Non-Electric & Cogeneration Virtual Workshop with Regulators

WORKSHOP SYNOPSIS AND FINDINGS

12-13 November 2025; 13:00–16:00 CEST
Virtual

Contents

Workshop Overview and Key Findings

Key Insights from the Workshop

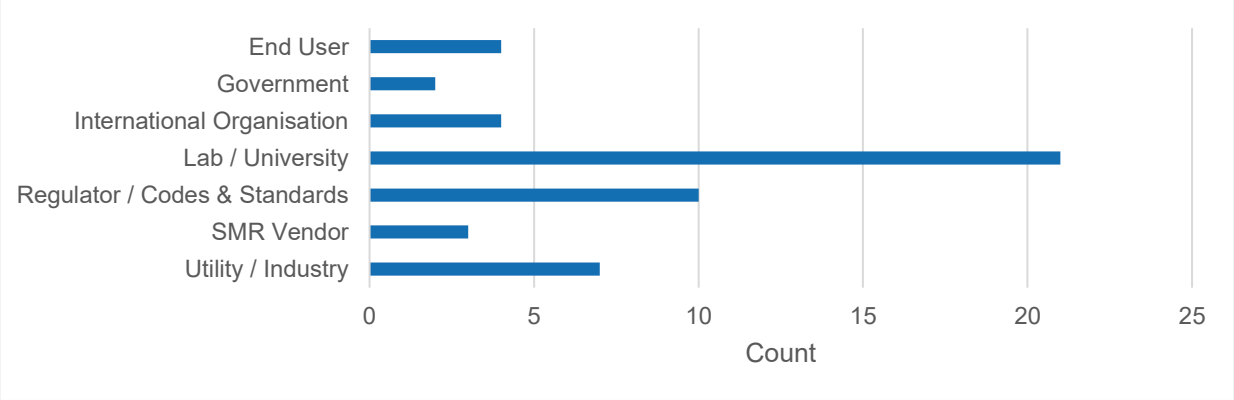
- Regulators have mechanisms to handle new technologies and innovations, and non-electric or cogeneration applications are not expected to be unique within these frameworks.
- Key challenges are (1) cost and economics, (2) regulatory or licensing uncertainty, and (3) deployment timelines.
- Demonstration projects and pilot plants are critical for building operational experience, validating safety cases, and increasing stakeholder confidence. To maximise learning from early demonstrations, collaboration among vendors, licensees, regulators, and industrial partners are crucial. Proponents must be informed on the relevance of specific project details in order to apply it to follow-on projects, especially in different jurisdictions.
- Proponents may be required to demonstrate the best available techniques to mitigate the impact of the nuclear power plant (NPP) on coupled industrial processes.
- There is a mismatch between the high safety standards required for nuclear facilities and those required at most industrial sites. Cooperation with regulators in non-nuclear industries is encouraged.
- Liability arrangements in cogeneration projects were highlighted as an area needing improved understanding. Historic examples of cogeneration could have benefited from more robust frameworks in place to handle liability in the event of a radioactive release.
- Regarding timelines, participants noted challenges for commercial planning. Industry energy planning decision timelines are quicker (~5 years and earlier) than current regulatory timelines for NPPs (10-15 years), and there is a desire to accelerate nuclear project timelines. On the regulatory side, the maturity of the design and the application of best available techniques to minimise cross-contamination are key factors in expediting approvals. Parallel processing of licensing steps, rather than a strictly sequential approach, was suggested as a way to reduce overall project duration.
- Changing the typical nuclear boundary in cogeneration projects was identified as a potential option to enable holistic regulatory review. Early demonstrations could benefit from a wider boundary, with subsequent projects having a smaller boundary once impacts are understood.
- NPPs could serve heat networks. Heat end users may need to act predictably so that heating networks can effectively serve as heat sinks for NPPs.

Workshop Overview

The Generation IV International Forum's Non-Electric and Cogeneration Applications of Nuclear Energy (NECA) Working Group hosted the Non-Electric and Cogeneration Virtual Workshop with Regulators as a follow up to the NECA Virtual Workshop with End Users in June 2025. This virtual workshop focused on identifying challenges faced by regulators to enable non-electric and cogeneration applications of nuclear energy and also address policy frameworks, implementation logistics, and operational feasibility.

