



**(Project Number: 945 041)**

**DELIVERABLE D6.6**

**Final workshop report**

Lead Beneficiary: EVALION

Due date: 30/09/2024

Released on: 23/09/2024

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<b>For the Lead Beneficiary</b>	<b>Reviewed by Work package Leader</b>	<b>Approved by Coordinator</b>	
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Start date of project:

**01/10/2020**

Duration: **48 Months**

Project Coordinator Organisation:

**VUJE, a. s.**

VERSION: 1.1

<b>Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Horizon 2020 Programme</b>		
<b>Dissemination Level</b>		
<b>PU</b>	Public	<b>X</b>
<b>RE</b>	Restricted to a group specified by the Beneficiaries of the SafeG project	
<b>CO</b>	Confidential, only for Beneficiaries of the SafeG project	

### Version control table

Version number	Date of issue	Author(s)	Brief description of changes made
1.0	12/09/2024	Michaela Velckova	1 <sup>st</sup> draft
1.1	23/09/2024	Slavomir Bebjak	Review of 1 <sup>st</sup> draft Final version

### Project information

Project full title:	Safety of GFR through innovative materials, technologies and processes
Acronym:	SafeG
Funding scheme:	Research and innovation action
ECGA number:	945041
Programme and call	Horizon 2020 Framework Programme for Research and Innovation (2014-2020) NFRP-2019-2020 (Nuclear Fission and Radiation Protection Research)
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*„This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945041”.*

## **EXECUTIVE SUMMARY**

The [SafeG Final Worskhop](#) took place in Bratislava (Hotel Clarion) on 11<sup>th</sup> of September 2024. During the several hours the SafeG leaders and members participating at the various stages of the project presented the key result in area of GFR core and fuel design, GFR material, and safety-related R&D. SafeG members shared the outcomes of the educational and on-the-job training activities carried out within the project, along with the results of the SafeG benchmarking activities. The invitation was sent to various target groups with aim to reach widest expert community and researchers in nuclear field. The event was attended by 43 persons (in person) and 10 remotely connected.

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## 1 INTRODUCTION

The global objective of the SafeG project is to further develop the GFR technology and strengthen its safety. The project supported the development of nuclear low-CO<sub>2</sub> electricity and industrial process heat generation technology through the following main objectives:

- To strengthen safety of the GFR demonstrator ALLEGRO
- To review the GFR reference options in materials and technologies
- To adapt GFR safety to changing needs in electricity production worldwide
- To bring in students and young professionals, boosting interest in GFR research
- To deepen the collaboration with international non-EU research teams

Aim of the SafeG Final Workshop was to present how these goals were achieved and by what specific project activities, findings and deliverables. The audience was informed about advancements of the SafeG to the areas mentioned above, about produced reports, lessons learnt for further steps in development and research, as well as about current trends and possibilities in area of GFR development, materials, technologies and safety.

## 2 FINAL WORKSHOP STRUCTURE

The final workshop was structure to provide a complex overview of the main topics and results of our 4 years effort within the SafeG project implementation. According to the essential outcomes of the project, the workshop was divided among four most significant fields we have been working during the project period – GFR core and Fuel Design, GFR material R&D, Safety-related R&D and Education and Training.



<b>PROGRAM</b>
<b>08:45 – 09:00</b> Welcome to participants, possibility to connect to the meeting remotely
<b>09:00 – 09:30</b> Introduction
GFR technology and the SafeG project overview - Petr Vácha (UJV)
<b>09:30 - 10:15</b> GFR Core and Fuel Design
Improvements of refractory core design - Petra Pónya (EK)
<b>10:15 – 11:15</b> GFR material R&D
Material R&D done in the SafeG - Jana Kalivodová (CVR)
Advanced manufacturing process outcomes and next steps in the development of safety critical GFR components for ALLEGRO- Udisien Woy (USFD)
Needs for material standardization specific for GFRs – Petr Vácha (UJV)
Assessment of technology readiness level of GFR and R&D need - Nawal Prinja – Jacobs
<b>11:15 - 11:30</b> Coffee break
<b>11:30 – 12:20</b> Safety-related R&D
S-ALLEGRO experiments – Tomáš Melichar (CVR)
ALLEGRO core CFD simulations – Jan Komrska (UJV)
Nitrogen injection simulations - Boris Kvizda (VUJE)
<b>12:20- 13:00</b> Education and Training
SafeG Education and On-the-Job Training – Václav Dostál (CTU)
Results of the SafeG benchmarking activities – Boris Kvizda (VUJE)
<b>13:00 – 13:15</b> Final discussion
<b>13:15 - 14:00</b> Lunch (optional)

*Figure 1: Program of the SafeG Final Workshop*

## 2.1 Introduction

### 2.1.1 GRF Technology Overview

Presentation by Petr Vacha (UJV)

Presentation of WP4 leader Petr Vacha focused on introduction of the Gas-cooled fast reactor (GFR), its history and current research and design related to this type of reactor. The workshop audience got know information on ALLEGRO reactor design and design of selected main systems and components (core region, main cooling loops, decay heat removal system and containment).

