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Generation IV International Forum: A decade of progress through international cooperation

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ABSTRACT

The Generation IV International Forum has marked significant progress in developing a next generation of reactor technologies that break out of the limitations of currently deployed nuclear energy systems. In slightly more than 10 years, the Forum down selected to the six most promising systems, forged a powerful framework for multilateral cooperation, organized itself into the necessary functional groups, created four overarching research objectives, established a dozen international projects, and completed hundreds of milestones. The Forum has focused research on viability and performance issues. A revised technology development roadmap completed in 2013 lays out the research agenda for the next decade. This paper summarizes the overall accomplishments of the Forum and the development status of the six advanced reactor systems. Accompanying papers describe the related research and development activities for each system.

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1. Introduction

The Generation IV International Forum (GIF) is the leading organization for multinational collaboration on research and development (R&D) for advanced nuclear energy systems. (Bouchard and Bennett, 2008; Nuclear News, September 2013) In the dozen years since nine countries signed the original charter, GIF has made estimable progress that includes developing a legal framework for cooperation; establishing overarching goals for Generation IV reactors; selecting six promising advanced reactor concepts for development from among 130 proposals; establishing formal system arrangements for four of the systems and provisional arrangements for the other two; setting up 11 current R&D projects; establishing a policy group, an experts group, systems steering committees, and project management boards to conduct and oversee the work; establishing working groups to develop tools for measuring progress against goals; setting up temporary task forces to address hot-button issues such as thorium fuel cycles, advanced modelling and simulation, safety design criteria, and small modular reactors; and, providing a catalyst for reenergizing indigenous nuclear energy R&D programs around the globe. By mid-2013, some 650 research deliverables had been received from GIF participants. The current number of signatories is 13, of which ten are active members.

The Forum was born of necessity. By the close of the twentieth century, nuclear electricity generation was considered to be a mature technology. Nuclear energy research programs were failing to spark much enthusiasm in national legislatures, most notably in the United States. Several like-minded nations, agreeing that a bold new idea was needed, convened in Washington, DC, in January 2000 to discuss development of next-generation technologies. Those first deliberations set in motion an international resolve to collaborate on the development of a completely new generation of nuclear reactor systems and ultimately the creation of the Generation IV International Forum to manage the collaboration.

The essential pieces quickly fell into place and the nine founding members (Argentina, Brazil, Canada, France, Japan, Republic of Korea, Republic of South Africa, United Kingdom and United States) signed the GIF Charter in July 2001. A twenty-first century organization was created, i.e., a virtual organization without a bricks and mortar address or a heavy bureaucracy. The Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) was chosen to provide the technical secretariat for GIF. It was up to each member to provide staffing for the working groups and committees that fell within its areas of interest. Between 2002 and 2006, Switzerland, Euratom, Russian Federation, and People's Republic of China added signatures to the GIF Charter. Argentina, Brazil and United Kingdom are not currently active participants.

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For a variety of practical reasons, most GIF member states have separately negotiated bi-lateral and tri-lateral cooperative R&D agreements, i.e., GIF does not have a monopoly on international collaboration. However, the GIF Framework is the most powerful legal vehicle for multilateral cooperation in advanced nuclear technology development. The Framework took about three years to negotiate, with first signatures collected in 2005. While the legal teams hammered out the Framework Agreement, the technical teams embarked on a major collective effort to complete a Technology Roadmap for Generation IV Nuclear Energy Systems, (A Technology Roadmap, 2013) published in December 2002. The first GIF project arrangements were signed in 2006. GIF will issue a revised technology roadmap in early 2014.

Detailed achievements for the six GIF reactor systems are covered in companion papers (Taylor, 2011; Alemberti et al., 2014; Serp et al., 2014; Aoto et al., 2014; Schulenberg et al., 2014; Fütterer et al., 2014) in this special Generation IV *issue of Progress in Nuclear Energy*. This overview provides a top-level comparison of the systems, the overarching goals that drive their development, unique GIF tools for measuring progress against the goals, the alignment of collaborating members for each system, and the outcome of topical studies completed by appointed task forces. Most of the material covered here can be found in greater detail in annual reports (GIF 2012 Annual Report, 2013) and symposia proceedings (GIF R and D Outlook, 2009) on the GIF public website http://www.gen-4.org/. A more comprehensive overview of the six reactor systems can be found in the article on *Introduction to Generation-IV Fission Reactors* in the *Wiley Encyclopedia of Nuclear Energy* (McFarlane, 2011) published in 2011.