This closed-door workshop brought together industrial energy end users and regulators to discuss non-electric and cogeneration applications of nuclear energy. Fifty participants joined the workshop, including engaged participation from regulatory bodies, codes and standards organisations, or technical service organisations that support regulators.

Figure 1: Composition of the audience.



A range of countries participated in the discussion: Canada (8), China (8), France (7), UK (7), Korea (5), USA (5), Austria (3), Japan (3), as well as participants from Belgium, Czechia, Finland, Netherlands, and Norway.

During registration, participants were asked optional questions to help inform the discussion. Twenty-nine participants answered the following questions:

1. In your opinion, what are the most significant challenges for using nuclear cogeneration?
2. In your opinion, are there any challenges or barriers that you feel receive too much attention in current discussions?
3. In your opinion, are there important challenges or barriers that are not being discussed enough, and should be given more attention?

In general, respondents emphasised economics and financeability, as well as regulatory or licensing complexity, as the primary challenges to nuclear cogeneration. In particular, there is a lack of data to understand:

- the required scale of capital costs,
- the comparative cost versus conventional heat generating options,
- additional costs associated with participating in heating networks,
- and business case fundamentals.

Many respondents noted that the added regulatory complexity of both a nuclear and non-nuclear industrial regulator may have a significant impact.

Respondents also noted that there is uncertainty on technical aspects of integration, as there will be new requirements for the plant operator to:

- couple the nuclear island with industrial processes,
- manage transients and ramp rates, and
- ensure reliable interfaces and boundaries.

Siting, management of external hazards, market demand, policy coherence, and fit-for-purpose regulation was also cited as a potential challenges for nuclear cogeneration.

For Question 2 and 3, there was no firm agreement among participants on which challenges may be receiving too much attention and which are not receiving sufficient attention. Several responses suggested

that generic “regulatory uncertainty” may be overstated as regulators have processes in place to manage hazards that would be introduced through cogeneration, while others argue that there is a lack of evidence of regulatory readiness for coupled facilities - in the absence of real demonstration units.

Similarly, public acceptance was viewed by some as receiving disproportionate emphasis, while others suggest it is critical to successful projects and should be discussed more often and more broadly, especially with respect to locating co-generation units near demand centres.

