workshop 64
European forum for nuclear codes

Thoughts on Qualification & CEN WS 064 Design and Construction Codes for Gen II to IV nuclear facilities

PG2 Mechanical Components Innovative Reactors

16th of November 2023

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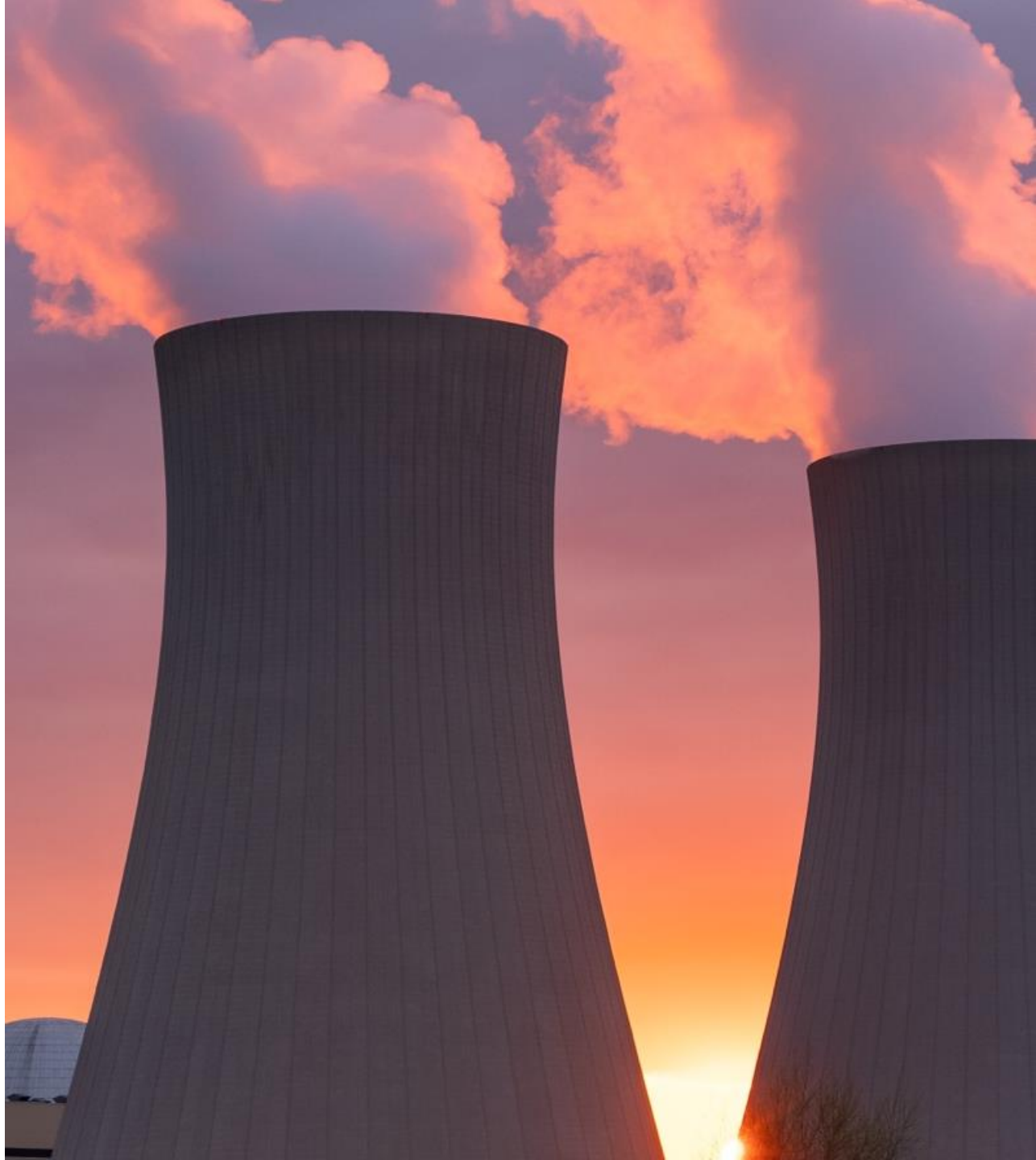


Materials & Components : From idea to product

10 – 20 years

Development

Qualification

10 – 20 years

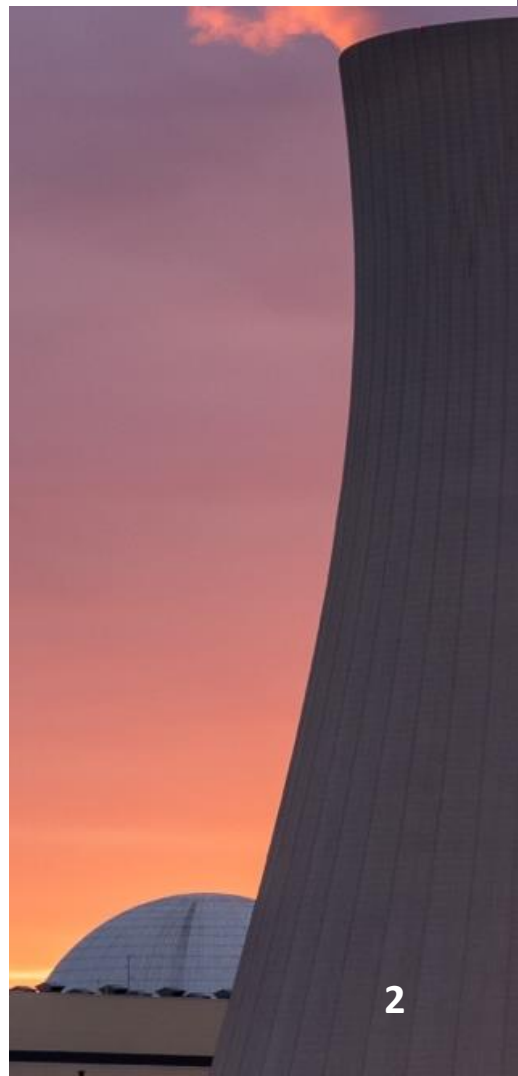
Demonstration

Deployment

IAEA definiton: ”A qualification programme for items important to safety shall be implemented to **verify** that **items important to safety a**t a nuclear power plant are capable of **performing their intended functions** when necessary, and in the **prevailing environmental conditions, throughout their design life**, with due account taken of plant conditions during maintenance and testing.”

