# 5 Task force reports

## Advanced Manufacturing and Materials Engineering Task Force

Although some small modular reactors (SMRs) under development are based on simplified LWR technology, many are based on Generation-IV (Gen-IV) technology that utilizes the inherent safety capability arising from non-water-cooled reactors. A key to the successful mass deployment of the SMR approach is the assertion that the agile manufacturing of components and structures in factory-like environments enabled by large-scale production will substantially reduce the capital cost of new nuclear deployment. This reduction in capital cost requires innovation in the nuclear supply chain, particularly in the areas of advanced manufacturing and materials engineering, if they are to be delivered on time and on budget.

Nuclear design codes, however, typically dictate that only qualified materials and processes can be used, making qualification a potentially long and complicated process. Furthermore, developments in advanced manufacturing are occurring faster than our ability to introduce new materials and methods into design codes, potentially stifling innovation and hampering deployment.

The GIF Advanced Manufacturing Materials Engineering Task Force (AMME-TF) was formed to determine how collaborative R&D could be used to enable such advances so as to reduce the time to deployment of Gen-IV and comparable advanced reactors.

In 2019, the AMME-TF undertook a survey of advanced nuclear reactor vendors, supply chain specialists, regulators and other experts, discovering that most advanced manufacturing methods were considered opportunities by potential end users, and that 90% of respondents identified the greatest obstacle to their adoption as the creation and approval of the appropriate codes and standards.

In the first half of 2021, the task force undertook a second survey to investigate the "if and how" the community's activities and opinions on these issues had changed. The survey was sent to nuclear reactor vendors, supply chain specialists, regulators, national laboratories and potential end users. The distribution list was created based on recommendations from GIF member country representatives and similar experts. The intent, as in 2019, was to gather the opinions of people actively engaged in the design and manufacturing of advanced nuclear reactors. The size of the distribution list had doubled since 2019, providing further anecdotal evidence that the community working on the manufacturing and deployment of advanced reactors has continued to grow. Consequently, the number of survey responses also increased concomitantly. Replies were nearly equally divided from North America, Asia and Europe.

Turning to the survey itself, it is interesting to compare the responses from the 2019 survey to the 2021 survey. Overall, active interest in advanced manufacturing has expanded, with significant increases in reported efforts to support codes and standards and to secure regulatory approval, and with a substantial decrease in the number of respondents taking an interest, but adopting a "wait and see" attitude.

Regarding the application of advanced manufacturing, a change in the focus has been observed in terms of the reactor components being considered for advanced manufacturing, with an increase in interest in relation to reactor internals and heat transfer infrastructure (e.g. pipes, valves and heat exchangers) and a decrease in interest in relation to reactor vessels, fuel cladding and fuel assemblies. There was also an increased focus on the advanced manufacturing of traditional nuclear materials, with most efforts concentrated on stainless steels, low alloy steels and nickel alloys.

Overall, the results from the second survey in 2021 showed that both the size and the interest of the community had grown and become more focused. In addition, the community's focus on qualification, and modeling and simulation as a potential enabler for the qualification of advanced manufacturing and materials, was confirmed. Indeed, enthusiasm for engagement with the task force has also grown, with 54% of respondents reporting a *high* or *very high* interest in the idea of holding a workshop on modeling and simulation and 84% reporting a *high* or *very high* interest in holding a workshop on qualification.

In February 2020, before the COVID-19 pandemic began, the task force held an international workshop at the Nuclear Energy Agency (NEA) headquarters in Paris designed to investigate how collaborative R&D in the field of advanced manufacturing can be used to reduce the time to deployment of advanced reactor systems.

Details of the workshop, which was attended by over 70 representatives from conventional and SMR vendors, nuclear supply chain suppliers, regulators and researchers, can be found on the GIF website.[1]

1. See: www.gen-4.org/gif/jcms/c_115848/workshop-on-advanced-manufacturing.

The recommendation of the workshop was that collaborative activities should be actively encouraged in the following areas:

- qualification: including new modalities (e.g. real time process qualification);
- design and modeling: including the sharing of data for design optimization and modeling and simulation benchmarks.