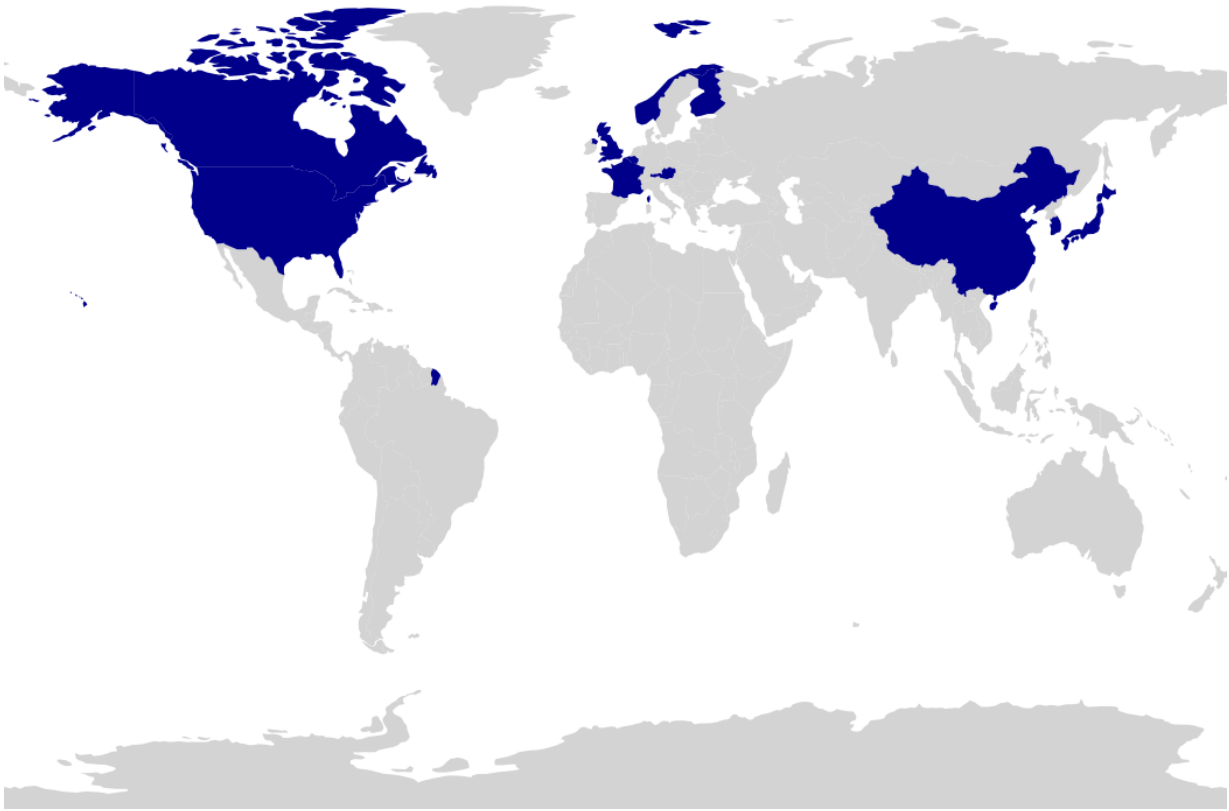
Finally, respondents simultaneously noted that analysis should focus on cogeneration markets requiring temperatures below 550°C given the very large relative size of this heat market, while others noted that the applicability for Gen-IV reactors to support higher temperature applications is not sufficiently addressed.

In general, recurrent themes in the responses included consideration for:

- interface safety and security,
- the importance to explore business models and risk management, and
- demonstrating coupling hardware with equipment testbeds.

Participants also called for more focus on the potential coupling of nuclear energy with data centres given their global relevance

Figure 2: Geographic distribution of the 50 attendees in 12 countries.



In addition to scene-setting remarks, information was provided through structured presentations and 90 minutes of interactive discussion each day. Besides the opening remarks, the event followed Chatham house rules. Comments are therefore intentionally included without attribution to the speaker to enable anonymity and foster knowledge sharing. Names are included in this document if permission was explicitly provided.

This virtual workshop builds on the success of previous end-user workshops hosted by the NECA Working Group, including:

- Non-Electric & Cogeneration Virtual Workshop with End Users held virtually in June 2025;
- Workshop on Non-Electric & Hybrid Applications of Nuclear Energy in Busan, Korea in April 2024.
- Workshop - Non-Electric Applications of Nuclear Heat in Toronto, Canada in October 2022

Workshop Summary

Day 1 Opening Session

Welcome Remarks

Michael Fütterer
Technical Director
GIF

- Michael Fütterer introduced the workshop by outlining its relevance to the mission of GIF: to develop advanced nuclear reactor systems that are safer, more efficient, and economically viable.
- The activities in GIF are timely given global efforts to deploy Gen-IV reactor technologies, and the NECA Working Group has particular relevant to evaluate opportunities for cogeneration in a carbon constrained world.
- The participants of the workshop and other stakeholders who support the NECA Working Group were thanked for their feedback and contributions to ongoing GIF analysis.
- The relevance of this discussion to the broader GIF ecosystem was noted including the work of the Risk and Safety Working Group and the Proliferation Resistance and Physical Protection group.
- The primary goals of the workshop were restated – to develop a shared consensus of the predominant regulatory and associated challenges with heat applications, and what can be done to overcome these.