Qualification: process do demonstrate that a material/component is fit-for-purpose

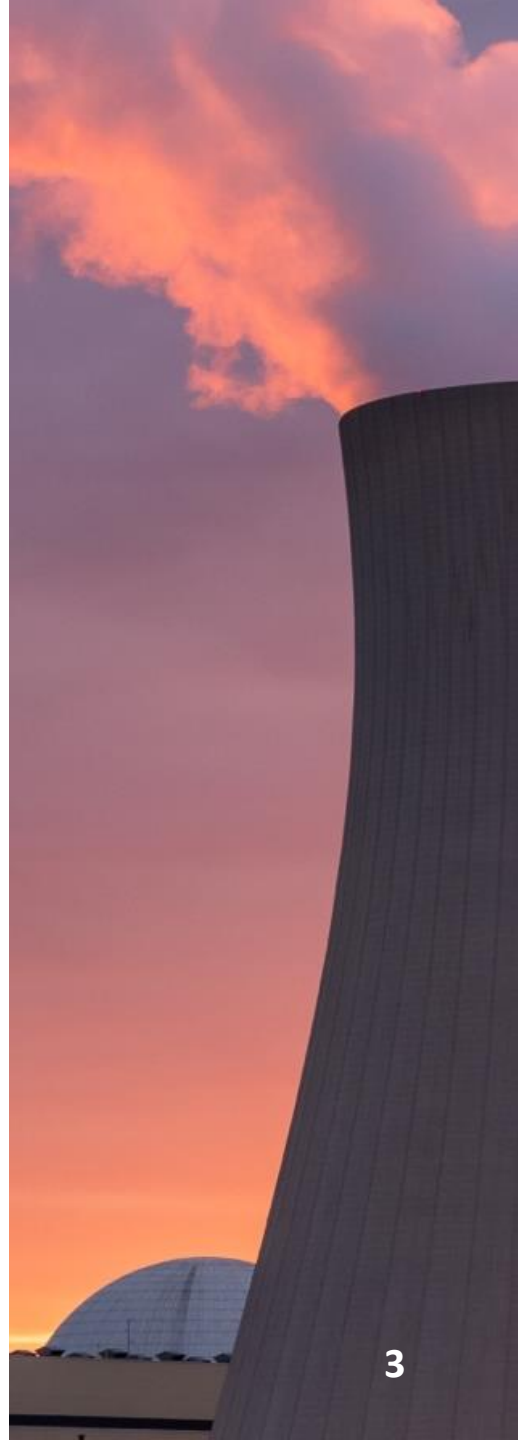
The key is to reduce the time from development to deployment, in particular accelerated qualification 20 → 5 years?



Qualification is closely linked to national regulation

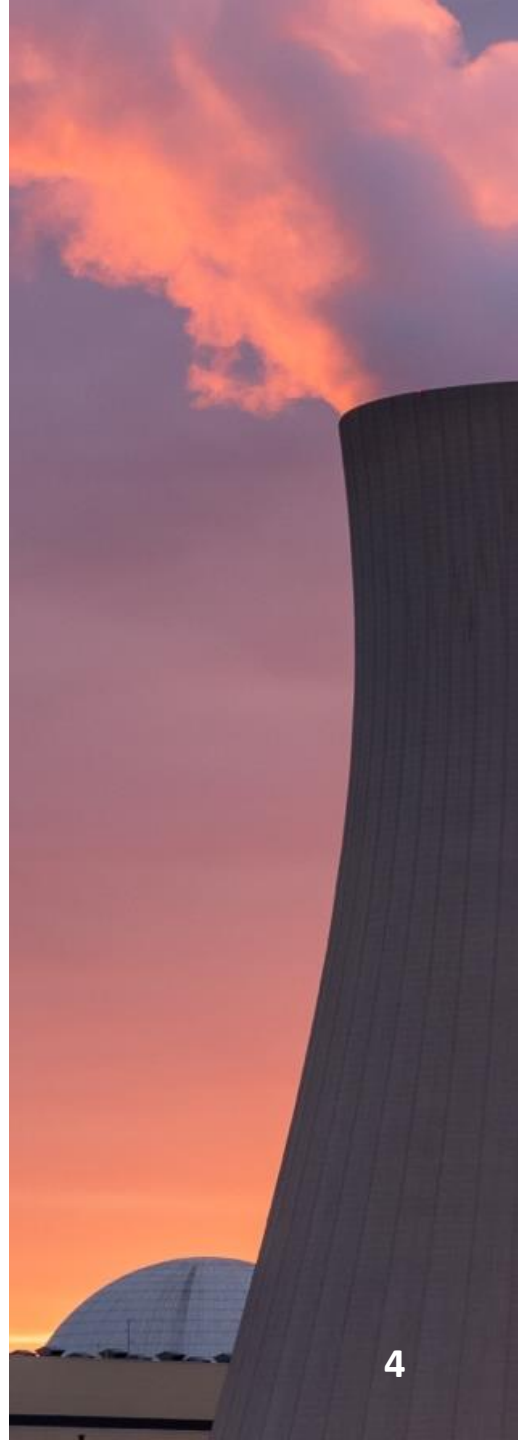
- Prescriptive : Follow Design Codes & Standards
- Performance-based -> up to licensee to justify fit-for-purpose

- Deterministic (typically for prescriptive)
- Probabilistic (more likely for performance-based)

