GEN IV International Forum
Expertise | Collaboration | Excellence

GIF structure as developer of Gen IV reactor concepts

Virtual 15th GIF-IAEA Interface Meeting
June 29-30, 2021

Nobuchika KAWASAKI (GIF PD)

GIF as developer of Gen IV reactor concepts

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Policy Group (PG)

Expert Group (EG)

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Senior Industry Advisory Panel

Policy Secretariats
Technical Secretariats

Methodology / Opportunity Working Group (WG)

- Risk and Safety Working Group (RSWG)
- Proliferation Resistance and Physical Protection assessment methodology Working Group (PRPPWG)
- Economic Modelling Working Group (EMWG)
- Education & Training Working Group (ETWG)

Task Force (TF to solves specific issue within the limited time scale)

- Advanced Manufacturing and Material Engineering Task Force (AMME-TF)
- Research & Development Infrastructure Task Force (RD-TF)
- Non-Electric applications of Nuclear Heat interim Task Force (NEaNH-iTF)

System Steering Committee (SSC)

Sodium-cooled Fast Reactor (SFR)	System Integration Assessment (SIA) Advanced Fuel (AF) Safety and Operation (SO) Component Design & Balance-Of-Plant (CD&BOP)
Very High Temperature Reactor (VHTR)	Fuel and Fuel Cycle (FFC) Code Verification (CMV) Materials (MAT) Hydrogen Production (HP) (System Integration Assessment: SIA)
Supercritical-water-cooled Reactor (SCWR)	Thermal-hydraulics and Safety (TH) Water Chemistry and Materials (CM) (System Integration Assessment: SIA)
Gas-cooled Fast Reactor (GFR)	Conceptual Design and Safety (CDS) (Fuel and Core Materials: FC)
Lead-cooled Fast Reactor (LFR)	
Molten Salt Reactor (MSR)	

Project Management Boards (PMB)

13 countries and 1 organization to develop 6 types of Gen IV reactors with Gen IV methodologies.

GIF activity concept map

Link-GIF-Partners
Link-Partners-activities

Outside GIF | Inside GIF

Private sectors

Non national SMR developers

Interface with GIF Partners

PG/EG
Driver

SSC
Reactor concepts developer

SIAP
Opportunity supplier

WG/TF
Methodology developer
Opportunity developer

GIF-IAEA interface meeting including Non-electrical applications & Hybrid energy systems Field

International Whole Nuclear Developer especially safety standards

GIF-IAEA Cooperate Matrix for Reactor Fields (FR, HTR, MSR, SCWR), Non-electrical applications & Hybrid energy systems Field, Economics Field, Safety Field, PR&PP Field, Education and Training Field, Research and Development Infrastructure Field, Modelling and Simulation Field

Non-electrical applications & Hybrid energy systems Field

A dialogue on the role that nuclear energy can play in clean energy systems of the future. To bring nuclear energy from traditional, nuclear-only fora to a broader, cross-sectoral discussion on clean energy at the ministerial level.

GIF as
6 types of Gen IV system developer
(Theoretically from SMRs to Large reactors if it fit to economical goal.
Historically country-base commitments.)

Interface with GIF Partners

Interface with GIF Partners

AMME-TF

AMM technology developments

(Potential partner)

International organization that represents the global nuclear industry. More than 177 vendors/utilities, promoting understand of nuclear energy, developing common industry positions, and contributing to the energy debate.

Intergovernmental agency that facilitates co-operation in nuclear safety, technology, science, environment and law. Especially **market, SMR, innovation, NI2050 & regulation needs. (including WGSAR)**

Other energy sources | Gen III+ | International Standards Organizations | Regulators

GIF-IAEA Cooperate Matrix

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MSR Field

Action item	Comments
External review of IAEA TRS GIF to be considered.	