The task force has thus developed an integrated plan for a series of workshops on both qualification and how modeling and simulation can be used to accelerate qualification. Since the outputs of a modeling and simulation workshop were perceived as representing a key input into a qualification workshop, it was decided to hold modeling and simulation workshop first on 8-9 November 2021.

The focus of the 2021 workshop was on how modeling and simulation can enable the qualification of advanced manufacturing. As was the case during the 2020 workshop, this virtual workshop contained several interactive small group sessions with peers, where attendees were asked to discuss and assess options and opportunities for the qualification of advanced manufacturing. Details of the workshop can be found on the GIF website,[2] and the workshop structure is shown in Figure AMME-1.

Session 1 of the workshop provided an overview of the potential for modeling and simulation to support the nuclear qualification of advanced manufacturing from both researcher and regulator's perspectives while session 2 showcased the activities of advanced reactor vendors and designers. Both sessions were designed to stimulate discussion among workshop attendees, with most of the time allocated to group sessions. In session 3, attendees were allocated to groups, and asked to discuss and identify opportunities for modeling and simulation that would help to accelerate qualification of advanced manufacturing. They were, then asked to prioritize, by likelihood of success, the best opportunities for deployment. The outputs of each of these deliberations were presented to the entire workshop during session 4, entitled "Comparing Group Outputs".

Some common themes emerged from the group presentations, enabling a number of distinct opportunities to be identified as areas for further analysis, and these include:

- collaborative modeling and simulation R&D to control the process (process qualification and quality assurance);
- collaborative modeling and simulation R&D to predict the microstructure and/or the material/component properties (enabling component design code compliance);
- collaborative R&D where modeling and simulation models, software and data are "shared" (including the idea of an advanced material property database);
- collaborative modeling and simulation R&D focused on codes and standards.

The task force is currently undertaking a detailed examination of the ideas and comments from the workshop and will present the full outcomes in 2022.

**Figure AMME-1: Content and methodology of the AMME-TF Modelling and Simulation Workshop, 8-9 November 2021**

***AMME Workshop on Advanced Manufacturing (Virtual) Nov 2021, OECD, Paris, France***

| **Mon 8 Nov** | **GIF AMME Workshop on Advanced Manufacturing DAY 1** |
|---|---|
| **Session 1 – Overview of workshop** | |
| 13:00 – 13.10 | Welcome and Introduction, overview of AMME-TF, purpose of workshop!<br>*Lyndon Edwards* ANSTO, AMME-TF Chair |
| 13:10- 13:35 | How Modelling and Simulation could be used to support the nuclear qualification of advanced manufacturing<br>*Albert To*, University of Pittsburgh (20mins+5 min questions) |
| 13:35 - 14:00 | Challenges to the use of M&S to support the nuclear qualification of advanced manufacturing: a nuclear engineer's perspective<br>*Pierre-François Giroux*, CEA (20mins+5 min questions) |
| 14:00 – 14:25 | NRC Action Plan for Advanced Manufacturing Technologies<br>*Carolyn Fairbanks*, NRC (20mins+5 min questions) |
| **Session 2 – Vendors and designers perspective: the view from the innovation front line** | |
| 14:30 - 14:50 | *David Huegel & Clint Armstrong*, Westinghouse (15mins+5min questions) |
| 14:50– 15:10 | *Jean-Marie Hamy*, Framatome (15mins+5min questions) |
| 15:10– 15:30 | *George Jacobsen*, General Atomics (15mins+5min questions) |
| 15:30– 16:00 | Summary, Panel Discussion and Group Activity Briefing |
| **Session 3 – Group activity 1** | |
| 16:00 – 17:30<br>**Includes break as necessary** | Attendees split into allocated groups, which undertake the following activities with the group Moderator/Rapporteur:<br>a. Discuss and identify opportunities for Modelling & Simulation to accelerate qualification of Advanced Manufacturing<br>b. Analyse each identified opportunity (SWOT analysis or similar)<br>c. Prioritise, by likelihood of success, best opportunities for 2030 deployment<br>d. Agree communication for Rapporteur to give to meeting at start of Day 2 (Can develop presentation overnight if necessary) |
| 17:30 | End of Day 1 |
| **Tue 9 Nov** | **GIF AMME Workshop on Advanced Manufacturing DAY 2** |
| **Session 4 – Comparing Group Outputs** | |
| 13:00 – 14:15 | Whole workshop undertakes the following activities:<br>a. Rapporteurs from each group presents group output (5 x 10 minutes)<br>b. List agreed areas to be addressed and potential collaborative opportunities |
| 14:15 — 14:45 | Break |
| **Session 5 – Group Activity 2** | |
| 14:45 – 16:00 | Attendees split into new opportunity specific groups (those identified as having highest priority) and undertake the following activities:<br>a. What needs to be done<br>b. How can collaboration help?<br>c. Identify and prioritize areas/ideas for AMME activities/projects<br>d. Agree communication for Rapporteur to give to meeting after break |
| 16:00 – 16:20 | Break |
| **Session 6 – Final Group Reporting and Meeting Outcomes** | |
| 16:20- 17:30 | Each Group present their findings and recommendations |
| 17:30 – 18:00 | Summarise findings and consensus of meeting |
| 18:00 | End of Meeting |