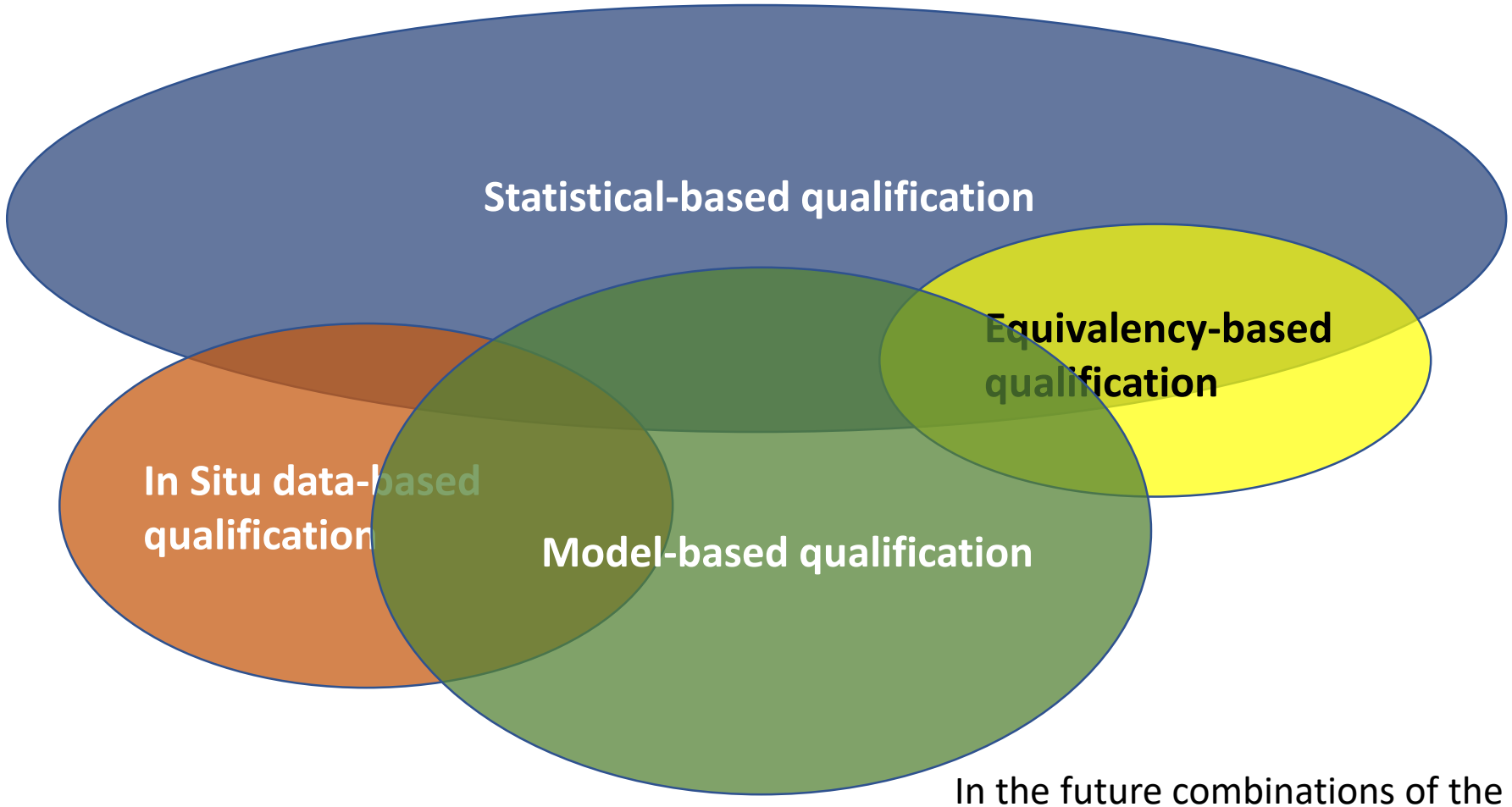


Qualification Approaches

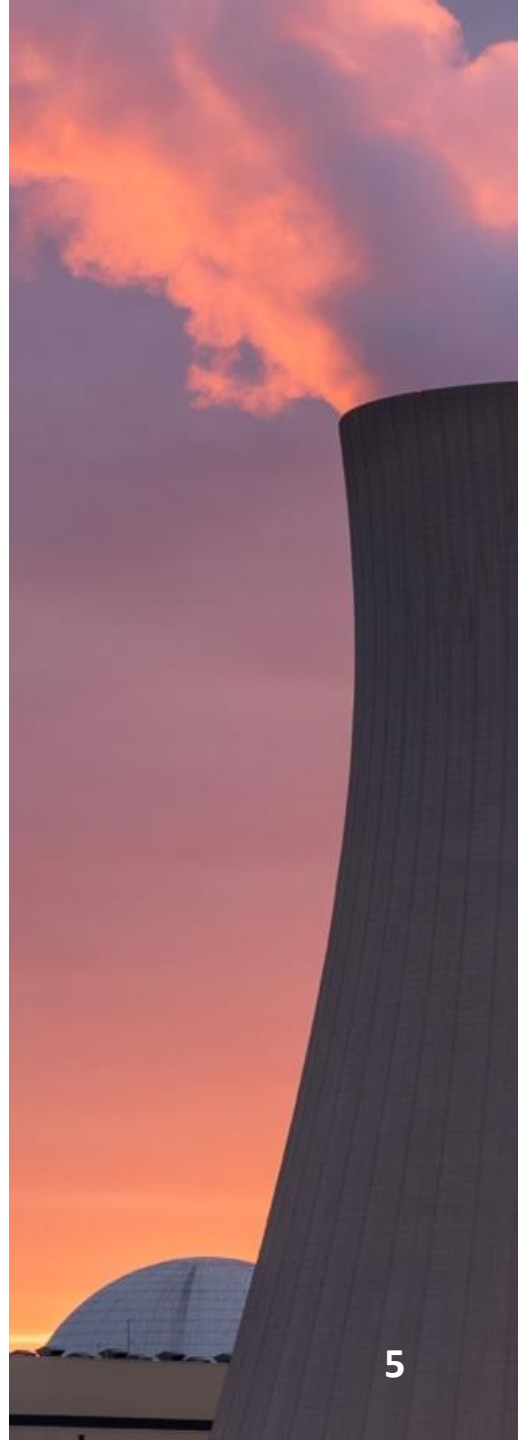
1. **Statistical-based qualification**
   - Extensive testing and empirical modelling; uncertainty mitigated by massive testing; questionable for large variability and low volumes, it is also time-consuming
2. **Equivalency-based qualification**
   - Demonstrate that a new material is equivalent to an already qualified material or process; existing material in a new environment equivalent to already qualified environment
3. **In Situ data-based qualification**
   - Relies on in-situ measurement data usually in connection with data-driven modelling & simulation
4. **Model-based qualification**
   - Computer-based modelling, data-driven and physics-based with a smaller amount of tailored testing and advanced material characterization; validation & verification of models; can provide quantitative understanding of processing-structure—property-performance.



Qualification Approaches



In the future combinations of the approaches will be applied depending on the specific case

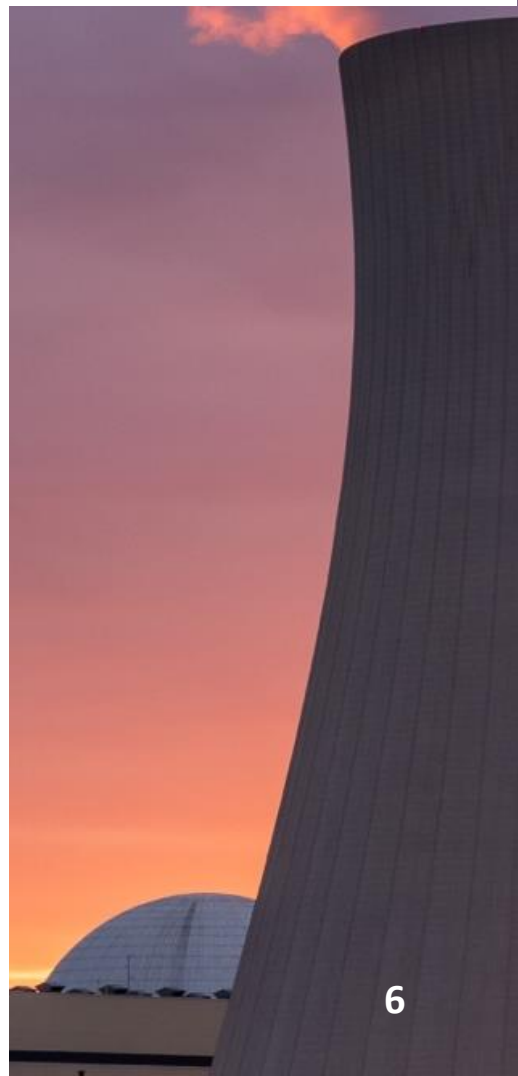


What are CEN workshop 64 objectives ?

