Advanced Manufacturing and Materials Engineering Working Group (AMME-WG)

Karl-Fredrik Nilsson

INNUMAT Workshop on Qualification
16-17 November 2023, Madrid Spain

GIF-AMME Objectives

Promote the use of advanced manufacturing and materials engineering technology to reduce the time to deployment of advanced reactor systems.

Specifically, the WG aims to promote international collaboration on the qualification of advanced materials and manufacturing processes for use in Generation IV reactors.

| 2019 Industry Survey | Feb 2020 Advanced Manufacturing Workshop | 2021 Revised TF Terms of Reference | April 2021 2nd Industry Survey | Nov 2021 Modeling and Simulation Workshop | June 2022 Qualification Workshop (Invited) | Oct 2022 Workshop @ GEN IV Industry Forum |

- Pursuing collaborative R&D opportunities (59%)
- Support for workshops (87%)

- >70 Delegates
- Private Sector
- SMR vendors
- Suppliers
- Regulators
- Researchers

- Requirements Capture
- Qualification, Demonstration & Deployment
- Design and Modelling

Very High Need:
- Reactor vessels & internals (42%)
- Heat transfer (30%)

Support efforts on:
- Codes & Standards
- Regulatory approvals

Materials Highest Priority:
- SS 38%
- Low Alloy Steel 24%
- Ni alloys 20%
- Ceramics & Fuel 16%
- Zr Alloys 2%

AM techniques:
- Adv welding processes
- PBF
- DED
- Coating deposition
- PM-HIP
- Cold/hot spray

↑ Establishing & predicting material and product properties

- 52 attendees from 13 countries
- Westinghouse (David Huegel & Clint Armstrong),
- Framatome (Jean-Marie Hamy),
- General Atomics (George Jacobsen),
- University of Pittsburgh (Albert To),
- CEA (Pierre-François Giroux)
- NRC (Carolyn Fairbanks)

- Westinghouse (Jurie van Wyk),
- CEA (Cecile Petesch),
- NASA (Richard Russel)
- NRC (Raj Iyengar)

- Jointly with G4SR
- Joint AM workshop with CAMiNA

Community formed with priorities on
- *Qualification for Demonstration and Deployment*
- *Design and Modelling*

- *2 surveys and 4 workshops for community*
- *Final outcome is four recommended activi*
- *Transition to Working Group approved at GIF EG/PG Spring Meeting 2023*

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- *Community grown since 2019*
- *No identified consensus on activity prioritization*
- *Strong Interest in collaborating (89%)*

AMME-TF Present membership

Céline Cabet	FR	Celine.cabet@cea.fr
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Outcome of Surveys

- AMME Survey 2019 & 2021
- OECD/WGSAR 2022

AMME Survey 2019 & 2021

akeholder groups: designers and developers of advanced reactor technologies, research institutions and national boratories, regulators, manufacturers and suppliers to the nuclear industry, codes and standards organization and uclear industry policy and trade associations. Number of respondents: 50 & 56

Key Message messages

- strong support for collaborating on establishing codes and achieving regulatory acceptance;
- greatest obstacle for the adoption of advanced manufacturing approval by code and regulatory bodies (90%);
- far the greatest support for collaboration was on testing and material performance combined with demonstrations in real world applications;
- The 2021 showed an increase interest for direct support to support codes and standards and to secure regulatory approval and decrease in "wait-and-see" attitude.
- Qualification a key issue, but no immediate path forward