UK Nuclear Regulation: A Pro-Innovation Approach

- The Office for Nuclear Regulation (ONR) and the Environment Agency (EA) presented an overview of the United Kingdom's approach to nuclear regulation, which aims to encourage innovation while maintaining robust safety and environmental standards.
- The ONR is responsible for nuclear safety, security, and the transport of radioactive materials, whereas the EA oversees environmental protection and the management of radioactive substances.
- The presentation covered the various stages of the UK's regulatory processes. Early engagement allows vendors and developers to seek regulatory advice in the initial phases of a project, offering three levels of engagement based on project needs. The Generic Design Assessment (GDA) process, which is optional and conducted in stages, helps identify and address safety, security, and environmental matters prior to construction, reducing project risks and costs.
- The ONR issues nuclear site licences with specific conditions to uphold safety, while the EA grants environmental permits to ensure that operational activities do not adversely impact people or the environment.
- Key regulatory considerations include defining the boundaries between nuclear and non-nuclear sites, managing safety and environmental challenges, and clarifying the roles and responsibilities of operators and regulators.
- The discussion noted advantages and challenges associated with locating cogeneration facilities on nuclear licensed sites, and highlighted the need to understand the interactions between reactors and non-electric applications.
- Regulators emphasise the need for risks to be reduced to As Low As Reasonably Practicable (ALARP) and for environmental impacts to be minimised through the application of "best available techniques".
- The UK's regulatory approach remains flexible, technology-neutral, and supportive of innovative solutions, while ensuring high standards are maintained throughout the sector.

Session 1: Challenges and considerations for interfaces between industrial plants and nuclear plants.

Previous workshops hosted by the NECA Working Group identified requirements (monitoring, shutdown mechanisms, separation distances, exclusion zones), and challenges (dependencies between plants) for NECA systems. Speakers in this session targeted discussion on how to identify real barriers from perceived challenges.

Session Speakers

- **Chair**: Francesco Ganda, Technical Lead, Non Electric Applications, International Atomic Energy Agency
- Speakers from the following organisations:
  - British Sugar (UK)
  - CSA Group (Canada)
  - Institute for Energy Technology representing the Halden Reactor Project (Norway)

Summary of discussion from session

The session identified challenges and considerations for interfaces between industrial plants and nuclear plants with perspectives from the UK, Canada, and Norway, each highlighting issues in integrating nuclear energy with industrial applications.

- Industry outlined challenges related to the timing of SMRs for industrial use. The anticipated commercialisation of SMRs is not expected before the mid 2030s, with initial units likely to support grid capacity rather than industrial sites. The deployment process involves a lengthy sequence of regulatory and construction steps, extending to 10-15 years with current regulatory processes. Industry planning timelines would prefer a technology to be available on the order of 3 to 5 years.
- There is uncertainty on the economic viability of SMRs compared to other low-carbon technologies, especially given the forecasted capital and operational costs, and there are concerns about the suitability of new sites with no prior licensing history.
- From a standards and regulatory perspective, work from the CSA Group in Canada showed that standardisation gaps at the interface between nuclear power plants and hydrogen production facilities may already be well-understood. In particular, a recently published report noted that the CSA N290.17 standard, which guides probabilistic safety assessments for nuclear plants, was found to be a robust tool for identifying hazards associated with hydrogen co-generation.
- Enhancements were also recommended to increase awareness of hazards and potential cascading effects.
- The Halden Boiling Water Reactor (HBWR) is a unique case of cogeneration as there is significant and recent operational history. The HBWR used cogeneration to provide heat to a neighbouring paper mill, which operated from 1959 to 2018 and provided a portion of the mill's heat needs.
- This arrangement required close coordination and communication between the reactor operator and the industrial partner, as the reactor's operation was dependent on the mill's ability to offtake heat as the primary heat sink for the research reactor. Legislative acts were in place to ensure a level of safety, security, and environmental protection.
- The presentation concluded that while the use of residual heat was sustainable and mutually beneficial, several risks require careful management, including changes in industrial strategies, evolving regulatory requirements and the need for a reliable heat sink to ensure reactor safety.

Day 1 discussion

An interactive discussion was held to reflect on the topics covered on the first day of the workshop, which was moderated by the Working Group co-chairs: Chuk Azih (Canada) and Aiden Peakman (UK).