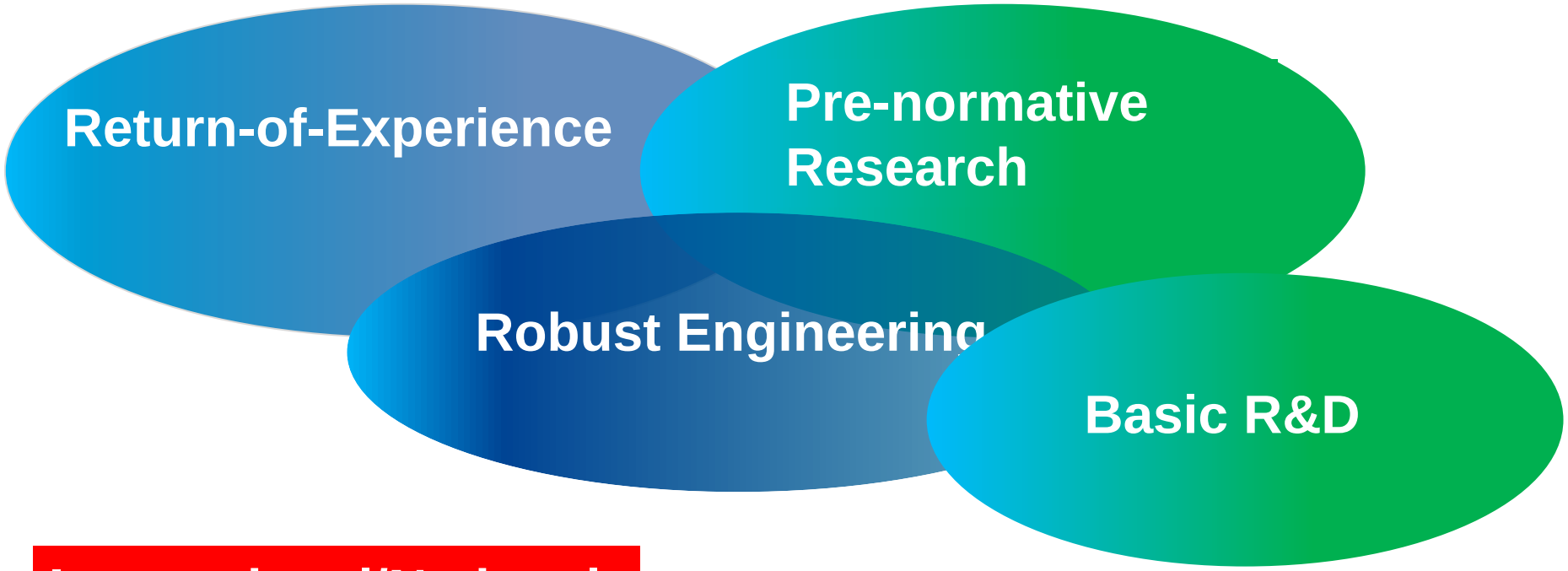
High level Goals

- **Promoting access to good industrial practices** for stakeholders from countries developing nuclear facilities,
- **Reducing the fragmentation** at European level of good industrial practices in the nuclear field **to improve the competitiveness** of the European nuclear industry,
- Favoring conditions for the **harmonisation** of codes and national regulations at European level…

Create a community of European nuclear codes experts



Basis & Targets for Nuclear Design Codes



International/National Standards

IAEA Safety Standards Safety of Nuclear Power Plants: Design Specific Safety Requirements No. SSR-2/1

4.16. Where an unproven design or feature is introduced or where there is a departure from an established engineering practice, safety shall be demonstrated by means of appropriate supporting research programmes, performance tests with specific acceptance criteria or the examination of operating experience from other relevant applications.

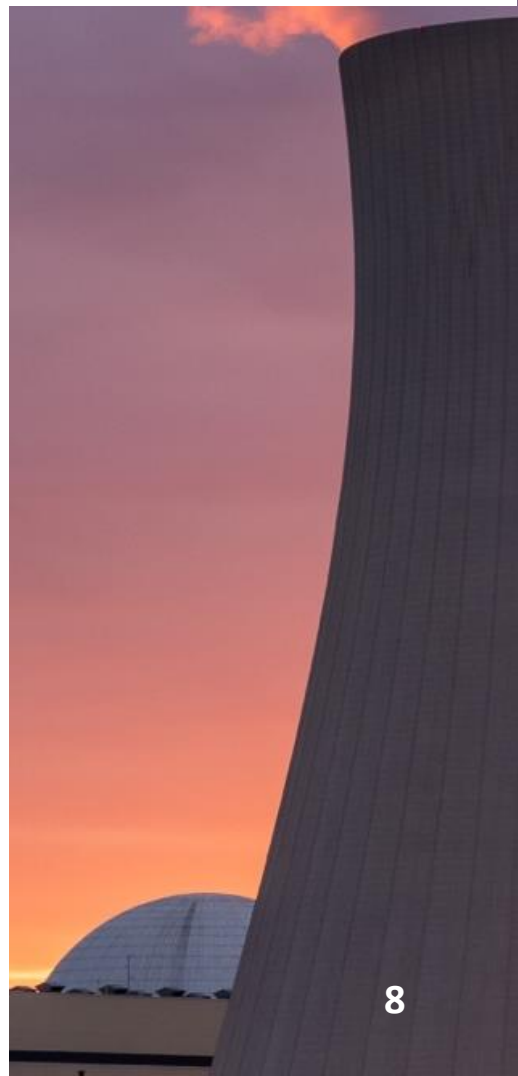
What is a CEN Workshop ?

a «project» which aims to develop best-practice recommendations in a specific area

- **Flexible** working platform:
  - Light procedures
  - **Direct and voluntary participation of stakeholders**
- **Open** to any company or organization:
  - **Inside or outside Europe**
- **Rapid** elaboration of **documents**
  - Few physical meetings
  - Work by electronic means encouraged

At the end of the workshop, a CEN WORKSHOP AGREEMENT (CWA) is published by CEN.
This document contains the recommendations from the WORKSHOP,

workshop 64
European forum for nuclear codes



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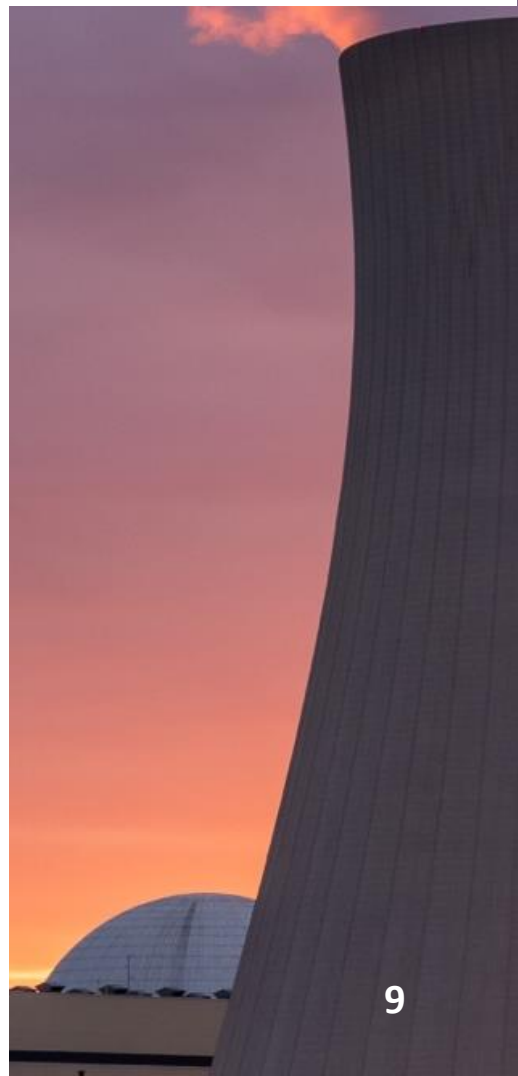
What are workshop 64 objectives ?

