5 Methodology working groups

Economic Modelling Working Group

The Economic Modelling Working Group (EMWG) was established in 2003 to provide a methodology for the assessment of Generation IV (Gen-IV) systems against two economic-related goals, as follows:

- to have a life-cycle cost advantage over other energy sources (i.e. to have a lower levelized unit cost of energy);
- to have a level of financial risk comparable to other energy projects (i.e. to have a similar total investment cost at the time of commercial operation).

In 2007, the EMWG published cost estimating guidelines and the Excel-based software package, G4ECONS v2.0, for the calculation of two figures of merit: the levelized cost of energy and the total investment cost, and to assess Gen-IV systems against GIF economic goals. These EMWG tools were made available to the public through the GIF Technical Secretariat, which has resulted in several publications that demonstrate the EMWG methodology for the economic assessments of Gen-III and Gen-IV systems, as well for cogeneration applications, such as hydrogen production.

G4ECONS v2.0 was also benchmarked against the economic tools of the International Atomic Energy Agency (IAEA), namely the Nuclear Economics Support Tool (NEST) and the Hydrogen Economic Evaluation Programme (HEEP), and the results have been published in peer-reviewed publications. Lessons learnt from the benchmarking exercise and from the feedback of users has informed the refinement of the G4ECONS tool. The EMWG released the new version, G4ECONS v3.0, with an improved user interface, in October 2018.

In 2016, the EMWG started to investigate the challenges and opportunities for the deployment of Gen-IV systems in emerging energy markets with an increasing share of renewable energy resources. The terms of reference for the EMWG were amended in 2018 to incorporate the expanded mandate so as to inform the GIF Policy Group and the Experts Group on the policies and R&D needs for the future deployment of Gen-IV systems.

Since October 2016, the EMWG has been working collaboratively with the Generation IV International Forum's Senior Industry Advisory Panel (SIAP) to investigate challenges and opportunities for deployment of Gen-IV systems in electricity markets with a significant penetration of renewable energy resources and to produce a position paper for the Policy Group. An abridged version of the EMWG position paper on the impact of increasing shares of renewables on the deployment prospects of Gen-IV systems was presented at the 4th GIF Symposium (2018) and an executive summary was posted on the GIF website (www.gen-4.org/gif/jcms/c_117863/2018-gif-symposium-proceedings). The study found that Gen-IV systems need to be more flexible compared to current reactors for deployment in low-carbon energy systems, and such requirements are already being proposed by the utilities. Large-scale energy-storage and cogeneration applications, for example, would allow flexible dispatch while ensuring high-capacity utilization. Nuclear-renewable hybrid energy systems with adequate energy-storage and cogeneration applications could, in this way, meet flexible demands from the grid while operating power generators at full capacity to ensure overall economically viable operation. However, such flexibility considerations impose additional requirements on the R&D of Gen-IV systems.

Activities in 2020

In 2020, the EMWG identified two priorities for its 2021 work program:

Advanced nuclear technology cost reduction strategies and a systematic economic review: The EMWG will evaluate nuclear cost reduction strategies based on past/current lessons learnt, along with assessments of readiness levels for the technologies and the potential for cost reduction. Key areas for nuclear cost reduction and enabling technologies will be researched under design, and construction/production, as well as project management. EMWG members will research specific strategies and technologies (e.g. functional containment, advanced concrete, machine learning) to assess cost reduction potential, applicability to Gen-IV technologies and technology readiness, as well as to identify further RD&D that may be needed to advance the strategy. This activity will develop a GIF systematic economic review process, where cost reduction strategies will be shared among GIF members (via the ETWG) and used for training and publication purposes. Results and the methodology developed can inform the design and selection of future cost reduction demonstration projects. Information and updates on cost reduction strategies and the study outcomes will be posted on an online repository ("Nukipedia").

The paper will outline a systematic economic review process to:

- identify opportunities/conditions for cost reduction under the categories of design, construction/production, and project management, emphasizing cost reductions for the balance of plant, with varying applicability to all Gen-IV technologies;
- provide a methodology to review progress in designs towards reducing costs;
- inform and provide training on cost reduction strategies for reactor designers and other stakeholders.

Advanced nuclear technology private financing: The EMWG has established a working group of financing experts to identify the changes that need to be made to international, low-carbon, sustainability principles in order to enable private sector financing of nuclear power, and particularly Gen-IV technologies.