### 2.1.2 SafeG project overview

Presentation by Boris Kvizda (VUJE)

The project coordinator Boris Kvizda (as well as WP3 leader) presented how the SafeG contributed to further develop the GFR technology and strengthen its safety. The presentation informed audience about general framework of the project, its objectives, period, involved partners and structure of the project activities. He presented the main goal of the project and by what project activities and results it was achieved during the project implementation.

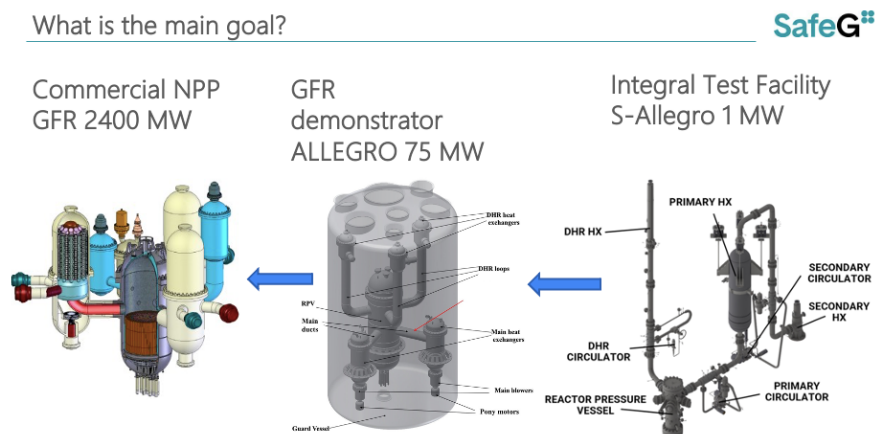


Figure 2: Main goal of the SafeG

## 2.2 GFR Core and Fuel Design

### 2.2.1 Improvements of refractory core design

Presentation by Petra Ponya (EK)

Petra Ponya from EK, as one of the main contributors to WP1 “Core safety, proliferation resistance”, presented an overview of refractory design with emphasis on:

*Refractory core optimization* (to fulfill safety criteria) – methodology, methodology of control and shutdown system, optimization processes and results;

*Reflector optimization* (to enhance efficiency of fuel utilization) - requirements of reflector materials, excess reactivity and peaking factors at BOC, assembly-wise power distribution, neutron spectrum of fuel assemblies, pin-wise power distribution,

*Shielding optimization* (to reduce radiation damage in RPV wall and reactor internals) - examination of potential shielding materials, examination of coolant channel arrangements.

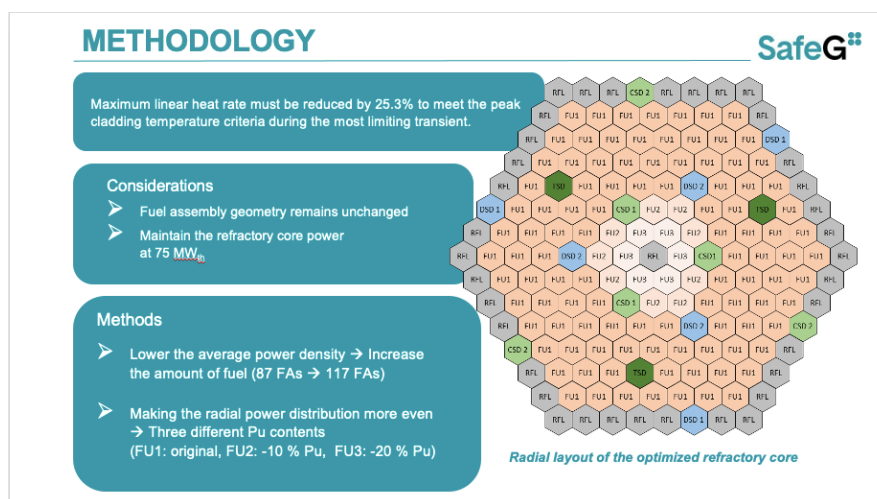


Figure 3: Methodology of refractory core optimization

## 2.3 GFR material R&D

### 2.3.1 Material R&D done in the SafeG

Presentation by Jana Kalivodova (CVR) – co-authors Udisen Woy (USFD), Jarosław Jasiński (NCBJ), Zoltán Hózer (EK), Tatsuya Hinoki (KU), Jan Berka (CVR)