In practice

- Common forum for engineers, designers, manufacturers, regulators, scientists
- Propose Code Evolutions for RCC-MRx
- Propose supporting pre-normative research activities

But also

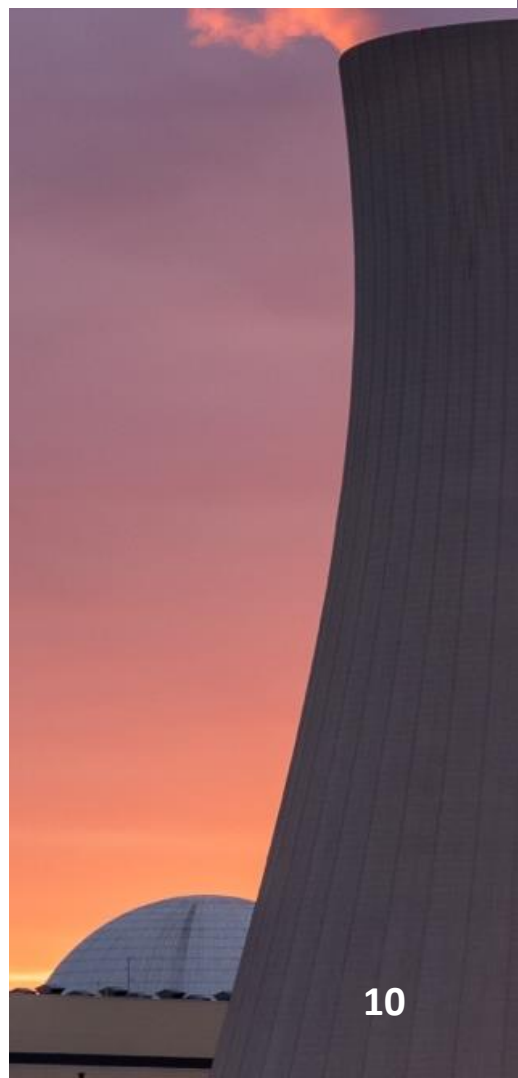
- Review & Assess Codes & Standards
- Develop Guidelines



Who is it for?

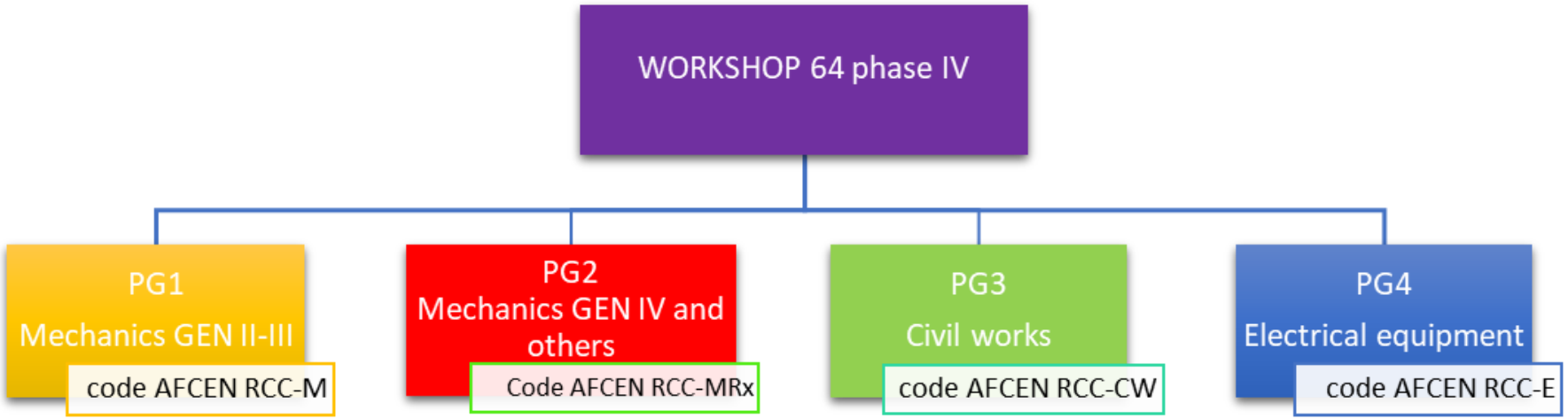
- **Safety Authorities and Technical Support Organisations**
  compare standards/codes used for designing and manufacturing new nuclear reactor projects.
- **Utilities**
  integrate your needs into a set of requirements and rules proposed as a European reference, to expand your suppliers' base for spare parts designing and manufacturing
- **Manufacturers**
  integrate your industrial practices into a set of requirements and rules with European reach, to expand the market for your products.
- **R&D organizations**
  Industrial feedback and support pre-normative research

people involved in an evaluation process of different types of reactors, in particular during the bid process.



What is the WS 64 organisation

- **4 specialised technical groups,** so-called “Prospective Groups (PG)”, in charge of elaborating recommendation proposals
- Each PG has a convener who leads its works and an **AFCEN correspondent**
- **The Workshop appoints a Secretariat** that manages the logistics and documentary aspects of the work



PG2 Proposals:
Phase 1: 30 Code Evolution 0 R&D
Phase 2: 6 Code Evolution 6 R&D
Phase 3: 10 Code Evolution 1 R&D

CEN Workshop 64 process

AFCEN codes

Needs of the Stakeholders

BRAINSTORMING
Identification and prioritization of Code Evolution and R&D needs (all partners) → identify topics

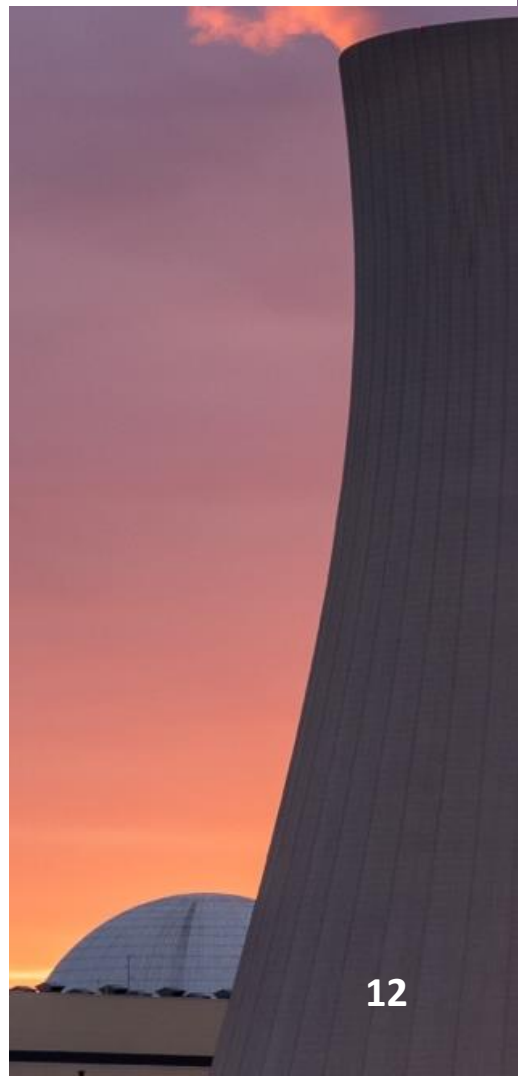
Discusssion & evaluation of identified topic
Usually lead by the proposer