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AMME Survey 2019

Which materials that are useable in advanced manufacturing should receive the highest priority for development and testing
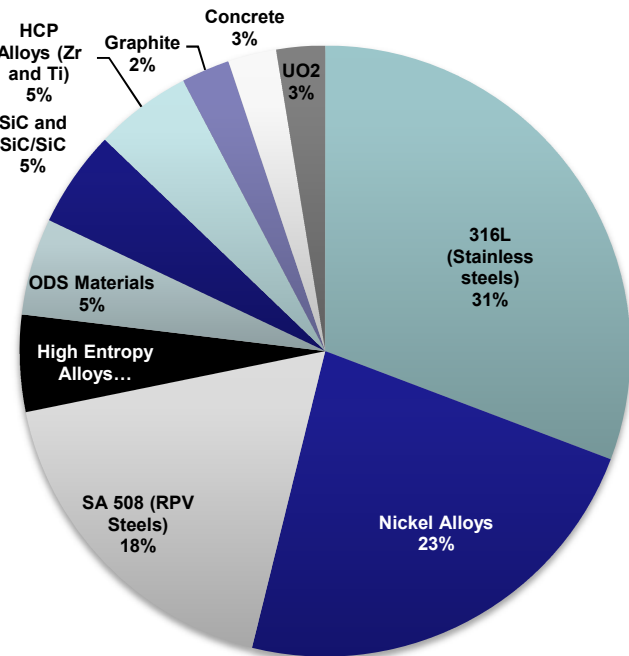
- Stainless Steels
- Nickel alloys
- RPV Steels

# Which materials properties are important?

What material properties are of the greatest interest compared to conventionally-produced materials?

- High temperature properties (e.g. creep & creep/fatigue)
- Irradiated properties
  (e.g. Irradiation affected toughness, creep, SSC etc)

Q6 Which advanced manufacturing techniques and processes are your organisation interested in? Please check all that apply:
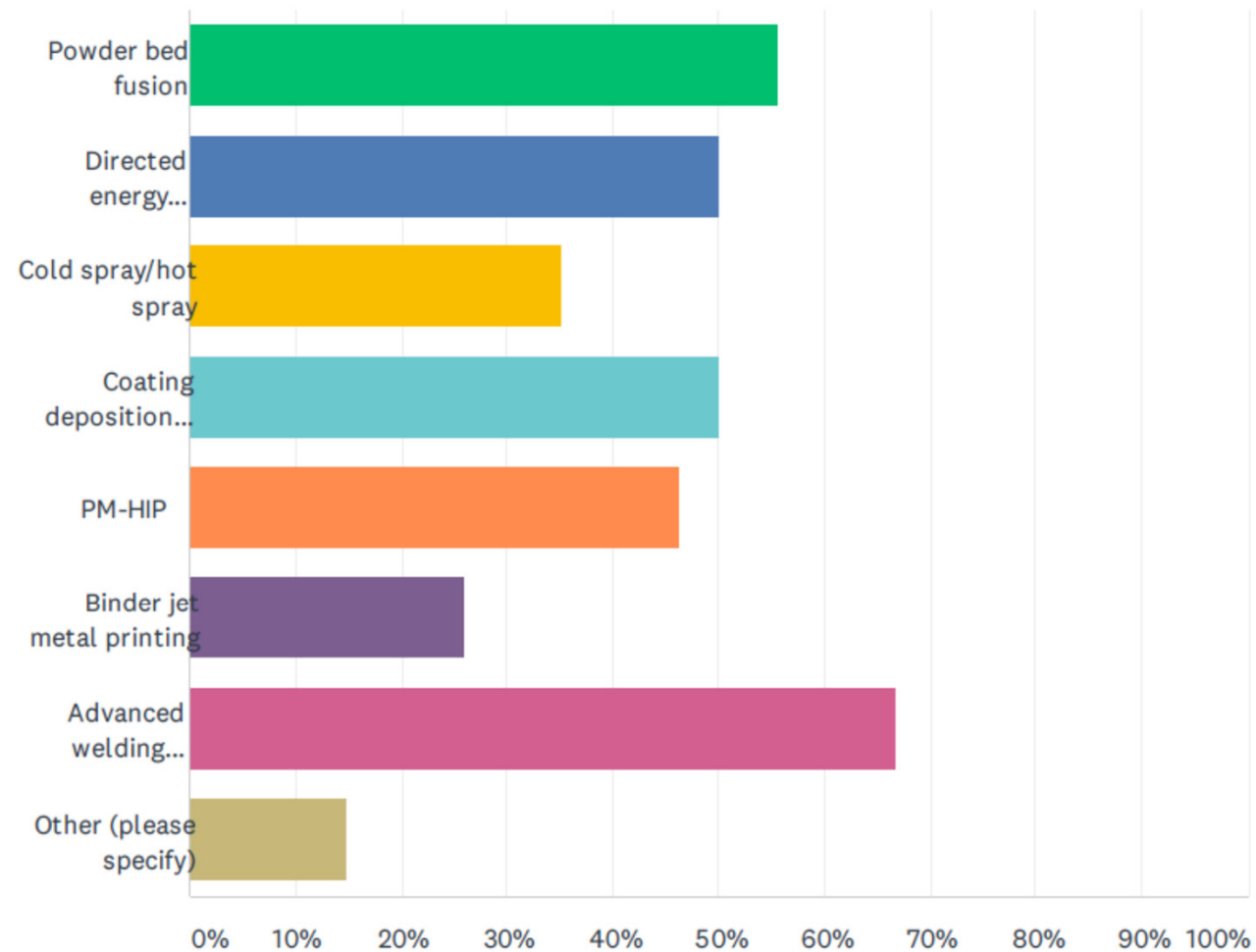
Rating of approaches in reducing the time to qualification of advanced manufacturing processes