WP2 leader Jana Kalivodová presented the main challenges in the GFR development on a level of fuel development and high-temperature materials. The special attention was given to following:

- *Fuel Development - High-Temperature Stability & Cladding Materials and Fast Neutron Environment*
- *High-Temperature Materials - Structural Materials and Thermal Fatigue and Creep*



Jana Kalivodova presented details on selected materials for HTGR systems, innovative cladding materials development & testing, innovative cladding material ODS material development and compatibility of materials with media in GFR conditions. Emphasis was given to an overview of Advanced manufacturing processes development made by partners involved in WP2 – National Centre For Nuclear Research (NCBJ) and University of Sheffield (USFD)- Outcomes of this activity was presented in detail in the next presentation by Udisen Woy.

### 2.3.2 Advanced manufacturing process outcomes and next steps in the development of safety critical GFR components for ALLEGRO

Presentation by Udisen Woy (USFD)

Presentation of Udisen Woy from USFD presented the main objectives of project activities related to the Task 2.3 “Advanced manufacturing processes”, and by what actions were achieved. The team connected with T2.3 focused on how to implement materials with better performance and processes with enhanced capabilities; basic characterisation studies to qualify and/ or quantify process suitability for design and construction of GFRs and additive manufacturing (AM) for critical parts fabrication. Her presentation gets informed on the SafeG advancement in area of material processing, material testing and feasibility demonstrator.

### 2.3.3 Needs for material standardization specific for GFRs

Presentation by Petr Vacha (UJV)

Petr Vacha presented general framework behind the needs for standardization and codes in the nuclear industry, especially in relation to GFR, and how were meet within the project. The presentation was focused on how to add new materials and processes into the code, ensuring validity of the data in the codes and topic of uncertainty and limitations of usage of the codified data.

#### Needs for standardization and codes in GFRs

- 3 major codes explored in SafeG:
  - AFCEN (RCC-M and RCC-MRx (Fr)
  - ASMEE III (USA)
  - R5 and R6 (UK)
- Generally, for GFR, there is a lack of high-temperature data for the materials
- Composite and ceramic materials (SiC and SiC composites) are not yet included in the codes
- GFR-specific areas – chemical and mechanical interactions, inspections of various components, effects of very hard fast spectrum – it's up to us, noone else going to do it
- Good thing – major similarities in needs with VHTRs

*Figure 4: Needs for standardization and codes in relation to GFRs*

### 2.3.4 Assessment of technology readiness level of GFR and R&D needs

Presentation by Nawal Prinja (JACOBS)

Presentation by the technology director of Jacobs Clean Energy Nawal Prinja informed the audience about various aspects of TRL on a level of benefits and limitations, assessment

method, TRL of GFR and remaining challenges and R&D needs. Special attention was given to process for applying TRLs and use of AI-powered cognitive search tool.

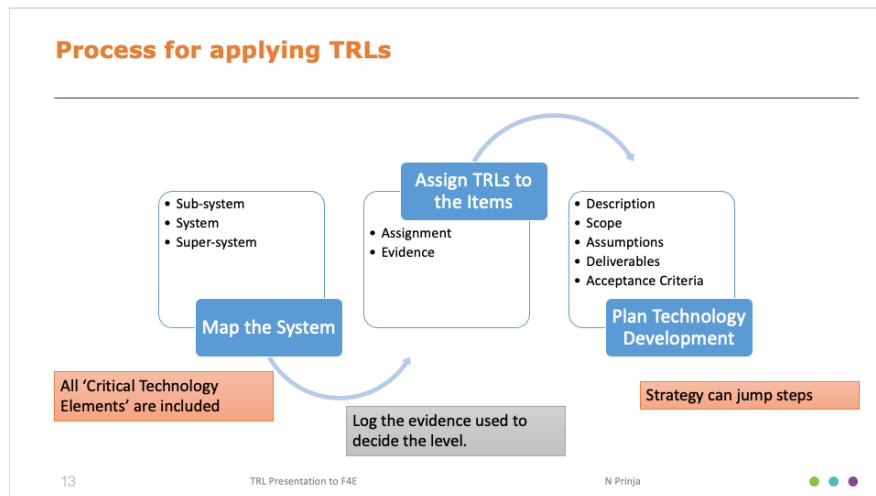


Figure 5: Example of applying TRLs in practise

## 2.4 Safety-related R&D

### 2.4.1 S-ALLEGRO experiments

Presentation by Tomas Melichar (CVR)

Tomas Melichar presented a detailed background of the S-Allegro, its layout with emphasis on loop design parameters, heating power and ability to simulate LOCA/LOFA and heavy gas injection. The S-Allegro experimental plan in relation to the structure of the SafeG activities was presented together with presentation on DHR loop operation, nitrogen injection and linked phenomenology and experiments for STH benchmarks.