The paper will consider:

- the enablers required to facilitate private financing of nuclear projects;
- the risks associated with nuclear projects, how such risks are mitigated and how these risks may vary (if at all) with Gen-IV technologies (adapted from existing materials);
- an assessment of international regimes on sustainable financing, including:
  - why nuclear projects are sustainable developments;
  - the environmental, social and corporate governance ("ESG") metrics (i.e. those used by investors to assess companies and projects to determine whether an institution should be invested), and what needs to change, if anything, to create a level playing field for energy technologies and to ensure that nuclear energy is assessed in line with other energy projects;
  - the various taxonomies and how nuclear power meets the "do-no-harm" principle;
  - the Green Bond Principles, and how nuclear meets these principles.

David Shropshire
Co-Chair of the EMWG

Megan Moore
Co-Chair of the EMWG

Fiona Reilly
Co-Chair of the EMWG

Education and Training Working Group

Background/terms of reference

GIF's Education and Training Working Group (ETWG) started as a task force in November 2015 and was elevated to a working group in 2020. It serves as a platform to enhance open education and training (E&T), as well as communication and networking of people and organizations in support of the Gen-IV International Forum. Several objectives of the working group focus on promoting E&T by developing the webinar series dedicated to Gen-IV systems and related cross-cutting topics, advertising these at the international level, converting all the archived GIF webinars to videos, and creating and maintaining a modern, social media platform (such as LinkedIn[1]) to exchange information and ideas on GIF R&D topics, as well as on related GIF E&T activities.

Main achievements

Numerous tools exist today designed to increase knowledge on a specific study. There is the traditional curriculum developed at universities for undergraduate and graduate students. Distance learning is also used at different universities and is undertaken via various technological media where the training course can be delivered simultaneously to students off campus. Massive open online courses (MOOCs) are free online courses aimed at unlimited participation and open access via the Internet. Because of its easy access, the ETWG decided to create a series of webinars, exploiting this modern Internet technology, so as to reach a broader audience long before the pandemic obliged organizations to more widely use this technology. To promote training in Gen-IV systems and to ensure that a knowledgeable workforce exists, GIF's ETWG therefore created and made available to the public since September 2016 a series of webinars on topics specific to advanced reactor systems. These webinars are intended to be of interest not only to students currently pursuing formal education in universities but also to those already in the workforce, who may be in need of a refresher course or a better understanding of a specific topic, but most importantly to the more general public. GIF is therefore developing and proposing world-class webinars that will also be useful for people like quality assurance officers, data validators, technicians, managers, regulators and others who may benefit from an enhanced understanding of advanced reactor concepts in their work. Forty-eight webinars have been developed thus far (See Table ETWG-1), recorded and archived, and can be found at www.gen-4.org/gif/jcms/c_82831/webinars.

Involving the junior workforce is a priority for the ETWG, and consequently the winner of the American Nuclear Society (ANS) 2019 "Pitch your PhD competition", Dr Coddy Wiggins, was invited to present a webinar in December 2020 entitled "Development of Multiple-Particle Positron Emission Particle Tracking for Flow Measurement".

As depicted in Table 1, a total of 12 webinars were presented and archived in 2020, with subjects varying from Gen-IV reactor systems and fuels to the sustainability of the fuel cycle. Each presenter is a renowned expert on the subject matter and is internationally recognized as being so.

Twelve webinars are planned in 2021 and are displayed in Table ETWG-2. The presenter scheduled for December 2021 will be the winner of the first "Pitch your Gen-IV research competition", and will be announced at the next Experts Group/Policy Group meeting scheduled for May 2021.

Table ETWG-2. GIF Webinar Series (January 2021 to December 2021)