CODE EVOLUTION PROPOSAL
- Prepared by PG expert
- Discussion (all)

R&D PROPOSAL
- Prepared by PG expert
- Discussion (all)

CE PROPOSAL SENT TO AFCEN
- AFCEN Feedback

R&D PROPOSAL SENT TO DG-RTD



SUMMARY OF CODE EVOLUTION PROPOSALS PHASE 2

	Proposal	Status
PG2/CE-01	"Use of the code in innovative coolant environment"	RCC-MRx 2018, DMRx 16-037, RPP 14
PG2/CE-02	“Consistent methodology for assessment of negligible creep curves”	Awaits publication of 13445, DMRxx 10-020, partially RCC-MRx 2022, DMRx 22-003
PG2/CE-03	“Extension of Temperature range for Mechanical Properties of Specific Materials in RCC-MRx“	Identified for 2025
PG2/CE-04	“Extension of creep strain and rupture data range for austenitic steelin RCC-MRx”	Not addressed yet, awaiting experts
PG2/CE-05	“Multiaxial Tube sheet Analysis”	Not addressed yet, awaiting experts
PG2/CE-06	“Re-introduction of 304LN SS in RCC-MRx”	RCC-MRx 2022, DMRx-19-030, RPP 18

SUMMARY OF R&D PROPOSALS PHASE 2

	Proposal	Status
PG2/RD-01	“Development of Design Rules and Characterisation of Material Behaviour in Heavy Liquid Metal (HLM) Environments”	EURATOM Project GEMMA
PG2/RD-02	“Methodology for the design and life-assessment of components exposed to 60 years' service-life”	JPNM Project DesignLife60+, ECCC project
PG2/RD-03	“Irradiated Characteristic for Advanced Reactor in Upset and Safety State”	
PG2/RD-04	“Optimal weld design of 316 type steels for enhanced creep-fatigue endurance”	
PG2/RD-05	“Creep/relaxation, creep-fatigue damage and their successful modelling for design rules application”	
PG2/RD-06	“Protective Coatings and Surface Alloys against corrosion in components working in Heavy Liquid Metal (HLM) Environments	EURATOM project : GEMMA, INNUMAT

SUMMARY OF CODE EVOLUTION PROPOSALS PHASE 3

	Proposal	Status
PG2/R&D-01	USING the small punch test techniques in support of material development and in-service life management	Partially implemented in R&D projects
PG2/CE-01	“Creep Fatigue rule for cyclic softening material”	Approved by AFCEN. It is included in the 2022 edition as probationary Phase rule n°19: RPP19-2022-RB3262 (DMRx 20-033)
PG2/CE-02	“Small Punch testing for material properties screening and in-service inspection Appendix 20”	Approved by AFCEN. It is included in the 2022 edition as probationary Phase rule n°20: RPP20-2022-SPT – Part 2 (DMRx 20-070)
PG2/CE-03	“Incorporation of ASME NQA-1 Nuclear Quality Assurance”	PG2/CE-03: “Incorporation of ASME NQA-1 Nuclear Quality Assurance” Approved by AFCEN. It is included in the 2022 edition in section II REC part: REC 4000 Special instructions for equipment subject to NQA-1 applied to a European facility (DMRx 20-071)
PG2/CE-04	" RB 2000 Materials Inclusion of Small Punch Test for material Selection"	Approved by AFCEN. It is included in the 2022 edition as probationary Phase rule n°20: RPP20-2022-SPT – Part 1 (DMRx 21-046)

SUMMARY OF CODE EVOLUTION PROPOSALS PHASE 3

	Proposal	Status
PG2/CE-05	" Incorporation of solid wire material 18Cr-12Ni-2Mo for Tungsten Inert Gas (TIG) welding process"	Approved by AFCEN. . It is included in the 2022 edition : Section III – Tome 4 – RS 2712.1 (DMRx 21-017)
PG2/CE-06	"Incorporation of 19Cr-12Ni-9Mo filler material properties for Tungsten Inert Gas (TIG) welding process"	Approved by AFCEN. . It is included in the 2022 edition : Section III – Tome 4 – RS 2712.1 (DMRx 21-017)
PG2/CE-07	"Incorporation of 19Cr-12Ni-9Mo filler material properties for Tungsten Inert Gas (TIG) welding process"	Approved by AFCEN. Work program for the 2025 edition
PG2/CE-08	"Inclusion Fracture Toughness A3.1S and A33S and revision of fracture toughness A9.J1S and A9.J3S"	Approved by AFCEN. Work program for the 2025 edition
PG2/CE-09	" Incorporation of more detailed specifications for the Dimensional Stability Heat Treatment (DSHT)"	Approved by AFCEN. It is included in the work program for the 2025 edition
PG2/CE-10	Guide for introducing a new material in the RCC-MRx Appendix A3 and Appendix A9 of the RCC-MRx	Approved by AFCEN. To be edited in 2023.

EXAMPLE LFR PHASE -2

RPP14-2018-RDG2320 Guidelines for innovative coolants

- Code Evolution Proposal

RDG 2321 **Use of the Code in innovative coolant environment**

The operator (Prime Contractor) should follow the recommendations hereafter in order to insure structural integrity under operating conditions (mainly coolant chemistry):

1. The chosen material, in the chemistry controlled coolant, has the same behavior as in air except for the depletion of the corrosion allowance,
2. All failure modes inside or outside of the design Code shall be identified and addressed,
3. Flaws, local corrosion and local thinning will be detected before defects become critical(*), assuming a limited corrosion speed,
4. The requested coolant parameters (composition, pressure, temperature, circulation speed…) will be satisfied all over the systems,
5. Failure of the chemistry control system that could cause high speed corrosion is detected and the grace time is sufficient to take corrective action.

These are satisfied including accepted and probable variations of both structural material and coolant.

(*) *Critical*, here means: will impede a safety function when needed for the considered events even just before end of life or before next inspection.

PHASE 3: DISCUSSED & PHASE 4 ISSUES

Faster Qualification & Codification of materials*

- Existing materials in new environments, e.g. lead, molten salt
- Advanced manufacturing, e.g. additive manufacturing 316L
- Innovative materials solutions, e.g. AFA steel

*** In particular long-term, slow processes: creep, creep-fatigue, irradiation, thermal ageing**

Digitalization

- AI, machine learning,
- Data management…

DISCUSSED & PHASE 4 ISSUES

Accelerated testing

- "Design of Experiments"
- Miniature testing
- Accelerated tests
- Modelling (engineering, physics-based & data driven)

Small & Advanced Modular Reactors

- Increases importance for standardization & codes but what are the specific issues?