Summary of discussion

- Defining the boundary between nuclear and industrial facilities was identified as an option for proponents to help manage the jurisdiction or authority mismatch between nuclear and non-nuclear regulators. Clear physical and procedural separation between the nuclear and industrial facilities is a recommended enhancement to existing standards.
- For a nuclear cogeneration project where heat is used by industry, there are benefits and drawbacks to having one single off-taker, or multiple off-takers through an energy park concept. For a single off-taker, such as the case for the Halden BWR project, the safety and business case could be impacted by the competitiveness and operational schedule of a single industrial off-taker, however the simplicity in managing operational issues was favourable with a single impacted industry and point of contact. In contrast, multiple off-takers allows for improved resilience in the system, but managing outages and operational schedules has increased expected complexity with additional impacted heat users in the network.
- Industry representatives highlighted long timelines and uncertainties associated with regulatory approval, construction, and commissioning of nuclear cogeneration projects to be a concrete barrier to industry adoption.
- Operational experience from the Halden BWR project, as a long-duration cogeneration project, illustrated the importance of strong cooperation, clear agreements, and robust emergency planning between nuclear operators and industrial partners.
- While international collaboration and sharing of operational experience are valuable, each country's regulatory process remains distinct, and proponents will be required to use the best available research and technologies and mitigate safety concerns by the regulator.
- Two cases were discussed, where there are existing multilateral arrangements between regulators, however, a challenge is that evaluations are at different stages in each jurisdiction such that direct opportunities for coordinated efforts would be limited.
- The discussion repeatedly returned to the need for risk-informed, graded regulatory approaches and the value of demonstration projects to build operational experience, which is currently lacking. It was noted that successful demonstrations can practically speed up future licencing processes by generating relevant operating experience, thus increasing confidence.

Day 2 Opening Session

Eetu Ahonen
Chair of the WGNT task group on non-electric applications
Finland

- Eetu Ahonen is the vice chair of the NEA Regulation and Safety Working Group on New Technologies (WGNT), a regulator-only working group that focuses on the integration of new technologies in the nuclear sector.
- Ahonen underscored the goal for regulators to gain a deeper understanding on a range of applications, including AI and non-electric applications, as many are currently unfamiliar with them.
- The WGNT's task force on non-electric applications plans to explore this topic through mock safety cases, with a workshop planned for Autumn 2026. This initiative aims to share experiences and good practices among regulators to enhance their readiness to license and review these applications.
- It is important to engage early with vendors, licensees, and regulators, as such collaboration is critical for the success of new build projects

Session 2: Considerations for hydrogen production

Session 2 focused on practical and safety considerations for producing hydrogen with nuclear energy.

Session Speakers

- **Chair**: Pierre Serre-Combe, Chair of Hydrogen Production Project, GIF
- Speakers from the following organisations:
  - Bruce Power (Canada)
  - Institute of Nuclear Energy and New Energy Technology, Tsinghua University (China)

Summary of discussion from session

- The Canadian perspective highlighted a pilot project at Bruce Power's Bruce A station, which explores the production of hydrogen using solid oxide electrolysis cell (SOEC) technology. The project is designed to leverage existing infrastructure and energy from the site's eight CANDU units, with an initial MW-scale pilot plant that will eventually scale up to 10's to 100's of MWs.
- To enable pilot projects to demonstrate concept, early phases will opt to release hydrogen to the atmosphere for simplicity. Later stages could aim to use the produced hydrogen for internal use at a NPP site.
- In China, various hydrogen production pathways are being designed to use energy from nuclear power, including for methane steam reforming (MSR), the iodine-sulfur (I-S) thermochemical cycle, and high-temperature steam electrolysis (HTSE). Heat from nuclear energy and SMRs also have promise for processes such as methanol steam reforming and methane pyrolysis.
- The presentation detailed historical and ongoing research in China, Germany, and Japan on steam methane reforming systems that could use nuclear heat as a realistic near-term option to produce hydrogen at scale using nuclear energy.
- Technologies to increase hydrogen production rates and process efficiency are being developed. Intermediate heat exchangers were noted for their role in mitigating tritium permeation.

Session 3: Regulation of cogeneration and safety evaluation of external hazards

Speakers focused on innovative approaches to regulate topics like cogeneration and introduced strategies to evaluate external hazards that may impact nuclear facilities.

