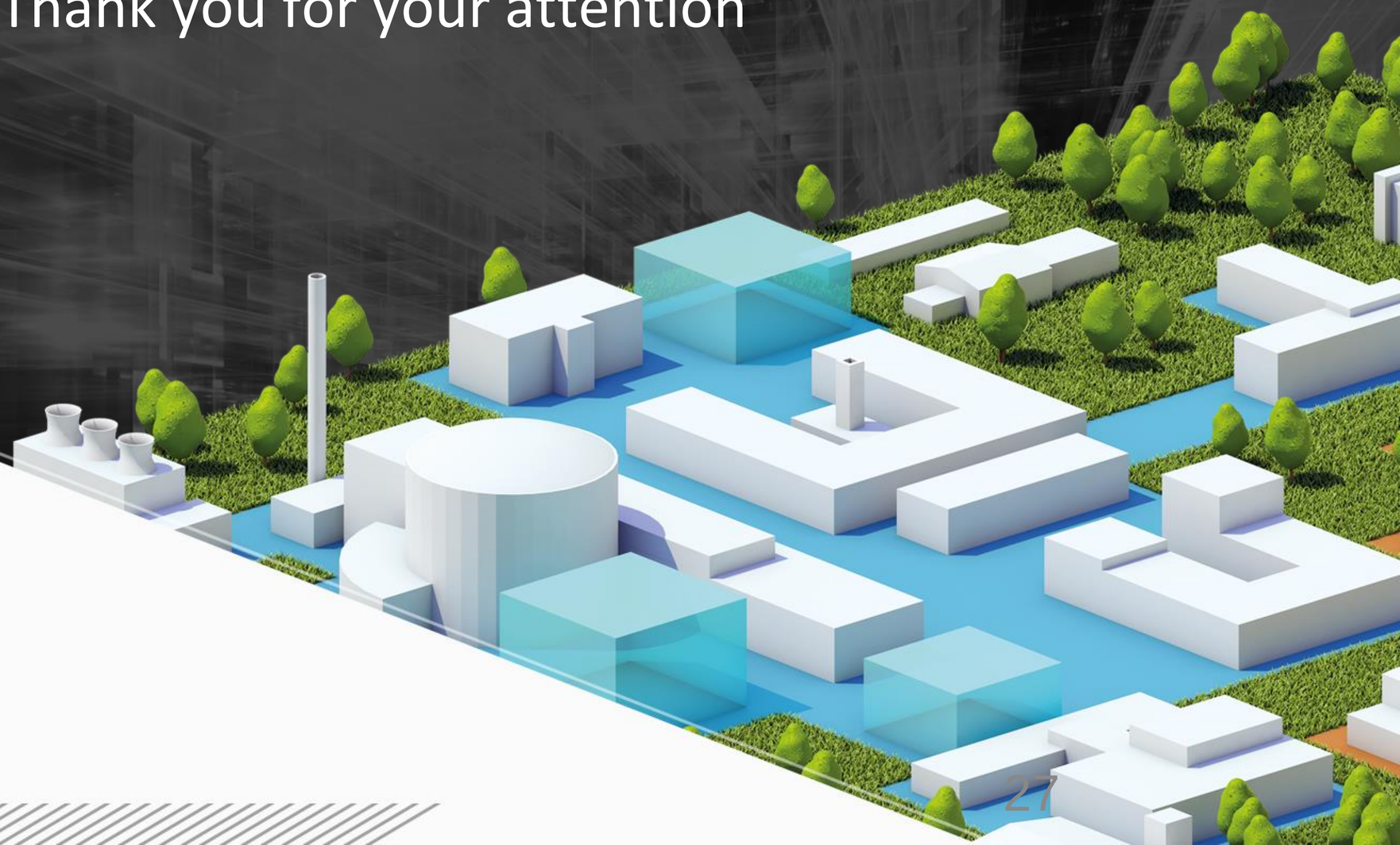
- The ALLEGRO Experimental Gas Cooled Fast Reactor Project, L. Belovsky, J. Gadó, B. Hatala and A. Vasile at the FR17 Conference, Yekaterinburg, June 2017
- ALLEGRO Gas-cooled Fast Reactor (GFR) demonstrator thermal hydraulic benchmark; Boris Kvizda a, Gusztáv Mayer, Petr Vácha, Janusz Malesa, Arkadiusz Siwiec, Alfredo Vasile, Slavomír Bebjak, Branislav Hatala; Nuclear Engineering and Design 345 (2019) 47–61

Thank you for your attention



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