	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH	TOTAL	WEIGHTED AVERAGE
Use of Integrated Computational Materials Engineering (ICME)	0.00% 0	4.35% 1	52.17% 12	39.13% 9	4.35% 1	23	3.4
Use of Probabilistic and statistical interference methods	0.00% 0	4.35% 1	69.57% 16	21.74% 5	4.35% 1	23	3.2
Use of in-situ based monitoring e.g. using sensors and NDE techniques	0.00% 0	0.00% 0	37.50% 9	45.83% 11	16.67% 4	24	3.7
Use of Data-based methods (artificial intelligence, machine-learning, neural networks)	0.00% 0	8.33% 2	33.33% 8	45.83% 11	12.50% 3	24	3.6
Component testing rather than material/process qualification	4.17% 1	8.33% 2	33.33% 8	37.50% 9	16.67% 4	24	3.5

OECD/WGSAR 2022

Question focussing on regular aspects: 21 respon...

Mixture of multiple choice and open-ended questions

⬇

3 main categories:

| Regulatory Structure | Materials Qualification | Lifetime Performance |

- Safety Organization/Regulator
- Research institute/Technical support organization
- Other
- Manufacturer of Nuclear Components/Equipment or Advanced Reactor Vendor
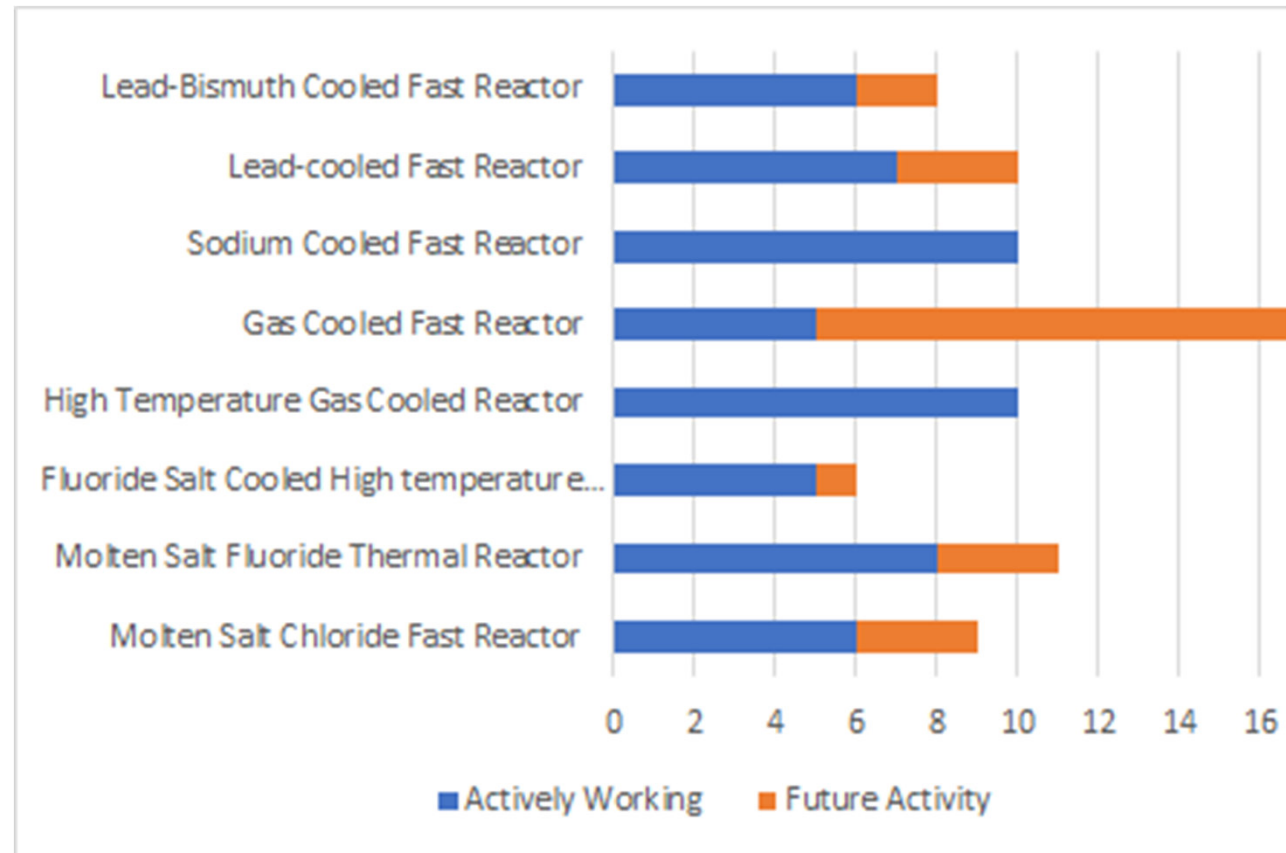
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ECD/WGSAR 2022