DISCUSSED & PHASE 4 ISSUES

Other issues

- Welded Joints (never ending story……..)
- Irradiation & Non-Ductile design (fusion)
- Creep Design Methodology
- Code Evolution in support of GFR & (V)HTR

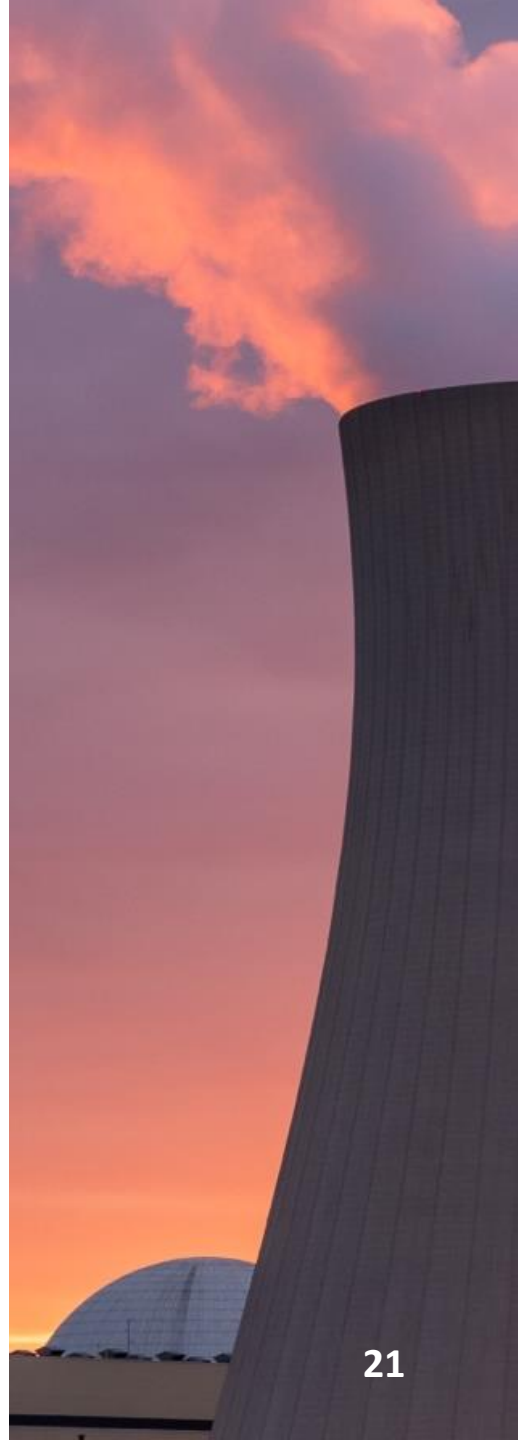
Active Members of PG2 – Phase 4

R&D	Industry	SME
CEA (F)	EDF R&D (F)	Thorizon (NL), MSR
JRC (Int)	JACOBS (UK)	NAAREA (F), MSR
ENEA (I)	UJV (Cz)	DAES (CH), design
SCK CEN (B)	TRACTEBEL (B)	Stellaria-energy (F), MSR
NCBJ (PL)	ENSA (E)	NewCleo (I), LFR
CIEMAT (E)	Framatome (F)	Renaissance Fusion (F)
KIT (D)	CORDEL* (Int)	
Coventry U. (UK)	AFCEN** (F/Int)	

ANSALDO (I)?

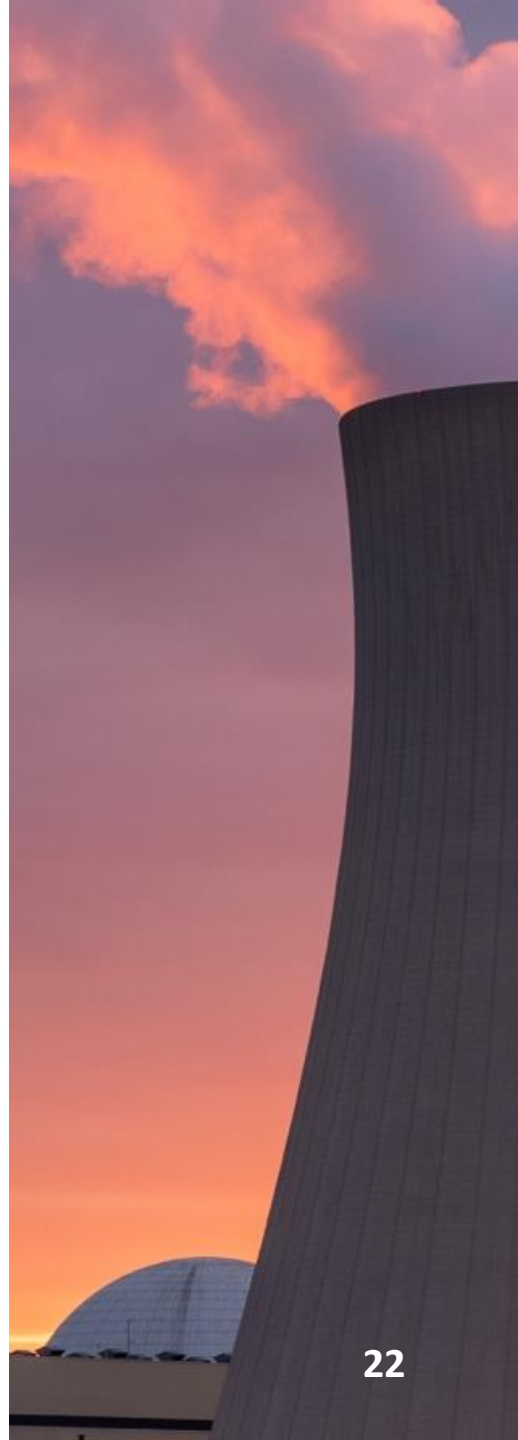
MOLTENFLEX (UK), MSR?
LEADCOLD (SE), LFR?
Marvel Fusion (D)??
DTU (DK)?
Copenhagen Atomics (DK) MSR?
Seaborg (DK), MSR?