#### S-Allegro Experiments - Motivation

- The large-scale experimental facility S-Allegro
  - Able to simulate thermal-hydraulic behavior of GFR reactor including passive decay heat removal (DHR) and accidental conditions
  - GFR-relevant conditions and layout
- Goals
  - To support assessment of safety functions of GFR system (WP3)
  - To produce data for validation of thermal-hydraulic codes and model (WP3)
  - To support education and training activity (STH benchmark) (WP5)



Figure 6: Presentation of experimental facility S-Allegro

### 2.4.2 ALLEGRO core CFD simulations

Presentation by Jan Komrska (UJV) – co-authors Václav Železný (CTU), Pavel Záchá (CTU)

Presentation by UJV member Jan Komrska informed audience on details of ALLEGRO Core CFD Simulations with focus on Models of individual sub-assemblies. Further, a model preparation strategy – CFD Simulation of Core Cooling LOFAs – was presented with link to the simplified model of core and models of individual sub-assemblies.

### 2.4.3 Nitrogen injection simulations

Presentation by Boris Kvizda (VUJE)

The project coordinator Boris Kvizda from VUJE presented the main conclusions and aspects connected with the nitrogen injection simulations with a special attention to:

- ALLEGRO 75 MW general layout and arrangement
- ALLEGRO TH model
- Initiating event selection
- Phenomena identification and selection of relevant inputs
- TH simulations
- Design change proposal and comparison with reference solution
- CFD simulations on injection line positioning

## 2.5 Education and Training

### 2.5.1 Education and On-job Training Activities of the SafeG

Presentation by Vaclav Dostal (CTU)


The SafeG aimed to involve current students in solving of actual cutting-edge research problems and to attract new students by offering interesting doctoral and masters theses with a clear connection to application of their results. Presentation by Vaclav Dostal from Czech Technical University offered an overview how the SafeG contributed to these goals and by what specific actions and events. Audience was informed about realization of the SafeG GFR summer school organized by CVR in Prague in summer 2022, about SafeG Workshop on advance modelling techniques organized by UCAM in Cambridge in summer 2023, as well as thermal-hydraulics benchmark focused on Ph. D. students and young professionals that was presented in the next presentation by Boris Kvizda (2.5.2). The presentation also showed a successful result in area of exchange students between universities involved in the SafeG and diploma theses connected to the project.

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### GFR Summer School

- Technical tours to multiple CVR experimental facilities such as:
  - Experimental nuclear reactor
  - HTHL loop
  - S-Allegro loop
  - HELCZA



*Figure 7: Participant of the GFR Summer School in Prague*

### 2.5.2 Results of the SafeG benchmarking activities

Presentation by Boris Kvizda (VUJE)

Boris Kvidza presented results of the thermal hydraulic benchmark on S-Allegro ITF and CFD benchmark on PIROUETTE facility. The presentation informed about specific aspects of S-Allegro Integral Test Facility (ITF), TH model development and validation, steady state TH calculations, on-transient TH calculations, flow Straightener CFD analyses and Rod Bundle CFD analyses.

### 3 IMPACT AND AUDIENCE OUTREACH

In order to maximize participation, an invitation for the SafeG Final Workshop was extended to several target group, especially to:

- Students and young researchers in nuclear field with aim to attract them to topic of GFR – done by personal contacts by the SafeG partners, direct email invitation, website, promotion on LinkedIn
- Nuclear research community with aim of increasing interest of GRF and related topics – done by personal contacts by the SafeG partners, direct email invitation, website, promotion on LinkedIn
- Members of linked initiatives and networks with goal to promote concrete project results and findings – V4G4, Generation IV Forum, ESNII - by personal contacts by the SafeG partners, website, promotion on LinkedIn, direct email invitation

The event was promoted at the project website within the webpage section [Events](#). The workshop was promoted at LinkedIn profile of the SafeG project for several times with offer of free registration and online connection.

<https://www.linkedin.com/feed/update/urn:li:activity:7236994755388219392>

The SafeG workshop was promoted also after the event as follows:

<https://www.linkedin.com/feed/update/urn:li:activity:7239617655467356162>

<https://www.linkedin.com/feed/update/urn:li:activity:7239563677102665728>

The event was attended by 43 participants in person and 10 remotely connected. The attachment of this report is presence list of attendees, as well as list of persons who joined us online.