is the current regulatory framework used to
e appropriate qualification and through life
rmance of materials in advanced reactors?
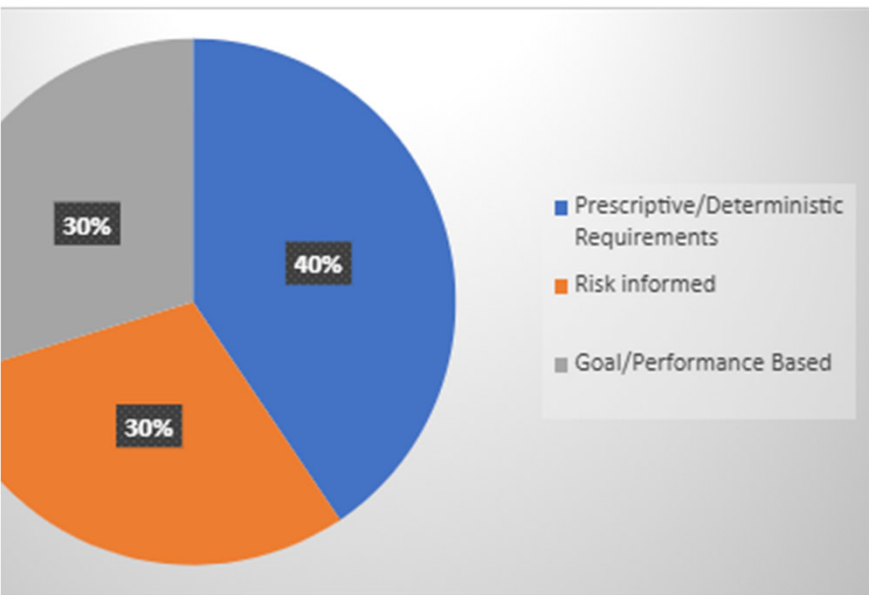
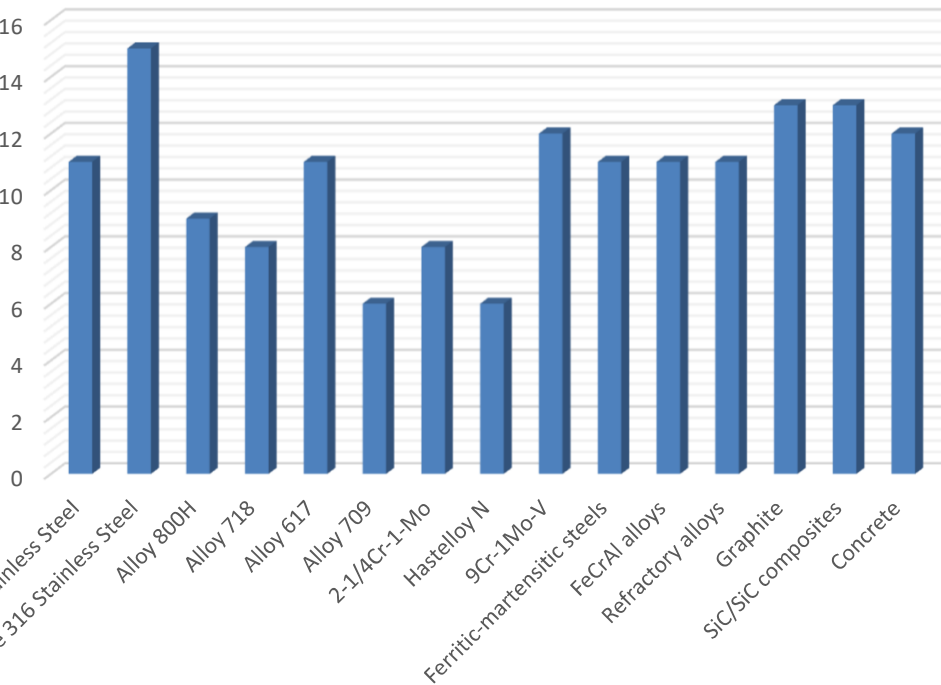What reactor types are