2. Generation IV goals

The founders of GIF established an ambitious set of high-level goals for the systems—targets that if achieved would ensure their relevance in the competitive energy market, as well as pave the way for broad public acceptance, and clearly distinguish them from current commercial reactors and fuel cycles. The four pillars of Generation IV development are sustainability, economics, safety, and proliferation resistance:

1. *Sustainability*: Generation IV nuclear energy systems will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel. They will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden in the future, thereby improving protection for the public health and the environment.
2. *Economics*: Generation IV nuclear energy systems will have a clear lifecycle cost advantage over other energy sources. They will have a level of financial risk comparable to other energy projects.
3. *Safety and Reliability*: Generation IV nuclear energy systems operations will excel in safety and reliability. Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage, and they will eliminate the need for offsite emergency response.
4. *Proliferation Resistance and Physical Protection*: 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 expectations for Generation IV systems were set very high in order to drive the research agenda. It was recognized from the outset that no single approach was likely to dominate in all four categories. The low bar was the third generation of light water reactors (LWRs)—machines optimized for reliable energy production, possessing very good safety characteristics, with relatively predictable economics, and a well-established safeguards regime. The advanced LWRs are, however, inefficient users of uranium resources and provide only modest options for recycle and waste minimization.

3. Methodology working groups and task forces

At inception, the Generation IV International Forum established the Experts Group, a technical support organization for the policymakers. Concurrently, three standing groups were formed to assess how well the systems were measuring up to the goals. Each of these groups reports to the Experts Group, but operates independently and in cooperation with other organizations. Several temporary task forces have also been formed to look at such specific issues.

A notable success of the forum has been the production of methodologies for measuring the progress of the reactor systems towards meeting three of the four major goals—safety, economics, and nonproliferation. The sustainability goal primarily addresses fuel cycle issues, which while covered by the GIF charter, has not been systematically investigated within the Forum. The three standing working groups set up to develop the GIF metrics toolbox are:

- Risk and Safety Working Group (RSWG)
- Proliferation Resistance and Physical Protection Working Group (PRPPWG)
- Economic Modeling Working Group (EMWG)

Each of these “horizontal activities” have produced methodologies that are mature relative to the reactor systems, but which may be further refined as the systems move into a demonstration phase. The working groups collaborate with other organizations that are developing similar or complementary methodologies, most notably with projects in the International Atomic Energy Agency (IAEA). More importantly, the working groups coordinate with each of the System Steering Committees (SSC) responsible for GIF collaboration in developing the six advanced reactor concepts. One unanticipated outcome of these horizontal activities is that the methodologies have found applications beyond advanced reactors because they are not unique to a specific technology.

4. Risk and Safety Working Group

The primary objective of the Risk and Safety Working Group is to promote a harmonised approach on safety, risk and regulatory issues in the development of Generation IV systems. The intent of RSWG-developed methodology is to yield useful insights into the nature of safety and risk of Generation IV systems, thereby allowing meaningful evaluations of Generation IV concepts relative to safety objectives. RSWG methodology does not constrain design innovation, either by dictating design requirements or compliance with quantitative safety goals.

The RSWG focused its early work on identification of high-level safety goals, articulation of a cohesive safety philosophy, and discussion of design principles, attributes and characteristics that may help to ensure optimal safety of Generation IV systems. In 2008, the RSWG reported a consensus regarding some of the safety-related attributes and characteristics that should be reflected in Generation IV nuclear systems. Major areas in which consensus have been reached include:

Table 1
Characteristics of the six generation IV reactor systems.