SCWR Field

Action item	Comments

HTR Field

Action item	Comments
SDC for HTGRs / VHTR Other topics identified On Safety: • Possible GIF review of the TRS (IAEA CRP Outputs) when finalized. • Availability of detailed design and cost information is lacking to do economic assessment / limited scope INPRO methodology assessments on safety and economics – (Action GIF: Fütterer to check availability of cost information in fuel group)	**VHTR SDC:** • Develop similar to SFR including review by IAEA and/or NEA, GIF. GIF is following the final output of the IAEA CRP for Modular HTGR Safety Design, i.e. a TRS under preparation by IAEA-NE. (Delayed pul involved in the develo • Alternatively develop • TECDOC-1936 on App Technologies Intended and HTGR. • Specialists in HTGR sa of Safety S VHTR SSC **Economics:** • INPRO is i economics this technology area. • Requires detailed desi the GIF VHTR fuel wor shared in IAEA meetin • New CRP to be define

FR Field

Action item	Comments
Collaboration on R&D and • documents received. Formal response being formalised by IAEA. • Discussion will be made on the cooperation between	• Exchange of information on SFR and LFR system developments FR meetings (Nov 17-20, 2020 and d on 30 March – 2 April 2021 • Current status of the SFR SDC/SDG and IAEA review presented. • GIF has recently requested the IAEA to review the SDC for LFR • Cooperation in areas of Education and Training and Research Infrastructures to be addressed in cross cutting topics (as same

Safety Field

Action item	Comments

PR&PP Field

Action item	Comments/Status
Continuous I collaboratior related activ Targeted effc mutual inter en identif coming ac WPs: LF dissemi SCWR, (complet PR&PP I ESARDA paper Crosscu INPRO r update IAEA SM PRPPW GIF 202	

Economics Field

Action item	Comments
Continue discussions on areas of cooperation between GIF and NENP/PESS on economics. New areas identified: • Multi-criteria evaluation to study of thresh effects	• G4-ECONS V3 released in summer 2018: Benchmark exercises completed and results available and reasons for differences well understood. • The GIF activities initially focused on cost calculation tools will probably be extended to a more comprehensive economic analysis for integrated systems, as well as a focus on flexibility (joint workshop held between System Steering exibility and other • IAEA-NEST tool includes multiple cost models covering open and closed fuel cycles, multiple reactors, sensitivity analysis, comparisons to alternative energy sources, etc. Currently migrating NEST to a modular software platform from Excel and including GUI for ease of use by Member States.

Reactor Concepts

Methodologies

Non-electrical applications & Hybrid energy systems Field

Action item	Comments
E in	tems; co-generation; energy storage. ities for Cogeneration with Nuclear rial Applications published and

Markets

GIF participation to:
• *to be updated*

IAEA Responsible	GIF Responsible
A. Van Heek (NE) B. Boyer (NE)	Megan MOORE (EMWG) Fiona REILLY (EMWG) David SHROPSHIRE (EMWG)

Research and Development Infrastructure Field

Action item	Comments
• Sharing information on existing DB and tools. • IAEA LMFNS DB to be regularly updated	• GIF r at Ja htt tas • GIF r nee • Shar ager HTG • ICER to in rese

Modelling and Simulation Field

Action item	Comments
• To be implemented via the TWGs • (FR, GCR, SCWRs, future perhaps also SMRs and MSRs)	• Number of on-going CRPs in this area related to benchmarking. • A focus the rel

IAEA Respo
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T. Jevremovic for H
PESS to decide (NI

Education and Training Field

Action item	Comments
	IAEA Portals on knowledge management for SFR and HTGR available Training Courses developed by different technologies Educational simulators on fast reactor and HTGR planned (not funded) Specifications under development. Status of webinars and LinkedIn exchanged Webinars GIF (can also consider IAEA presenters and topics associated with IAEA reports)

training course to be

Hard and Soft Infrastructures/ Fundamentals

Public open gates of Gen IV technologies

1. GIF monthly webinars, news letters, annual reports, etc. in GIF-HP
2. Special webinar/open events/ like Special Webinar: Progress and Future Prospects toward Deploying GEN IV reactors as Advanced Nuclear Energy Systems as 20th Anniversary Celebration, presently planning FORUM industry 2022
3. Open publications on Rector developments such as "Handbook of Generation IV Nuclear Reactors"
4. GIF open methodologies including Safety documents and PRPP evaluation methodologies
5. GIF methodological tools: ISAM, G4ECONS
6. Open activities in WGs/TFs (AMME survey, Future workshops including Non-Electric application of Nuclear Heat field)