Presenter	Title of webinar	Webinar presentation
Dr. Nathalie Chauvin, CEA France	MOX fuel for advanced reactors	January 2021
Dr David Peeler, PNNL, US	Overview of waste treatment plant, Hanford site	February 2021
Prof. Nawal Prinja, JACOBS, UK	Introducing new plant systems design (PSD) code	March 2021
Mr Etsuo Ishitsuka, JAEA Japan	Experience of HTTR licensing for Japan's new nuclear regulation	April 2021
Dr Isabella Van Rooyen, INL, US	Advanced manufacturing for Gen-IV reactors	May 2021
Dr François Baque, CEA, France	In-service inspection and repair developments for SFRs and extension to other Gen-IV systems	June 2021
Ms Jessica Lovering, Carnegie Mellon University, US Winner of the ANS 2020 Pitch your PhD competition	Evaluating changing paradigms across the nuclear industry	July 2021
Mr Vince (Alois) Chermak, INL, US	Comparing and contrasting approaches to quality assurance for nuclear applications	August 2021
Dr Julia Kyzina, IPPE, Russia	Experimental R&D in Russia to justify sodium fast reactors	September 2021
Dr John Vienna, PNNL, US	Nuclear waste management strategy for molten salt reactor systems	October 2021
Dr Jun Wang, University of Wisconsin, Madison US	Geometry design and transient simulation of a heat pipe micro reactor.	November 2021
1st Winner of the "Pitch your Gen-IV research 2021 competition"	To be determined.	December 2021

1. www.linkedin.com/groups/8416234.

Table ETWG-1. The GIF webinar series, presented and archived between 2016 and 2020

	2016 (4 webinars)	2017(12 webinars)	2018(8 webinars)	2019(12 webinars)	2020(12 webinars)
Introduction	**Atoms for peace** –John Kelly, US **Introduction to nuclear reactor design** – Claude Renault, France			**European sodium fast reactor: An Introduction** – Konstantin Mikityuk, Switzerland	
Gen-IV systems	**Sodium-cooled fast reactor** – Bob Hill, US	**Lead fast reactor** – Craig Smith, US **Gas-cooled fast reactor** – Alfredo Vassile, France **Very-high-temperature reactors** – Carl Sink, US **Supercritical water reactors (SCWR)** – Laurence Leung, **Canada Fluoride cooled-high-temperature reactors** – Per Peterson, US **Molten salt reactors** – Elsa Merle, France	**MYRRHA: An accelerator-driven system based on LFR technology** – Hamid Ait Abderrahim, Belgium **Molten salt actinide recycler & transforming system with and without Th-U support: MOSART** – Victor Ignatiev, Russia	**Lead containing mainly isotope Pb-208: New reflector for improving safety of fast neutron reactors** – Evgeny Kulikov, Russia **Gen-IV coolants quality control** – Christian Latge, France **Czech experimental programme on MSR technology development** – Jan Uhlir, Czech Republic	**GIF VHTR Hydrogen Production Project Management Board** – Sam Suppiah, Canada **Thermal hydraulics in liquid metal fast reactor** – Antoine Gerschenfeld, CEA, France **Micro reactors: A technology option for accelerated innovation** – D.V. Rao, US **Overview of small modular reactor technology development** – Frederik Reitsma, IAEA
Operational experience		**Feedback Phenix and Superphenix** – Joel Guidez, France	**Design, safety features and progress of HTR-PM** - Yujie Dong, China **ASTRID: Lessons learned** – Gilles Rodriguez, France **Advanced Lead Fast Reactor European Demonstrator (ALFRED) project** – Alessandro Alemberti, EC **Russia BN 600 & BN 800** – Ilya Pakhomov, Russia	**Safety of Gen-IV reactors** – Luca Ammirabile, EC **The ALLEGRO experimental gas-cooled fast reactor project** – Ladislav Belovsky, Czech Republic **Passive decay heat removal** – Mitchell Farmer, ANL US	**Molten salt SFR safety design criteria (SDC) and safety design guidelines (SDGs)** – Shigenobu Kubo, JAEA, Japan **Reactor safety evaluation: A US perspective** – David Holcomb, ORNL, US
Gen-IV cross-cutting topics		**Energy conversion** – Richard Stainsby, UK **Estimating costs of Gen-IV systems** – Geoffrey Rothwell, NEA	**Materials challenges for Gen-IV reactors** – Stu Maloy, US **Proliferation resistance and physical protection of Gen-IV reactor systems** – Robert Bari, US		**Maximizing clean energy integration: The role of nuclear and renewable technologies in integrated energy systems** – Shannon Bragg-Sitton, INL, US **Global potential for small and micro-reactor systems to provide electricity access** – Amy Schweikert, US **Neutrino and Gen-IV reactor systems** – Jonathan Link, US
Fuel types		**General considerations on thorium as a nuclear fuel** – Franco Michel-Sendis, NEA **Metallic fuels for SFRs** – Steven Hayes, US		**Advanced gas reactor TRISO particle fuel** – Madeline Feltus, USA	**Performance assessments for fuels and materials for advanced nuclear reactors** – Daniel LaBrier, ISU, US
Sustainability and the fuel cycle	**Closing the fuel cycle**– Myeung Seung, Korea	**Sustainability: A relevant approach for defining future nuclear fuel cycles** – Christophe Poinssot, France		**Scientific and technical problems of closed nuclear fuel in two-component nuclear energetics** – Alexander Orlov, Russia	**Comparison of 16 reactors' neutronic performance in closed Th-U and U-Pu cycles** – Jiri Krepel, PSI, Switzerland
Winners of the Pitch 2018 competition				**Formulation of alternative cement matrix for solidification/ stabilization of nuclear waste** – Matthieu de Campos, France **Interactions between sodium and fission products in case of a severe accident in a sodium-cooled fast reactor** – Guilhem Kauric, France **Security study of sodium gas heat exchangers in the frame of sodium-cooled fast reactors** –Fang Chen, France	**Development of multiple particle positron emission particle tracking for flow measurement** – Cody Wiggins, VCU, US