System	Neutron spectrum	System pressure (MPa)	Coolant	Outlet temperature (°C)	Nominal power density (MW/m^3)	Size (MWe)
VHTR (very high temperature reactor	Thermal	8	Helium	900–1000	8	100–300
SFR (sodium-cooled fast reactor)	Fast	0.3	Sodium	550	175	50–1500
SCWR (super-critical water cooled reactor)	Thermal/fast	25	Water	510–625	100	1000–1600
GFR (gas-cooled fast reactor)	Fast	7	Helium	850	100	1000
LFR (lead-cooled fast reactor)	Fast	0.3	Lead, lead/bismuth	480–800	70	20–1200
MSR (molten salt reactor)	Epithermal	0.6	Fluoride salts	700–800	170	1000
LWR (light water reactor)	Thermal	8–16	Water	325	100	600–1600

- A non-prescriptive cohesive safety philosophy applicable to all Generation IV systems.
- Objectives and ways to meet the potential safety improvement.
- Basic principles for an approach applicable to the design and the assessment of innovative systems including the ways to assess the adequacy of the defense-in-depth principle application and especially to address the treatment of severe plant conditions.
- Role of passive features.
- Role of the Probabilistic Safety Assessment (PSA) and other existing analysis approaches, and the need for developing innovative indicators and tools.

Subsequently, the RSWG produced an integrated framework for assessing risk and safety issues for use throughout the Generation IV technology development cycle. In 2011, the RSWG published the second report entitled *An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems*. (An Integrated Safety Assessment Methodology, 2011) GIF envisions that ISAM will be used in three principal ways:

- Throughout the concept development and design phases, insights derived from ISAM will underpin the basis for the design evolution. Application of ISAM provides a more detailed understanding of design vulnerabilities and their contributions to risk. Based on this detailed understanding of vulnerabilities, new safety provisions or design improvements can be identified, developed and implemented.
- Selected elements of the methodology will be applied at various points throughout the design evolution to yield an objective understanding of risk contributors, safety margins, effectiveness of safety-related design provisions, sources and impacts of uncertainties, and other safety-related issues that are important to decision makers.
- ISAM can be applied in the late stages of design maturity to measure the level of safety and risk associated with a given design relative to safety objectives or licensing criteria.

The integrated methodology consists of five distinct, well-established analytical tools and stages:

- Qualitative safety requirements/characteristic review (QSR).
- Phenomena identification and ranking table (PIRT).
- Objective provision tree (OPT).
- Deterministic and phenomenological analyses (DPA).
- Probabilistic safety assessment (PSA).

By providing specific tools to examine relevant safety issues at different points in the design evolution, ISAM offers the flexibility of a graded approach to the analysis of technical issues of varying complexity and importance. Although individual analytical tools can be selected for exclusive use, the stages of the methodology are well integrated. The full value of the integrated methodology derives from using each tool in an iterative fashion and in combination with the others throughout the design cycle.

The RSWG is currently assisting the system developers with application of ISAM, thereby clarifying safety characteristics and system-specific safety issues. This exercise provides early feedback to both the methodology developers and the system designers. The RSWG also interacts closely with such key organizations as the International Atomic Energy Agency (IAEA), the International Project on Innovative Reactors and Fuel Cycles (INPRO), and the Multinational Design Evaluation Project (MDEP).

RSWG members play key roles in the Sodium Fast Reactor (SFR) Safety Design Criteria (SDC) Task Force. Other interested members of the GIF SFR community comprise the balance of task force. The objectives of the Task Force are to establish the reference criteria of the designs of safety structures, systems and components that are specific for the SFR system, to clarify the criteria systematically and comprehensively when the concept developers apply the GIF safety approach and use codes and standards with the aim of achieving the safety goals of the Generation IV reactor systems. Following the nuclear accident at Fukushima-Daiichi in 2011, the Task Force ensured that the lessons learned from the event were incorporated into their report, with particular emphasis on external events.

The SFR SDC Task Force produced a high-level draft report that is being reviewed by the nuclear regulators in most of the GIF countries as well as the IAEA, and is available for review by other international regulatory groups. The Task Force is currently developing detailed guidelines for the safety criteria. GIF expects that the SFR activity will provide an SDC template for the other five reactor systems.

5. Proliferation resistance and physical protection working group

The Proliferation Resistance and Physical Protection Working Group (PRPPWG) was charged with developing a methodology for the systematic evaluation of Generation IV energy systems with respect to proliferation resistance and physical protection. The objective of the methodology would be to enable comparative evaluation of the performance of different systems against the GIF PRPP goal by using metrics that are as comprehensive and quantitative to the extent possible. The methodology was developed, demonstrated, and illustrated by use of a hypothetical “example sodium fast reactor”.