Session Speakers

- **Chair**: Tanju Sofu, Risk and Safety Working Group, GIF (USA)
- Speakers from the following organisations:
  - Canadian Nuclear Safety Commission (Canada)
  - China Nuclear and Radiation Safety Center (China)
  - Korea Institute of Nuclear Safety (Korea)

Summary of discussion from session

- Regulators broadly acknowledge that there is a need to keep pace with technological advancements, such as artificial intelligence (AI), through ongoing environmental scans, regulatory framework reviews, and technical assessments.
- Canada, the UK, and the USA collaborate trilaterally on joint work, and have completed a joint paper on AI considerations. Another international collaboration on regulator readiness involves the use of Regulatory Sandboxes (RegLabs), where regulators, industry, and academics jointly explore and test regulatory frameworks in controlled environments.
- Regulators have mechanisms to handle new technologies and innovations, and non-electric or cogeneration applications are not expected to be unique within these frameworks.
- The concept of identifying and evaluating hazards during regulatory reviews is common. Industrial applications that could off-take heat would be considered a human-induced external event (HIEEs) that would be reviewed. Additional considerations would be needed to ensure a reliable heat sink.
- The two main criteria used to determine the severity of a hazard are the proximity to the nuclear power plant, and the probability of occurrence.
- For hydrogen production, the approach for hazard assessment involves both a qualitative and quantitative evaluation that depends on the specific H_2 production technology, site location, and potential for cascading effects.
- A key issue for cogeneration is the mis-match in standards applied to safety criteria for industrial facilities compared to the typically higher standards at nuclear facilities. The need for probabilistic safety assessments and other analyses will be needed to ensure accident frequencies remain below nuclear safety goals.
- Hazard identification techniques and protection measures, such as blast walls and administrative controls, were highlighted as essential for managing risks. The role of independent circuits, reliable isolation devices, and appropriate pressure differences to prevent contamination and ensure user safety should be considered.
- Dedicated monitoring systems with appropriate alarm thresholds and sampling frequencies were recommended to detect abnormal radioactive levels.

Day 2 discussion.

- A business dependency is possible if an industrial facility relies on nuclear-generated steam for its processes, and when a nuclear reactor relies on the industrial facility as an off-taker. For example, if the industrial partner no longer requires the steam, this can pose a significant business risk for the reactor operator or developer which requires the offtake as a heat sink or source of revenue. The arrangement requires consideration of liability and contingency, as the loss of the industrial customer could undermine the economic case for the nuclear facility.
- Technical considerations around steam supply were discussed, particularly the impact of pressure and temperature requirements that would be specified by the industrial user. Pressure and temperature are often dictated by the end user, and it is possible that increased pressure could heighten the risk of tritium migration.
- Liability arrangements in cogeneration projects are an area of possible improvement. Historic examples of cogeneration did not appear to have robust frameworks in place to handle liability of in the event of a radioactive release. New cogeneration applications will need to consider this.
- Ideally, when regulators are considering cogeneration applications domestically, they can leverage related examples operating abroad. Joint or external regulatory reviews are a mechanism to share decisions and considerations with several countries. However, each regulator must conduct its own due diligence, and the ability to use external assessments will depend on
    - familiarity with the project details,
    - comprehending details of the other regulatory process, and
    - the customer's knowledge of the project relevance.
- Most regulators have a way to deal with off-typical applications such as co-generation, but there is more diversity in approach in this area compared to regulation of a NPP without cogeneration.
- Regarding timelines, participants noted challenges for commercial planning, especially as market conditions and technologies evolve. On the regulatory side, the maturity of the design and applying the best available techniques to minimise cross-contamination are key factors in expediting approvals. Parallel processing of licensing steps, rather than a strictly sequential approach, was suggested as a way to reduce overall project duration.
- Operational experience from past and current non-electric nuclear applications remains limited, and there is a recognised need to capture and share lessons learned to the maximum extent possible for early demonstrations. Regulators are generally more familiar with conventional light water reactor applications, and expanding knowledge on Gen-IV reactors and non-electric uses is seen as valuable for future assessments.
- In a heating network with multiple off-takers, liability and coordination challenges increase, and there is a trade-off between operational flexibility and ease of management.
- Changing the typical nuclear boundary in cogeneration projects was identified as a potential option to enable holistic regulatory consideration. The reactor, its controls, and waste management systems must be within the licensed site, but the placement of other components, such as generators or heat storage, may vary depending on the technology and the degree of decoupling from the end user. Regulatory jurisdiction may also shift depending on whether a facility is inside or outside the nuclear boundary, affecting oversight responsibilities.
- For early demonstrations wider site boundaries may be beneficial, with the possibility of narrowing the boundary as operational experience is gained.
- Early engagement with regulators was emphasized as essential for success, and while regulators do not design systems, they can provide preliminary feedback to guide project development.
- Not all non-electric applications have the same risk profile. A more nuanced, risk-informed approach will be used to help focus regulatory attention on higher-risk applications while facilitating earlier deployment of lower-risk cogeneration projects, such as data centres.
- End users in heating networks were compared to large gas consumers. In gas networks, end users have obligations to ensure predictable and stable off-take. This might need to be considered for heating networks that would act as a heat sink for NPPs.
- Market demand, cost competitiveness, and the alignment of project lifecycles between nuclear and industrial facilities were identified as key factors for successful deployment.
- Regarding decommissioning, for co-location, there may be some considerations for the deconstruction of the industrial plant if there are identified interdependencies.
- The session concluded with interactive polling and discussion to prioritise future work areas. The poll confirmed that the most significant barriers to nuclear cogeneration appear to be: cost and economics issues; regulatory and licensing issues; and deployment timelines for cogen systems