of interest to your organization?

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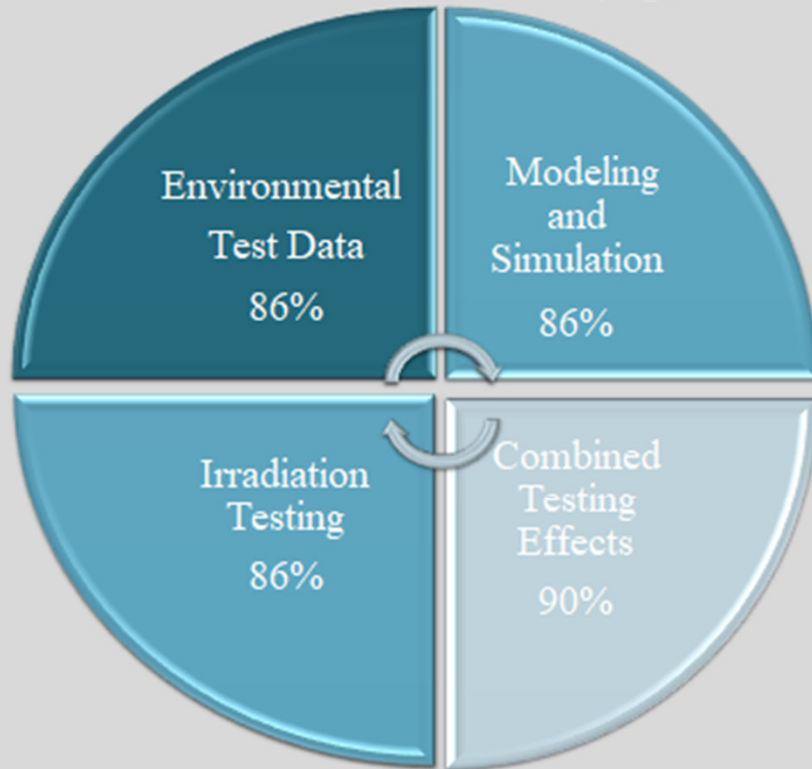Which materials will likely be deployed in advanced reactors in the next decade? Check all that apply.