Starting in 2007, the PRPPWG and the six system steering committees (SSCs) conducted a series of workshops on the PRPP characteristics of their respective designs and identified areas in which R&D is needed to further include such characteristics and features in each design. A common template was developed to collect in a systematic way Generation IV design concepts information and PRPP features and issues. This work culminated with

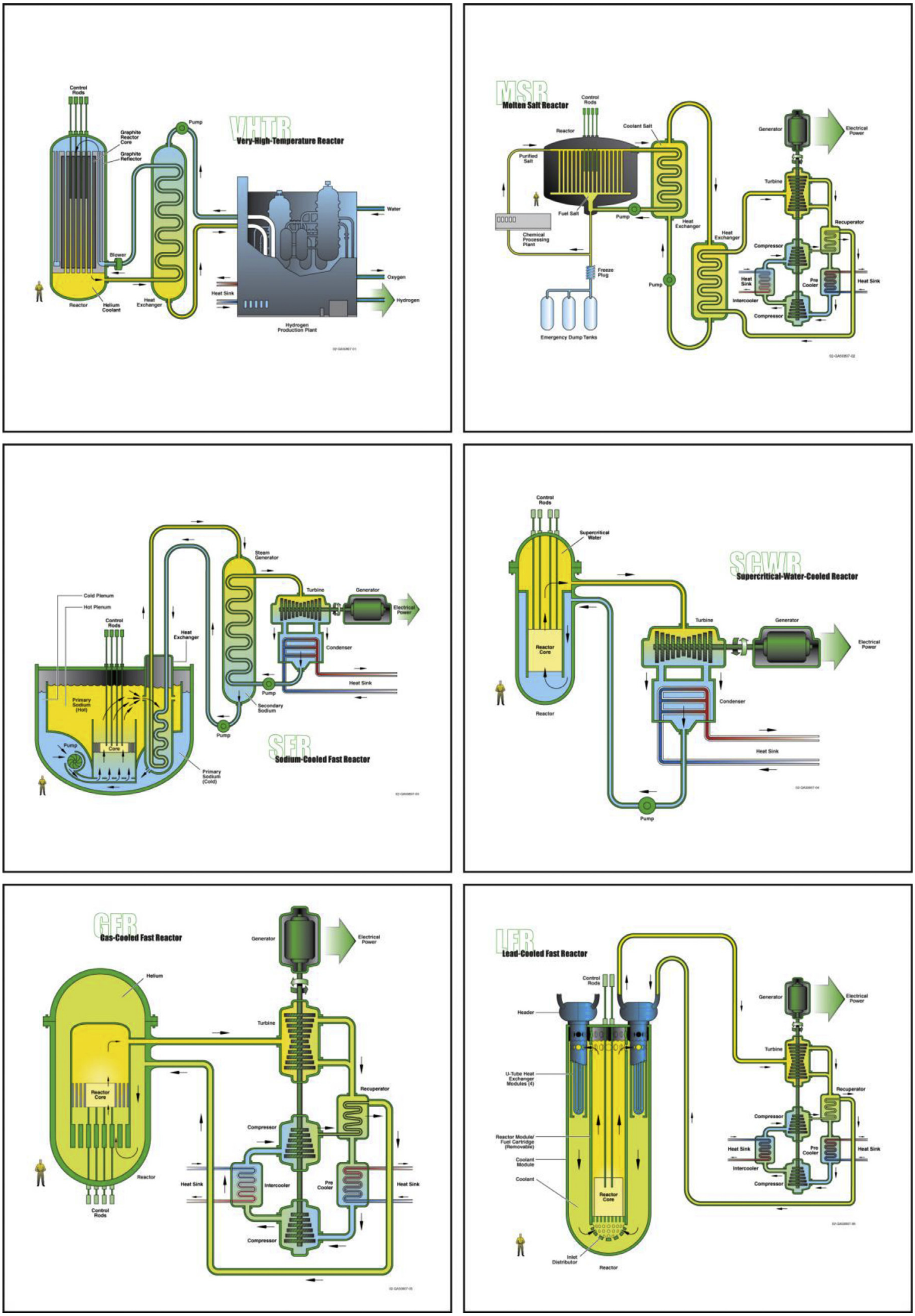


Fig. 1. The six generation IV reactor systems.