*Figure 8: Participants of the SafeG Final Workshop*





*Figure 9: Participants of the SafeG Final Workshop*

The event gave an opportunity to gain general knowledge of current status of research and development related to GFR. The participants were informed about advancements of the SafeG to the field of GFR development, technology and safety. Audience got know information on improvements of GFR refractory core and fuel design, GFR materials and advanced manufacturing process outcomes in the development of safety of the GFR or needs for material standardization specific for GFRs. The speakers presented details on S-Allegro experiments, ALLEGRO core CFD and nitrogen injection simulations. The event presented successful education and training activities and events.

## **4 CONCLUSIONS**

The aim of SafeG Final Workshop was to present the key results and outcomes of our 4 years effort within the SafeG project to nuclear community and young generation of researchers. The event took place on 11<sup>th</sup> of September, 2024 in Bratislava and was attended by 43 participants (+ 10 remotely connected). Audience was informed about essential findings and conclusions of the project on a level of GFR Core and Fuel Design, GFR material R&D, Safety-related R&D and Education and Training.

## 5 ANNEX 1.

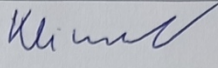
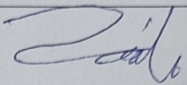
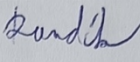
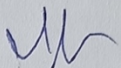
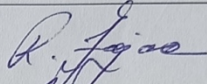
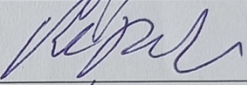
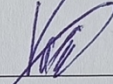
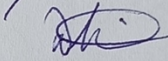
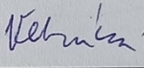
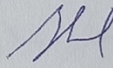
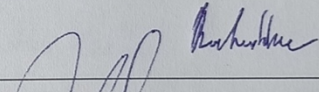
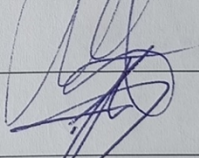
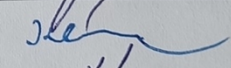
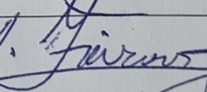
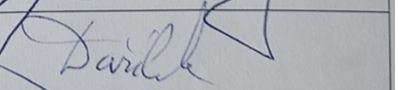
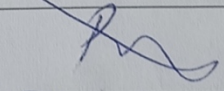
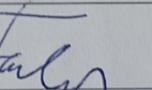
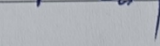


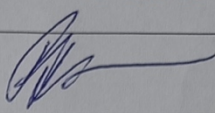
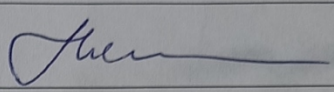
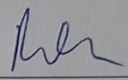
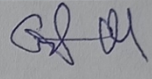
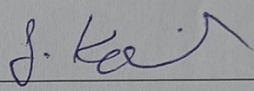
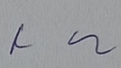
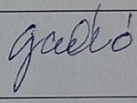
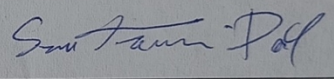
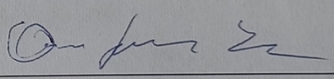
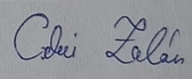
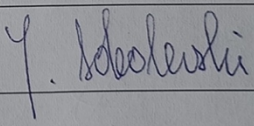
### SafeG Final Workshop Presence list

**Date:** 11/09/2024  
**Event:** SafeG Final Workshop  
**Venue:** Hotel Clarion, Bratislava

Name	Institute/Company	Signature
Boris Kvizda	VUJE	
Slavomír Bebjak	VUJE	
Gusztav Mayer	EK	
Zsombor Bali	EK	
Martina Neštická	VUJE	
Nawal Prinja	JACOBS	
Gerd Brinkmann	BriVaTech	
Michaela Velčková	EVALION	
Vladimír Slugeň	STU	
Tomasz Stasiak	NCBJ	T. Stasiak
Jaroslav Jasinski	NCBJ	Jaroslav Jasinski
Udi Woy	USFD	Udi Woy
Jakub Heller	EVALION	
Congjin Ding	UCAM	Congjin Ding
Jan Komrska	UJV	



Tomas Kliment	VUJE	
Pavel Zacha	CVUT	
Marek Randik	VUJE	
Tomáš Melichar	CVR	
Radoslav Zajac	VUJE	
Vaclav Dostal	CVUT	
Petr Vacha	UJV	
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