Featured Recent GIF Publications

- GIF 2020 Annual Report
- 2018 GIF Symposium (We are planning Forum GIF INDUSTRY 2022 for future public event)
- GIF R&D Outlook for Generation IV Nuclear Energy Systems: 2018 Update
- Handbook of Generation IV Nuclear Reactors, 2016 (Presently updating)
- The High Temperature Gas-Cooled Reactor, 2020 (M. Fütterer, et al., Reference Module in Earth Systems and Environmental Sciences, https://doi.org/10.1016/B978-0-12-409548-9.12205-5)
- Sodium Fast Reactor: Safety Design Guidelines on Safety Approach and Design Conditions (SA SDG), 2020
- LFR Safety Design Criteria (SDC), 2021
- Lead-cooled Fast Reactor (LFR) System Safety Assessment, 2020
- An Update of the GIF Proliferation Resistance and Physical Protection White Papers for the Six Gen IV Systems,2019 (Cipiti, B. et al, 9th INMM/ESARDA/INMMJ Joint Workshop. See PRPPWG-BIBLIOGRAPHY Rev. 8 April 2021)
- The GIF Proliferation Resistance and Physical Protection methodology applied to GEN IV system designs, 2019 (Cheng, L. et al., ESARDA'19: ESARDA Symposium 2019 - 41st Annual Meeting See PRPPWG-BIBLIOGRAPHY Rev. 8 April 2021)
- NICE Future Initiative/ Flexible Nuclear Energy for Clean Energy Systems, Chapter 13: Generation IV International Forum: Delivering Next-Generation Nuclear Systems, 2020
- Impact of Increasing Share of Renewables on the Deployment of Generation IV Nuclear Systems, 2018
- GIF workshop on R&D Infrastructures needs and opportunities, 2020
- R&D Infrastructure Task Force Final Report, 2021


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GIF-IAEA relationship

Common activities

GEN IV International Forum
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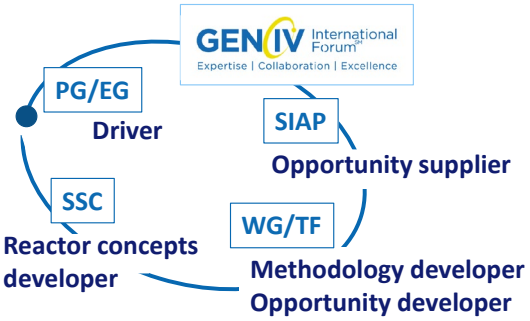
International country groups developing Gen IV reactors.
12 active countries, with 6 Reactors SCs, 7 Methodology/Opportunity WG/TFs and SIAP.



To commonly develop/review in System and methodology fields
FR, HTR, SCWR, MSR Fields
Safety, PR&PP Fields
Economics Field

To share strategy/platform
Non-electrical applications & Hybrid energy systems Field

To share strategy/platform
Research and Development
Infrastructure Field
Education and Training Field
Modelling and Simulation Field

IAEA International Atomic Energy Agency

International Whole Nuclear Developer especially safety standards

IAEA TECDOC SERIES

Standards

Tools, databases, and Coordinated Research Projects

Common interests

Steering meeting : GIF-IAEA interface meeting with Cooperate Matrix
Webinars/ Publications : List
Participating Meetings : IAEA side: GIF PG meeting, GIF RSWG ,PRPPWG, EMWG meetings
GIF side: IAEA TWG-FR, TWG-GCR, IAEA-INPRO Steering Committee

GIF-NEA relationship

common activities

International country groups developing Gen IV reactors.
12 active countries, with 6 Reactors SCs, 7 Methodology/Opportunity WG/TFs and SIAP.