Table 2
Potential industrial heat applications for generation IV nuclear reactors.

Application	Range (°C)	LWR	LFR	SCWR	SFR	MSR	GCR	VHTR
District heating & desalinization	80-200	Green	Green	Green	Green	Green	Green	Green
Petroleum refining	250-550		Green	Green	Green	Green	Green	Green
Oil shale & oil sand processing	300-600		Yellow	Yellow	Yellow	Green	Green	Green
Cogenerate steam & electricity	350-800		Yellow	Yellow	Yellow	Green	Green	Green
Steam reforming of natural gas	500-900					Green	Green	Green
H_2 production & coal gasification	800-1000						Green	Green
Green: Potential application								
Yellow: Possible application with auxiliary heat source to boost temperature								

six evaluations prepared jointly by the PRPPWG and the SSCs responsible for each design.

The PRPPWG also prepared an overall report (Proliferation Resistance, 2011; Evaluation Methodology for Proliferation, 2011) that captures the current salient features of the GIF system design concepts that impact their PRPP performance. It identifies cross-cutting studies to assess PRPP design or operating features common to various GIF systems; and it suggests beneficial characteristics of the design of future nuclear energy systems, beyond the nuclear island and power conversion system, that should be addressed in subsequent GIF activities.

Since inception, the PRPPWG has coordinated closely with the IAEA, i.e. there has always been an IAEA representative on the PRPPWG who has contributed to the work of the group. Moreover, there continues to be a close association between the PRPPWG and the IAEA/INPRO effort on proliferation resistance.

National and international programs external to GIF have adapted the PRPP methodology to their specific needs and interests. In the USA, the methodology has been used to evaluate alternative spent fuel separations technologies; in Canada there has been a safeguards-by-design application of the PRPP methodology. The PRPP framework is also being applied for providing proliferation resistance consideration within a European R&D project on a Sodium Fast Reactor. In Belgium there has been an application to an accelerator-driven fission system. In Japan, PRPP methodology has been used for non-proliferation study for fast reactor fuel recycle project.

A summary (Nuclear technology, July 2012) of the work of the PRPPWG over the past decade appears in a special issue on PRPP of the ANS journal, *Nuclear Technology*, in July 2012, Volume 179. Future emphasis for the PRPPWG will be on enabling safeguards by design, conducting pilot workshops, and promoting acceptance of the methodology by decision makers.

6. Economic Modeling Working Group

Because the fuel, coolant, operating parameters and fuel cycles of Generation IV systems differ vastly from the currently installed nuclear power fleet, GIF chartered the Economics Modeling Working Group (EMWG) to develop new tools for their economic assessment. The purpose of the tool is to be able to compare technologies on an equitable basis and to answer questions on optimal configuration and deployment ratios.

The EMWG has delivered a cost estimating methodology, (Cost Estimating Guidelines, 2007) the G4-ECONS software to facilitate the application of the methodology, and training programs for those wishing to apply the methodology. User experience and feedback motivated a number of improvements. Economic literature review is an ongoing task so the latest information may be made available to the GIF teams. The methodology is used to assess the cost structure of the Generation IV systems in comparison to Generation III systems, identify cost drivers and potential for design improvement. Because of the early state of system definition, G4-ECONS uses a top-down approach with scaling factors for cost estimation.

At this stage, the software tool is considered relatively mature, enabling the EMWG to focus more effort on training and application.

Table 3
Design approaches to achieving the four overarching GIF goals.