**Lyndon Edwards**
Chair of the AMME TF,
with contributions from
AMME members

2 See: www.gen-4.org/gif/jcms/c_82829/workshops.

## Non-Electric Applications of Nuclear Heat Task Force

In November 2020 and February 2021, GIF held two, open brainstorming meetings out to exchange expert views on the position of Gen-IV systems (and particularly advanced modular reactors) regarding non-electric applications of nuclear heat (NEaNH). The outcomes from the brainstorming sessions suggested a path forward for the development of a NEaNH-related activity, and the following key areas were identified:

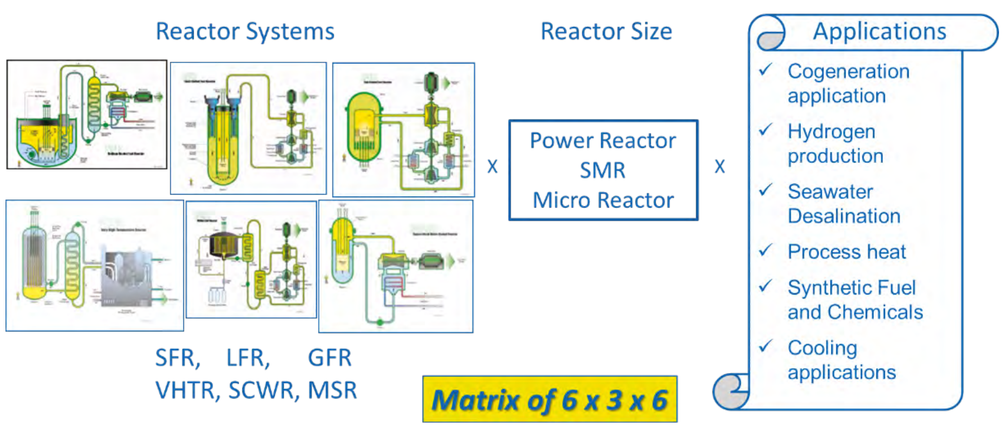
- GIF can play an important role in identifying the specific benefits that Gen-IV reactor technologies could bring to the NEaNH sector in the context of future energy markets.
- The development of a NEaNH-related activity launched under the auspices of GIF should be based upon the considerations listed below.
  - Organizations and members express an interest in contributing to the proposed activity and are able to share foundational knowledge and input data on the subject, such that a limited but relevant amount of useful documentation can be identified and produced to support the NEaNH objectives.
  - Overlaps with similar efforts undertaken within other nuclear organizations (e.g. IAEA, IEA, NEA, WNA) are avoided and opportunities for collaboration pursued.
  - An optimal balance is sought between addressing potential NEaNH configurations that can be achieved with Gen-III technologies (mainly pressurized water reactors) and those addressing specific high-temperature NEaNH processes, requiring that Gen-IV technologies be deployed. The complexity and variety of boundary conditions (e.g. local/global economy, geopolitics, government strategies) must be taken into account to determine the optimal combination of reactor technology, power level and NEaNH to fulfill specific requirements; this activity should aim at providing decision makers with the tools for pursuing optimal solutions which-depend on their specific needs rather than suggesting a technology down-selection.
  - In order to address the previous item, this activity should explore combinations arising from the "6 (NEaNH processes) x 3 (levels of power) x 6 (GIF reactor systems) matrix" (see Figure NEaNH-1) from different perspectives (geopolitical, economic, R&D, regulation). Use of such a matrix would enable the identification of potential technical and economic hurdles specific to the most promising combinations.
  - Efforts are needed to reach out to technical-economic communities beyond the nuclear power sector. In particular, efforts should be made to engage stakeholders in the high-temperature community (e.g. concentrated solar power, industrial processes, thermal energy storage).