Intergovernmental agency that facilitates co-operation in nuclear safety, technology, science, environment and law.
Especially **market, SMR, innovation, NI2050 & regulation needs. (including WGSAR)**

Task Force on Safety Design Criteria

The Activities of SDC-TF

The GIF Policy Group established the safety and reliability goals for Generation-IV Nuclear Energy Systems in 2002 in a publication titled "Generation-IV Nuclear Energy Systems under the GIF Roadmap" and the GIF Risk & Safety Working Group proposed the "Basis for safety approach for design & assessment of Generation-IV Nuclear Systems". In addition, the SFR System Steering Committee set the design goals for the SFR systems in 2007 in the publication "SFR System Research Plan". It is recognized that domestic codes and standards will be used when developing the detailed designs of structures, systems and components. However, there is a large gap between the high-level safety fundamentals and the detailed codes and standards, as illustrated in below figure.

Figure 1: Hierarchy of Safety Standards

Risk & Safety Working Group (RSWG)

Generation IV nuclear energy systems will aim to achieve the following safety goals:

- to excel in safety and reliability;
- to have a low likelihood and degree of reactor core damage;
- to eliminate the need for offsite emergency response.

Lead-cooled Fast Reactor (LFR) System Safety Assessment (2020)

This document was prepared as a safety assessment for the Generation IV LFR system. The objective of the report is to review and identify the main safety advantages and possible challenges of the technology, to assess the current status of safety-related research & development (R&D) activities, and to identify future R&D needs for the LFR system. In preparing this analysis, the LFR pSSC has placed emphasis on the assessment of the fulfillment of the Generation IV goals, to highlight the attractiveness of the LFR technology for future extensive implementation. The report concludes that gaining safety and operational experience feedback through licensing and operation of demonstration plants is a prerequisite to bring the LFR to the industrial deployment.

Download the Assessment

Very High Temperature Reactor (VHTR) System Safety Assessment (2018)

Download the Assessment

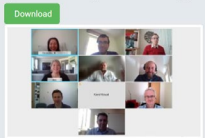
Supercritical-water-cooled reactor system (SCWR) System Safety Assessment (2018)

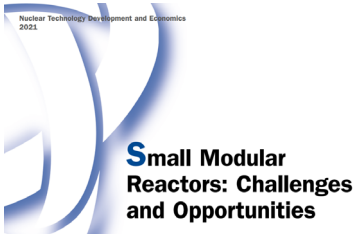
Download the Assessment

Sodium-Cooled Fast Reactor (SFR) System Safety Assessment (2017)

This document was prepared as a safety assessment document for the Generation IV SFR systems, through the feedbacks between RSWG and SFR System Steering Committee. The main

NEA Working Group on the Safety of Advanced Reactors (WGSAR) meeting, 21-23 April 2021





From NI2050 to Disruptive Technologies for Nuclear Safety Applications

Common activity: OECD/NEA CNRA WGSAR
Reviews of GIF SDC/SDGs,
Joint initiative on development of a Risk-informed Approach for event selection, component classification, and DiD assessment

Webinars/ Publications : List

GIF-CEM NICE Future relationship

Single issue focused initiative

A dialogue on the role that nuclear energy can play in clean energy systems of the future. To bring nuclear energy from traditional, nuclear-only fora to a broader, cross-sectoral discussion on clean energy at the ministerial level.