Select 3 materials that will have greatest data needs qualification/approval in advanced reactor designs.

Material vs. Expected Likelihood of Deployment

Material vs. No. of Respondents Ranking in Top 3 Wrt Qualification Data Need
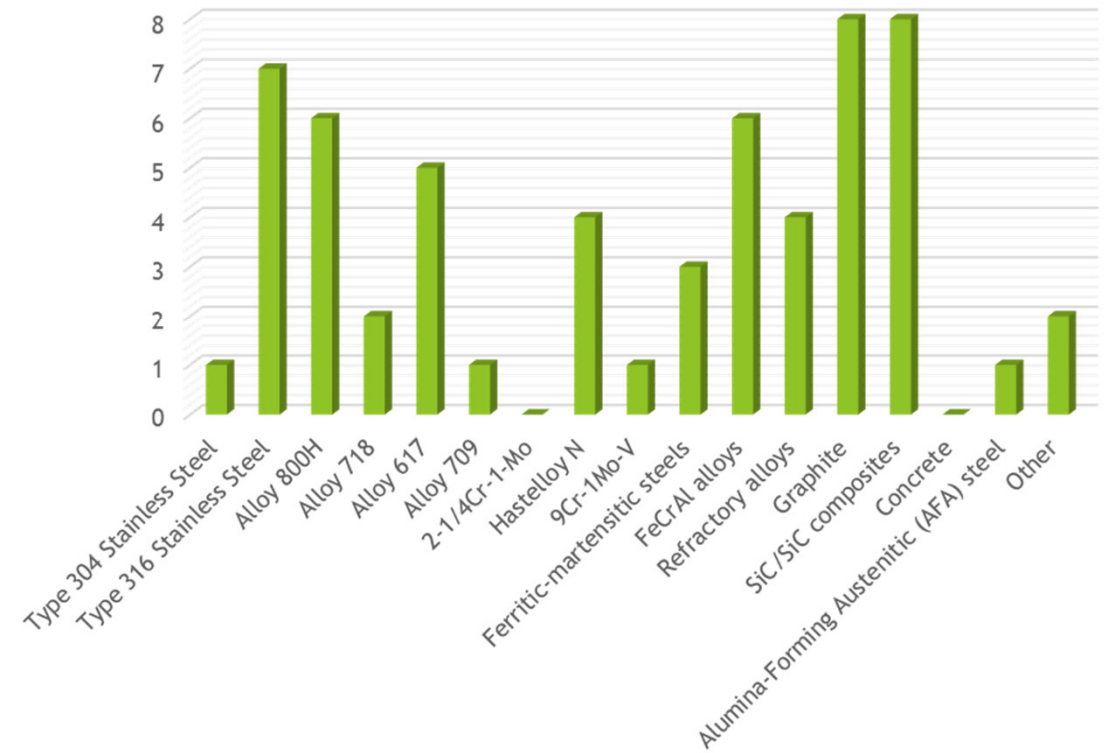
What would your organization expect to be included in a test program for materials that may be subjected to a non-water environment (e.g., molten salt, molten lead)?

Environmental Test Data 86%

Modeling and Simulation 86%

Irradiation Testing 86%

Combined Testing Effects 90%

Different materia test are expected to be needed → Significant work!