As of December 2020, attendance during the live webcasts totalled 3 990. It is worth mentioning that attendance during the calendar year (CY) 2019 was 2 179. The number of viewings of the recorded webinars in the online archive is 5 657, a strong increase when compared to attendance in CY 2020, which totalled 3 747. Total viewing over the four-year period was 9 647.

Participants in GIF webinars include representatives from organizations such as federal agencies, national laboratories, state agencies, universities, international organizations, contractors and commercial organizations. Figure ETWG-1 presents a comparison of GIF webinar attendance distribution for the 36 webinars presented at the end of CY 2019 against the 48 webinars presented in CY 2020. The figure shows an increase of viewing by international organizations (i.e. 35% of viewers were from international organizations in CY 2019, and this figure increased to 54% in CY 2020).

The increase of international participation is also reflected by an increase in the number of countries that are participating in either the live webinar presentation or watching the recorded webinars (Figure ETWG-2)

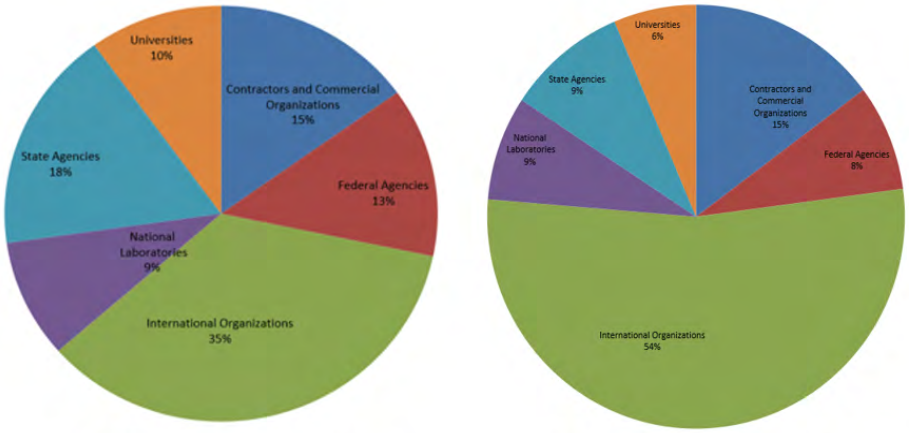
GIF continues its efforts to advertize the webinars by presenting them at different venues. A paper summarizing the ETWG's activities, entitled: "Gen-IV Education and Training Working Group Webinar Initiative" was presented at the virtual American Nuclear Society winter meeting (16-19 November 2020), paper No. 32874.

To facilitate the advertisement of the webinars, a handout containing a list of all the webinars that have been presented, as well as those proposed in future, has been created and is available during each live presentation. Participants can download the flyer as a PDF file (see Figure ETWG-3).