### Objectives of the GIF NEaNH Task Force

In order to fulfill the requirements outlined above, a dedicated, new task force was created in October 2021, the Non-Electric Applications of Nuclear Heat Task Force, or NEaNH TF (pronounced "NENH"). This task force is initially defined for a duration of 24 months, with a predefinition of the following items:

- Item 1: provide to GIF a position paper on its vision for NEaNH coupled to GIF systems (near term and transition to future).
- Item 2: upgrade and share the general level of knowledge to all GIF members by organizing an open workshop and establishing a shared database, implemented on the GIF website and updated regularly.

Figure NEaNH-1: Definition of the 6x3x6 matrix: 6 Gen-IV systems over 3 power ranges to address 6 major non-electric applications



- Item 3: highlight relevant solutions of the 6x3x6 matrix; creating a dedicated mind map to fill in potentially viable configurations.
- Item 4: implement within GIF a network that extends beyond the nuclear field and connects with the high temperature community.
- Item 5: analyze these systems in view of:
  - technology readiness levels, timeliness/ geographical suitability and footprint/$CO_2$ emission reduction potential;
  - cost evaluation (USD/t $CO_2$ saved), return on investment evaluation (annual emission reduction/required investment); several tools from the IAEA and OECD/NEA, as well as from participant organizations if available as open source tools, could be applied;
  - boundary conditions that are necessary to make such systems viable (e.g. cost of competing energy sources such as natural gas, levels of $CO_2$ tax, interest rates, discount rates).

With these results, GIF could deliver advice to policymakers, industry, licensing authorities and investors in terms of which nuclear applications are likely to be best suited (i.e. effective, timely) for meeting specific policy goals, how much these options may cost and how much economic benefit they could potentially offer. Participation in the GIF NEaNH TF has been confirmed by the following member countries: Australia, Canada, China, Euratom, France, Japan, Korea, Russia, the United Kingdom and the United States GIF plans regarding the NEaNH TF were shared at the IAEA Technical Meeting on the Role of at a Nuclear Cogeneration Applications Towards Climate Change Mitigation, held on 11-13 October 2021.[1]

**Shannon Bragg-Sitton**
Chair of the NEaNH TF,
with contributions from NEaNH TF members

1. See GIF presentation by G. RODRIGUEZ entitled "Non-Electric Applications of Nuclear-Heat: A new Generation IV International Forum initiative" IAEA Technical Meeting on the Role of Nuclear Cogeneration Towards Climate Change Mitigation, Virtual Meeting, Oct. 11-13, 2021 (Event code: EBT2003995).