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AMME – TF Workshops on Advanced Manufacturing

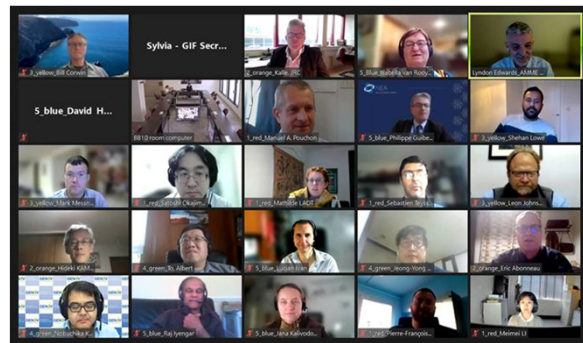Paris February 2020: "Opportunities & Challenges"

On-line November 2022: "Modelling & simulation to accelerate Qualification"

On-line June 2022: "Qualification"

Toronto October 2022: "Qualification – Next steps"

rmat for all Workshops:

- Invited expert presentations
- Break-out Working Group brainstorming discussions
- Conclusions

Robust Group Discussion

Conclusions from the AMME Workshops

Focus on qualification and design/simulation;

Need to narrow focus to representative components and operating conditions;

Long term testing will be needed;

Try to learn from non-nuclear industries;

Concrete paths forward identified

- Identify any unique characteristics of advanced manufactured materials that will affect qualification, ver conventionally manufactured components.

- demonstrate machine learning and correlate processing history to material structure

- develop non-destructive inspection techniques able to identify defects in advanced manufactured parts

- conduct round robin benchmark studies for accelerated qualification approaches to provide codes and standards bodies and regulators evidence of their effectiveness, compared to slower, conventional qualification approaches.

- Set-up of a forum for sharing, coordinating, and harmonizing work on advanced manufactured compon at worldwide codes and standards bodies

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15

Overall AMME -TF achievements and outcomes

y achievement of the Task Force has been the **identification of and engagement with a community that share the Task Force's vi**
e potential to undertake collaborative work.

tion, the following accomplishments have been identified:

ating awareness in the larger community of the current opportunities and challenges remain regarding the implementation of adv
nufacturing for high temperature reactors

creation of tools to engage the community has led to both GIF and the community gaining a better understanding of cognate acti
er business and regulatory environments worldwide

development of an understanding in the community that constraints and challenges of introducing advanced manufacturing into
lear supply chain are universal and that, in the case of advanced high temperature reactors GIF is the key body capable of creating
ernational framework for sharing information to support the introduction of advanced manufacturing

derstanding that the community possesses **heterogeneous relevant expertise** in different domains (e.g. reactor developers, regula
ply chain providers, researchers) which **need to work collaboratively** to accelerate deployment of GEN IV reactors

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AMME WG 2023 - Four initial topic areas

Initial work will focus on four topics

1. Maintain, develop, and continue to distribute the advanced materials and manufacturing industry survey.

2. Setup a forum for sharing, coordination, and demonstration of work on the qualification of advanced materials and manufacturing techniques.

3. Develop activities and projects to promote the qualification of advanced manufactured systems, components, and structures through innovative use of modelling and simulation.

4. Develop activities and projects to promote the qualification of advanced manufacturing systems, components, and structure through innovative testing and monitoring techniques.

Work can immediatel commence

Some form of data-sharing mechanism likely required

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17

Benefit for Europe to interact closer with AMME WG

Partnership with larger community (industry, regulators, research)

Sharing information for accelerated progress:

– Access to non-EU projects/activities/Data (in particular USA and Canada)

– Analysis and review of EU projects/activities/Data by non EU

International harmonization of Qualification methodologies

→ Accelerated deployment of GEN IV reactors through collaboration

EURATOM participation AMME WG

- I am the official EURATOM representative, but we would welcome additional active contributors
- I will retire in May 2025 and a replacement as EURATOM representative is needed.

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Forum

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19