VHTR		
	Safety	Restricted to 600 MW(thermal); huge thermal inertia of graphite structure and matrix; fuel not damaged below 1600 °C, single phase inert coolant
	Sustainability	Not a focus of current development
	Economics	Very high thermal efficiency; multiple non-electric applications
SFR		
	Safety	Inherent features such as natural circulation cooling and fuel expansion; single phase coolant with high margin to boiling
	Sustainability	Primary application of SFR, potential for a factor of 60 or more improvement in uranium utilization; potential for transmutation of long-lived waste
	Economics	Good thermodynamic efficiency; long operating cycles
SCWR		
	Safety	Single phase coolant; passive safety systems
	Sustainability	Can be designed for high conversion ratio, modest transmutation capability
	Economics	Transfers vast experience from supercritical coal plants; high thermodynamic efficiency
GFR		
	Safety	Very high temperature fuel; complex engineered safety systems
	Sustainability	Comparable to other Generation IV fast reactors
	Economics	High thermodynamic efficiency and potential for industrial process heat application
LFR		
	Safety	Single phase, high enthalpy coolant; large margin to boiling; amenable to natural circulation cooling
	Sustainability	Comparable to other Generation IV fast reactors
	Economics	Good thermodynamic efficiency
MSR		
	Safety	No possibility of fuel melt; low fissile inventory; relatively low fission product inventory
	Sustainability	Comes with a built-in recycling plant
	Economics	High thermodynamic efficiency; potential for multiple applications

Table 4
Major R&D challenges of the six generation IV reactor systems.

System	Principal R&D challenges/technology gaps
VHTR	Fuel qualification; development of composite components; pressure vessel materials; materials for heat utilization systems; qualification of graphite internals; balance-of-plant components for high temperature operation; hydrogen production subsystems
SFR	Fuel handling system improvements to reduce outage times; increased fuel burnup and cycle length; improved instrumentation for sodium leaks; in-service inspection and repair capabilities; extended system lifetime; inspection and diagnostics capabilities; seismic design; resilience in the face of severe natural events
SCWR	Non-uniformities of local power and coolant mass flow rate; high temperature cladding alloy development; identifying and managing safety system differences relative to conventional LWRs; water chemistry related to radiolysis and corrosive product transport; incompatibility of fast spectrum version with safety requirements
GFR	Fuel capable of containing fission products at temperatures up to 1600 °C for several hours; components for gas circulation; thermal barriers; valves and check valves; instrumentation
LFR	Corrosion control; core instrumentation; fuel handling; fuel development; in-service inspection and repair techniques; seismic design
MSR	Physical-chemical behaviour of fuel salts; compatibility of salts with structural materials; instrumentation and control; on-site fuel processing

On the other hand, the six Generation IV reactor systems are relatively immature and assigning much value to the initial round of comparisons is questionable. At this early stage of development, Generation IV systems are challenged to compete on a levelized cost of electricity basis with third generation light water reactor systems.

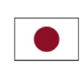
7. Generation IV reactor systems

Generation IV is not the logical evolution of reactor systems from the Generation III LWRs that are just now being introduced primarily in Asia, Europe, the Middle East and North America; it is a radical design break from the more than 400 successful commercial reactors currently in operation around the globe. The vision for Generation IV is 1000+ reactors operating for centuries with concomitant demands on uranium supply, safety, affordability, nonproliferation assurance and responsible waste management.

While the worldwide growth of nuclear energy slowed during the 2008–2009 global economic recession and the aftermath of the Fukushima-Daiichi nuclear accident, the *World Energy Outlook 2012* (World Energy Outlook, 2012) projects a minimum of 40% increase in nuclear electricity production by 2035. With stricter climate change policies, doubling of nuclear electricity would be required. On their current development schedule, Generation IV reactors would start to penetrate the commercial electricity market about 2035. Generation IV reactors could also open new industrial heat markets for nuclear energy in the same time frame.

Generation IV concepts employ a variety of design innovations to achieve the four goals that distinguish them from currently deployed technology. To compete economically with optimised LWRs, Generation IV systems all operate at higher temperatures that enable up to 40% improvement in thermodynamic efficiency. They make greater use of the inherent and passive safety features that have been introduced into some of the more advanced Generation III designs. They have the tools to incorporate unprecedented proliferation resistant in their design. Finally, most Generation IV concepts can be designed for a high conversion ratio that would enable up to two orders of magnitude improvement in utilization of uranium resources.

Table 5
Participating members in GIF R&D projects.