GIF position

- Flexibility is necessary attribution for future nuclear systems in sustainable energy market. GIF has focused on importance and effect of flexibility from early stage, and internally released "GIF POSITION PAPER ON FLEXIBILITY OF GEN IV SYSTEMS" in 2019. Presently GIF has developed Non-Electric applications of Nuclear Heat (NEaNH) iTF.
- CEM NICE Future is an international initiative of the Clean Energy Ministerial. GIF is cross-sectoral partners of CEM NICE Future, and has co-developed flexible report "Flexible Nuclear Energy for Clean Energy Systems" and "Pathways to net zero using nuclear innovation: international perspectives on the role of nuclear energy and innovation in reaching our climate targets"

2.1 Generation-IV International Forum (GIF)

The six most promising nuclear energy systems identified by GIF are:

- Sodium-cooled Fast Reactor (SFR)
- Very High Temperature Reactor (VHTR)
- Gas-cooled Fast Reactor (GFR)
- Molten Salt Reactor (MSR)
- Lead-cooled Fast Reactor (LFR)
- Super Critical Water-cooled Reactor (SCWR)

The Generation-IV International Forum (GIF) is a multinational co-operative endeavor organized to foster the research and development needed to accelerate the deployment of the next generation of nuclear reactor systems. Since its foundation in 2000, GIF has identified six nuclear energy systems being the most promising to meet its objectives, assuming a deployment horizon beyond 2030.

As well as the GIF Goals of sustainability, safety, Proliferation, Risk, and Physical Protection (PRPP) and, economics, the flexibility characteristics are becoming increasingly recognised as essential attributes for future energy sources. In the NICE Future initiative's "Flexible Nuclear Energy for Clean Energy Systems" report, GIF set out the flexibility characteristics of Gen IV reactors in Chapter 13.

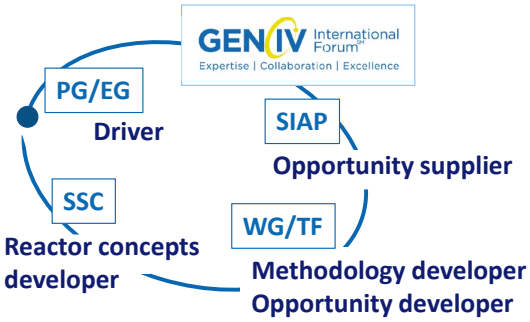
Sustainability is a key issue of Generation-IV reactor systems, as these technologies enable stable and long term utilization of nuclear across a broader clean energy system. These new designs aim to efficiently use uranium resources and further minimize waste and environmental load. The minimization of environmental load means not only being CO_2-free but also reducing the amount of high level radioactive waste by means of burning of long term radioactive nuclides of Minor Actinides in the spent fuel.

One particular benefit of the Generation-IV reactor systems is higher outlet temperatures ranging 700 to 950°C (i.e., VHTR, GFR, LFR, and MSR), and ~550°C (SFR). This high temperature brings flexibility of energy use. This includes non-electrical applications of their nuclear heat, such as hydrogen production, industrial process heat to chemical processing facilities, and efficient heat storage.

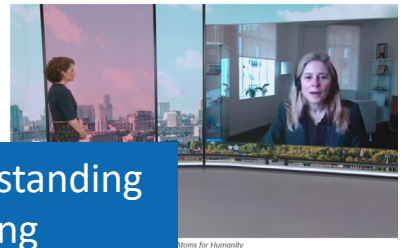
GIF-WNA relationship

On searching common activity

International country groups developing Gen IV reactors. 12 active countries, with 6 Reactors SCs, 7 Methodology/Opportunity WG/TFs and SIAP.



International organization that represents the global nuclear industry. More than 177 vendors/utilities, promoting understand of nuclear energy, developing common industry positions, and contributing to the energy debate.



WNA Cooperation for Rosatom's Atoms for Humanity initiative

Reactor developments within members under IP protection. Methodology/Opportunity developments widely applied to Gen IV reactors.

Promotion for a wider understanding of nuclear energy by producing authoritative information, developing common industry positions, and contributing to the energy debate.

Communication path : GIF-WNA communication meetings (Presently in trial)

Webinars/ Publications : List including report "Design Maturity and Regulatory Expectations for Small Modular Reactors (CODEL: SMR TF and Licensing and Permitting TF)"

Activities :

Interview to GIF Technical Director in WNA Strategic e-Forum

Two GIF presentations at World Nuclear Association Symposium 2021 (to be presented)