Looking ahead

The ETWG is planning to organize a "Pitch your Gen-IV research competition" that will be launched on 1 February 2021 (see Figure ETWG-4). The

Figure ETWG-1. Comparison of participants by organization type in 2019 and 2020



1a: GIF Webinar attendance distribution in 2019

1b: GIF Webinar attendance distribution in 2020

Figure ETWG-2. Comparison of international participation in the GIF webinar series

October 2019

Participants from **20 countries** have listened to at least one webinar

May 2020

Participants from **41 countries** have listened to at least one webinar

December 2020

Participants from **58 countries** have listened to at least one webinar

Figure ETWG-3. Handout advertising the GIF webinar series

Figure ETWG-4. Flyer announcing the "Pitch your Gen-IV research competition"

Pitch your Gen-IV research competition will be open to: a) currently enrolled PhD students and b) post-doctoral fellows and junior researchers who defended their PhD after 1 January 2019. The research must be related to GIF advanced nuclear energy systems and could be either an independent research project or one that concerns a research mentor. Participants will be asked to submit a short executive summary, and the 25 pre-selected candidates will be invited to record a three-minute video pitch of their project.

The expected schedule is as follows:

- 1 February 2021 – Executive summary submission opens
- 28 February 2021 – Executive summary submission closes
- Mid-March 2021 – 25 finalists selected
- 31 March 2021 – Video submission due
- 1 April 2021 – Popular voting begins
- 30 April 2021 – Popular voting ends
- May 2021 – Winners announced at the EG/PG meeting

Patricia Paviet
Chair of the ETWG, with contributions from ETWG members

Proliferation Resistance and Physical Protection Methodology Working Group

The Proliferation Resistance and Physical Protection Working Group (PRPPWG) was established to develop, implement and foster the use of an evaluation methodology so as to assess Gen-IV nuclear energy systems with respect to the GIF PR&PP goal, whereby:

> "Generation IV nuclear energy systems will increase the assurance that they are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism."

The methodology provides designers and policymakers with a technology-neutral framework and a formal comprehensive approach to evaluate, through measures and metrics, the proliferation resistance (PR) and physical protection (PP) characteristics of advanced nuclear systems. As such, the application of the evaluation methodology offers opportunities to improve the PR&PP robustness of system concepts throughout their development cycle. The working group released the current version (revision 6) of the methodology for general distribution in 2011,[1] and Japanese and Korean translations of the methodology report have been produced for national use.

Since 2018, the main focus of the PRPPWG has been on updating the white papers on proliferation resistance and physical protection robustness of the six GIF design concepts. This is a joint effort with the System Steering Committees (SSCs) and provisional System Steering Committees (pSSCs) of the six Gen-IV technologies. The first versions of these white papers were produced in the period

Table PRPP-1. System designs considered in the white paper updates

GIF System	System options considered in the update	Design tracks considered in the update	Comments
GFR	Reference concept	2400MWt GFR ALLEGRO as a GFR demonstrtor (EU)	Other Gen- IV designs include: EM2 (GA) ALLEGRO (V4G4) High-energy neutron modular helium reactor (HEN MHR) (CEA-ANL and GA-AREVA)
LFR	Large system	ELFR, (EU))	These are the three reference design configurations discussed in the GIF-LFR System Research Plan
	Intermediate system	BREST-OD-300, (RF)	
	Small transportable	SSTAR, (US)	
MSR	Liquid-fuelled with integrated salt processing	MSFR (EU), MOSART (RF)	There is a wide variety of MSR technologies, encompassing thermal/fast spectrum reactors, solid/ fluid fuel, burner/breeder modes, Th/Pu fuel cycles, and on-site/ off-site fissile separation.
	Solid-fuelled with salt coolant	Mk1 PB-FHR (US)	
	Liquid-fuelled without integrated salt processing	IMSR (Canada)	
SCWR	Pressure vessel	HPLWR (EU) (thermal)	Most concepts are based on "familiar' technology, such as light water coolant, solid fuel assemblies, and batch refuelling. Implementation of Th and Pu fuel cycles creates additional, special nuclear materials of concern.
		Super FR (Japan)	
		Super LWR (Japan) (thermal)	
		CSR 1000 (China) (thermal)	
		Mixed spectrum (China)	
		Fast core (RF)	
	Pressure tube	Canadian SCWR (Canada) (thermal)	
SFR	Loop configuration	JSFR (Japan)	Expect key PR&PP issues to be tied to fuel handling, TRU inventory and fuel cycle options.
	Pool configuration	ESFR (EU), BN-1200 (Russia), KALIMER-600 (Korea)	
	Small modular	AFR-100 (US)	
VHTR	Prismatic fuel block	Modular HTR, Framatome (ANTARES)	SC-HTGR is a follow on of the ANTARES and the GA GT-MHR development. Expect some PR&PP differences between the prismatic block and pebble bed design.
		SC-HTGR, Framatome (US)	
		GT-MHR General Atomics (US)	
		GT-MHR OKBM (Russia)	
		GTHTR300C, JAEA (Japan)	
		NHDD, KAERI (Korea)	
	Pebble bed	Xe-100, X-Energy (US)	
		HTR-PM (China)	