Agenda for the Non-Electric & Cogeneration Virtual Workshop with Regulators

12 November 2025

13:00 – 13:35 ***Opening Session:*** *Welcome address and scene setting remarks*	
Welcome remarks (10 min)	Michael Fütterer, Technical Director, GIF
UK Nuclear Regulation: A Pro-Innovation Approach (25 min)	Office for Nuclear Regulation and Environment Agency
13:40 – 14:30 ***Session 1:*** *Challenges and considerations for interfaces between industrial plants and nuclear plants.*	
Chair of session:	Francesco Ganda, Technical Lead, Non Electric Applications, International Atomic Energy Agency
Previous workshops identified requirements (monitoring, shutdown mechanisms, separation distances, exclusion zones), and challenges (dependencies between plants). Speakers will help to identify barriers to be distinguished from challenges	British Sugar (UK) CSA Group (Canada) Representative from the Halden Reactor Project (Norway)
14:30 – 16:00 ***Interactive discussion.*** *Moderated by Chuk Azih and Aiden Peakman, Co-chairs, NECA WG*	

13 November 2025

13:00 – 13:10 ***Opening Session:*** *Day 2 opening remarks*	
Opening remarks on the importance of discussing potential challenges in advance of a license application.	Eetu Ahonen, Chair of the WGNT task group on non-electric applications (Finland)
13:10 – 13:45 ***Session 2:*** *Considerations for hydrogen production*	
Chair of session:	Pierre Serre-Combe, Chair of Hydrogen Production Project, GIF
Speakers will discuss practical and safety considerations for producing hydrogen with nuclear energy.	Bruce Power (Canada) Institute of Nuclear Energy and New Energy Technology, Tsinghua University (China)
13:45 – 14:30 ***Session 3:*** *Regulation of cogeneration and safety evaluation of external hazards*	
Chair of session:	Tanju Sofu, Risk and Safety Working Group, GIF (USA)
Speakers will focus on focus on innovative approaches to regulate topics like cogeneration and strategies to evaluate external hazards that may impact nuclear facilities.	Canadian Nuclear Safety Commission (Canada) China Nuclear and Radiation Safety Center (China) Korea Institute of Nuclear Safety (Korea)
14:30 – 16:00 ***Interactive discussion.*** *Moderated by Aiden Peakman, Co-chair, NECA WG (UK)*	