GIF member	System arrangement				MOU[a]	
	GFR	SCWR	SFR	VHTR	LFR	MSR
Canada						
China						
European Union						
France						
Japan						
Korea						
Russia						
Switzerland						
United States						
No. of Projects	1	2	5	3	–	–
Demonstration phase begins	>2030	2025	2022	2025	2022	>2030

[a] Memorandum of Understanding, a provisional arrangement for collaboration.

Much recent publicity has gone to small modular reactors (SMR) and thorium fuel cycles, which from the outset have been considered within GIF, but at a measured pace. The Forum has used special task forces to produce internal white papers addressing these topics. SMR versions of most concepts have been included in the GIF systems. Lacking a fissile isotope, thorium itself is not nuclear fuel, but can be readily converted to ^{233}U and has interesting chemical and thermal properties as a part of a fuel matrix. Consequently, thorium options are considered in most GIF systems.

Table 1 introduces the six GIF reactor systems and identifies the acronyms by which they are commonly known. A range of power is shown for some concepts, indicating the multiple tracks of development. The parameters for LWRs are given as a benchmark. The range of system pressure for LWRs differentiates boiling water reactors from pressurized water reactors. Still relevant for basic understanding, the original system concept schematics are shown in Fig. 1 The modern concept drawings are presented in the companion papers for each of the systems.

Developing advanced materials that can stand up to extreme temperatures, high radiation fields, and repeated thermal shocks over periods of years to decades is a common challenge for Generation IV systems. Corrosion control is a major issue for the supercritical water, molten salt and lead systems. Instrumentation is a common challenge in the high-temperature, harsh environments of the systems. For systems with opaque coolants (sodium or lead) or solid moderator (graphite), inspection and maintenance present development opportunities.

Beyond electricity, the most impactful way to increase the application of nuclear energy and reduce greenhouse gas emissions would be to substitute high quality nuclear generated steam for fossil fuels in energy-intensive industrial applications. The idea of using higher temperature reactors to produce process heat precedes the formation of GIF. Within the GIF collaboration, the VHTR has been primarily developed for process heat applications. It has the advantage of being able to produce temperatures above 700 °C using current technology and can be designed for the exceptional safety required for colocation with a petrochemical plant. Some potential process heat applications of Generation IV reactors are shown in Table 2. The Generation III LWR is included as a baseline.

GIF's ambitious goals drive research and development, but approaches differ by system and the six systems do not all compete within the same niche. For example Generation IV systems strive to achieve extraordinary safety performance by a variety of means, including high thermal inertia of coolant and structures, natural circulation, passive heat removal, extremely high melting temperature fuel, safety systems engineered for assured reliability, single phase coolants, and maximum size restriction. No system tries to apply all approaches simultaneously.

Table 3 provides a thumbnail sketch of the different approaches that the six systems take toward achieving the four GIF goals. Proliferation resistance and physical protection is omitted because it is the least clear what those specific requirements will be and the working assumption is that all system designs will incorporate whatever PRPP features are necessary.

Generation IV systems would not be subject to intense international collaboration if they were not facing design challenges, either for the initial prototype or for future improved, commercially viable designs. Table 4 summarizes the principal R&D challenges for each system.

While each member country has national programs that exceed its level of participation in the Generation IV International Forum, collaboration is an essential element of ultimately achieving a globally accepted, reliable advanced reactor system ready for licensing and commercialization. Table 5 shows which member countries are collaborating on each of the six systems. Formal collaboration has been established for 4 of the systems, while the LFR and MSR operate under an informal arrangement. Although no project arrangements are shown for the LFR and the MSR in the table, considerable activity is ongoing on a provisional basis. The onset of the demonstration phase in the last row of the table may not necessarily mean construction and licensing. Transition from performance R&D to demonstration will occur when detailed engineering for a specific design gets well under way.

8. Conclusion

The Generation IV International Forum remains a viable entity for organizing international collaboration on advanced reactor technology development. It has proven flexible in admitting capable new partners, while allowing nations to withdraw support from systems that no longer align with their policies and objectives. Recent initiatives have produced an updated technology development roadmap, developed safety design criteria for sodium fast reactors, increased public awareness and transparency of activities, and fostered even stronger cooperation between GIF members and with other compatible organizations. The Forum should be seen as a major resource for objective information for decision makers.

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