1. www.gen-4.org/gif/jcms/c_40413/evaluation-methodology-for-proliferation-resistance-and-physical-protection-of-generation-iv-nuclear-energy-systems-rev-6

2008-2011. The white papers were included as individual chapters of an integrated report that was published in 2011 and is available on the GIF website.[2] The papers are being updated according to a revised, common template. The current update reflects changes in designs, new tracks that were added (see Table PRPP-1) and advancements in the designing of the six GIF systems, with enhanced intrinsic PR&PP features.

Individual white papers, after endorsement by both the PRPPWG and the responsible SSC/pSSC, will be transmitted to the EG for approval and published as GIF documents. Cross-cutting PR&PP aspects that transcend all six GIF systems are also being investigated. The plan is to complete the white paper updates in 2021. Below is a summary status of each white paper as of the end of 2020.

- LFR – paper endorsed by the PRPPWG and the LFR pSSC; EG completed review.
- SFR – paper endorsed by the PRPPWG and the SFR SSC; EG completed review.
- SCWR – paper incorporated comments from the SSC and endorsed by the PRPPWG; awaiting endorsement by the SSC.
- MSR – paper incorporated comments from the pSSC and endorsed by the PRPPWG; awaiting endorsement by the SSC.
- VHTR – PRPPWG presented a draft of the white paper at the last VHTR SSC meeting (October 2020); the final draft is being reviewed and revised by the PRPPWG before being released to the SSC for endorsement.
- GFR – early draft reviewed by the PRPPWG and the GFR SSC; a final draft is under preparation to incorporate comments from the PRPPWG and the GFR SSC.

The PRPPWG holds monthly teleconferences to report on the progress of group and member activities. In 2020, Russia appointed Mr Vladimir Artisyuk from Rosatom as a new member of the PRPPWG.

The group maintains an annually updated bibliography of official publications, of publications referring to the PR&PP methodology and of relevant issues. The latest edition, revision 7, was published in March 2020. It is available on the GIF website.[3]

The PRPPWG maintains regular exchanges with the IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) and the agency's Department of Safeguards. An IAEA representative participates regularly in the PRPPWG activities. The PRPPWG made a presentation at the 14th GIF-IAEA Interface meeting on 8 July 2020, highlighting collaboration on the INPRO PR methodology that the IAEA plans to update, as well as on emerging safeguards issues related to the deployment of small modular reactors and micro reactors. Collaboration with the RSWG was strengthened through personal exchanges at each group's meeting. PRPPWG representatives attended the 31st and 32nd meetings of the RSWG. A discussion was initiated to explore the interfaces between safety, security and safeguards.

The group held its 31st annual meeting on 9-11 December 2020 via video conference. All member countries, including, for the first time, China and South Africa, attended the meeting and delivered country reports. Representatives from the IAEA and the RSWG also participated. The meeting was dedicated to discussing the advancement of the white papers, planning of new activities – namely cross-cutting topics from the white papers – and developing the work plan for the period 2021-2022.

Giacomo Cojazzi
Co-Chair of the PRPPWG

Lap-Yan Cheng
Co-Chair of the PRPPWG

2. www.gen-4.org/gif/jcms/c_40414/proliferation-resistance-and-physical-protection-of-the-six-generation-iv-nuclear-energy-system.

3. www.gen-4.org/gif/jcms/c_101559/gif-prppwg-bibliography.