Convener: K-F Nilsson (JRC)
AFCEN expert: Cécile Pétesch (CEA)



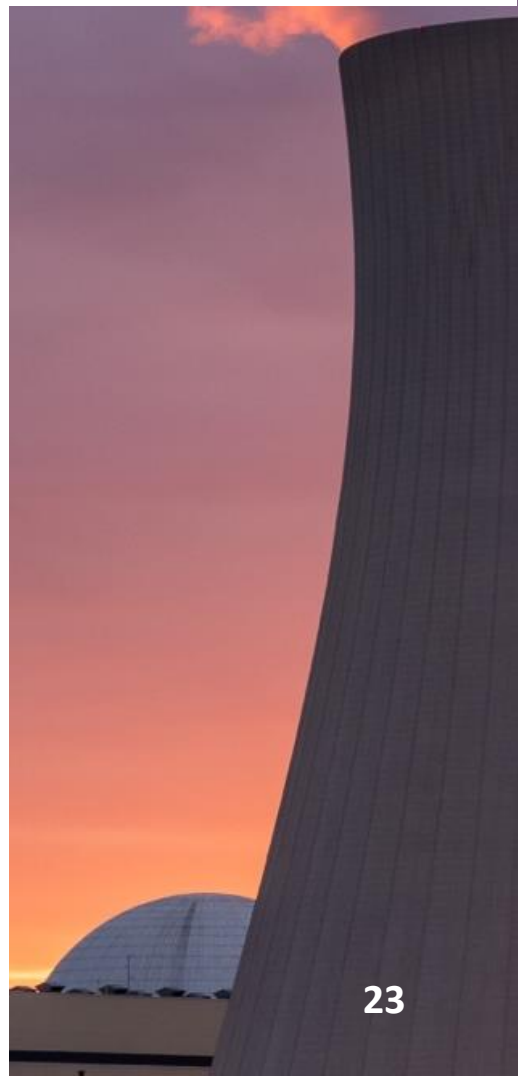
Actions from Kick-off (October 4) to be discussed next meeting (December 4)

	Topic	Responsible and date
1.4	Discussions on MSR, based on GIF report, which is prepared for AI use. Ideas for activities. For efficiency, it would be advantageous if the MSR designers could coordinate their input in advance.	N. Prinja circulates the GIF-MSR AI document. The MSR designers provide feedback and provides ideas. At next meeting.
1.5	Presentation of 15-15Ti of existing data and how this can be introduced in the code	S. Holmström (existing data), C. Petèsch (introducing into the code). At next meeting.
1.6	Case Study on use of AI to fill gaps in code data 316L(N) and CuCrZr.	Nawal Prinja and C. Petesch. At next meeting.
1.7	LFR - Outcome of GEMMA. Where do we stand? and way forward towards LFR qualification	K-F Nilsson, S. Bassani, J. Aktaa. At next meeting.
1.8	Presentation of RR on small punch test and invitation to attend.	S. Holmström At next meeting.
1.9	Review Probationary Rule innovative coolant to full code.	T. Lebarbé, but feedback from all. At next meeting.
1.10	Presentation of ASME activities on ceramics and composites.	P. James. At next meeting.
1.11	Preparatory work on ceramics and composites. Form a small group .	W. Schoenmaker organizes the group and presents outcome. At next meeting.
1.12	Report on the status of HARMONISE project	K-F Nilsson, L. Allais or C. Petesch. At next meeting.



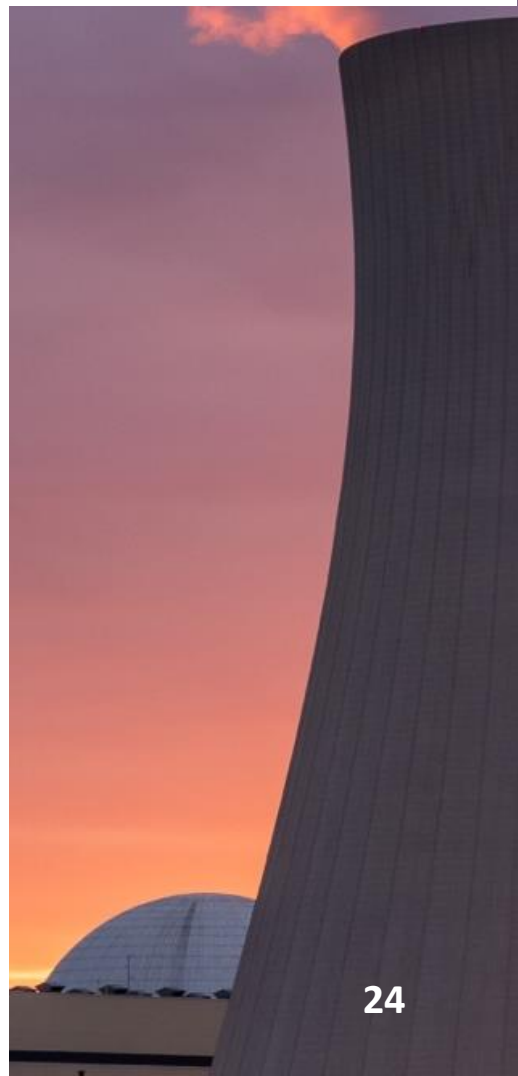
Practical information

- **Phase IV duration :** 4 years from mid-2023 to mid-2026
- **3-4 PG meetings** per year,
- **Plenary meeting** per year (not for 2023)
- PG2 secretariat provided by : **Djida LAOUBI**
  djida.laoubi@afnor.org



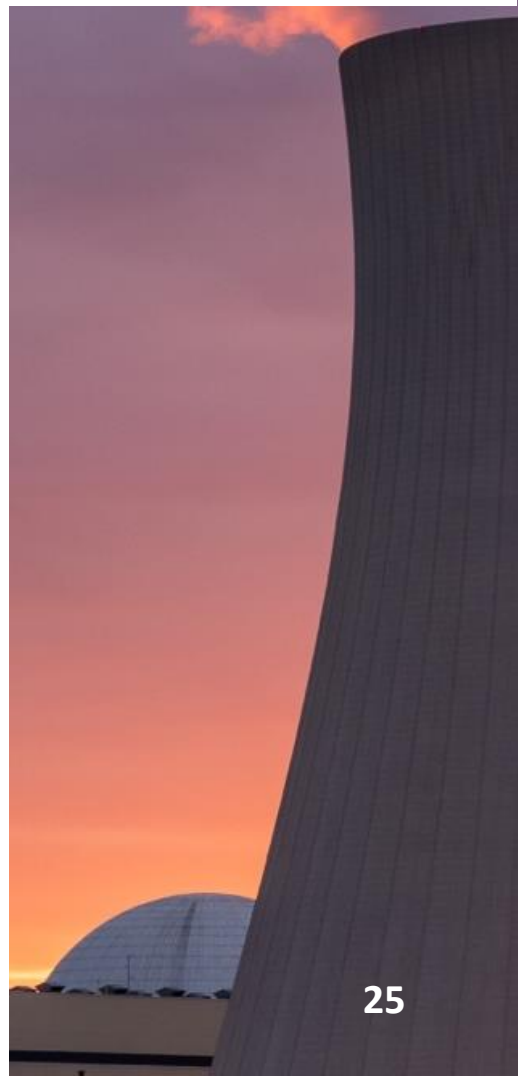
Practical information : contract

- **Fee participation :** 2000 € per year and per PG (
  - fixed amount for the whole of Phase IV,
  - no multi-year commitment,
  - to cover secretarial costs (AFCEN covering the remaining costs)



Practical information : supply of AFCEN code

- **Supply of AFCEN** code to WS64 participants is only for WS64 use (mark version)
- RCC-MRx (2022 English version) will be sent by MFT:
  - after receipt of the signed contract
  - To people appearing on WS64 registration form (nominating experts that are involved)



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THANK YOU FOR YOUR ATTENTION

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