Risk and Safety Working Group

The Risk and Safety Working Group (RSWG) has been an active methodology working group since 2005, with a mission to establish a harmonized approach to, and provide assessment tools for, the risk and safety of Gen-IV systems. RSWG membership currently includes representatives from Canada, China, the European Union, France, Japan, Korea, South Africa, Russia, the United Kingdom and the United States as a forum of advanced reactor designers and regulators. The IAEA also participates as an observer. Prior to 2020 the RSWG:

- proposed a set of broad safety principles and attributes based on GIF safety and reliability goals as input to R&D plans for specific Gen-IV design tracks;
- developed a technology-neutral, comprehensive, integrated safety assessment methodology (ISAM) as a toolkit to evaluate risk and safety for all six systems based on a consistent framework, and supported its implementation for specific Gen-IV design tracks;
- established technical interfaces with the IAEA and the NEA Working Group on the Safety of Advanced Reactors (WGSAR) under the NEA Committee on Nuclear Regulatory Activities (CNRA).

Ongoing RSWG projects include the development of white papers on: 1) a pilot application of ISAM to assess its impact on the design and licensing of select, Gen-IV design tracks; and 2) preparation of system safety assessments as summaries of high-level safety design attributes and remaining R&D needs. Both of these white papers will be elaborated in close co-ordination with the respective GIF System Steering Committees (SSCs). Published white papers and system safety assessment reports can be downloaded from the GIF RSWG web page: www.gen-4.org/gif/jcms/c_9366/risk-safety. Development of safety design criteria and guidelines for specific Gen-IV systems are also an ongoing collaborative effort between the RSWG and SSCs to establish the basic requirements for design, fabrication, construction, testing, and operation of Gen-IV systems.

As a result of the ongoing COVID-19 pandemic, the RSWG held both of its 2020 semi-annual meetings in virtual format through online meetings. A major RSWG accomplishment in 2020 was the update of the *GIF Basic Safety Approach* report (www.gen-4.org/gif/jcms/c_9366/risk-safety). The updated report captures post-Fukushima recommendations and requirements to ensure a level of safety for Gen-IV systems compatible with the expectations of safety authorities. It also provides common definitions for the plant states considered in a design and their alignment with levels of defence in depth, reinforces the independence of prevention/mitigation features at different defence-in-depth levels, and clarifies the concepts of design extension conditions and practically eliminated accidents.

Efforts also continued in 2020 towards a new RSWG-WGSAR joint initiative on the development of a risk-informed approach to the selection of licensing basis events and the safety classification of systems, structures and components. Novel aspects of numerous Gen-IV systems make the identification of hazards, initiating events and event sequences a challenge, requiring a systematic approach for their design and licensing. Critical examination of these designs, their safety behavior, and all aspects of their operations is key to addressing uncertainties, mainly due to initially limited information. The proposed risk-informed approach offers a process that combines both deterministic and probabilistic input in a complementary way for a systematic search of accident scenarios, which enables a classification of the responding plant equipment based on their risk significance.

It aims to establish event sequence categories that must be included in design assessments and reviews, integrate the deterministic inputs and risk insights so as to identify axnd classify initiating events and event sequences in each category, evaluate the event sequences against the regulatory criteria based on defined frequency-consequence targets, classify the plant equipment to identify risk-significant items, and define design-basis accidents and design extension conditions.

Having completed most of its missions, in 2019, SFR Safety Design Criteria Task Force (SDC TF) members joined the RSWG to contribute to the drafting of safety design criteria for other Gen-IV systems, including the lead- and gas-cooled fast reactors, as well as very-high-temperature reactors. The RSWG will inherit the remainder of work on updating the Safety Design Guidelines Report for SFR structures, systems and components based on comments received from the IAEA and WGSAR in October 2020. IAEA and WGSAR comments will be addressed and incorporated into the next version of the report in 2021. SDC TF members also support the implementation of the proposed risk-informed approach for GIF SFR design tracks in an effort to develop best-practice guidelines for its application and to ensure its consistency with the SFR SDC and *Safety Design Guidelines* (SDGs) completed in earlier years.

The RSWG, with the support of new SDC TF members, plans a more proactive participation in the new IAEA initiative on the development of safety standards for small modular reactors (SMRs) since non-LWR SMRs have many technical similarities to GIF systems. Reflecting GIF experience in the development of safety design criteria and guidelines for specific Gen-IV systems, in 2020, the RWSG already made some important contributions to the IAEA initiative by supporting the development of a safety approach/methodology for non-LWR SMRs, assessing the applicability of design requirements in safety considerations, and making direct contributions to the IAEA's new safety document: *Towards a Technology Neutral Nuclear Safety and Regulatory Framework: Applicability of IAEA Safety Standards to SMRs.*

Tanju Sofu
Chair of the RSWG, with contributions from RSWG members