

# ***Generation IV International Forum: Path Forward***

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CEA / Nuclear Energy Director*

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# ***Technical Roadmap 2013 Update*** ***Tracing the road up to 2025-30***

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***GIF Policy Group decided in 2013 to update the Original 2002 Technical Roadmap, with the objectives to:***

- Re-visit original orientations regarding the 4 strategic Goals and the 6 selected Systems,**
- Actualize the 6 systems development timelines,**
- Point out the Key R&D subjects along with the integration of Fukushima accident teachings.**

# Update of the GIF Technology Roadmap

*Published in January 2014*

Figure ES.2: System development timelines as defined in the original 2002 Roadmap (left) and in the 2013 update<sup>4</sup>

Technology Roadmap Update  
for Generation IV  
Nuclear Energy Systems

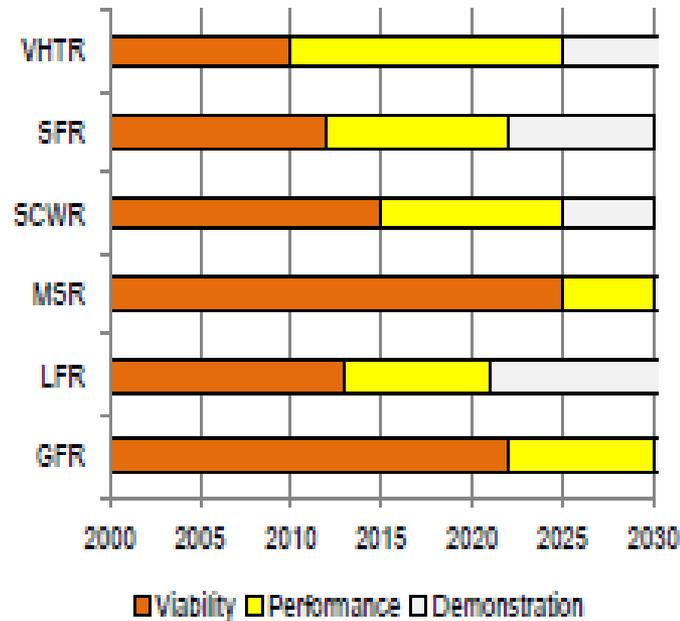
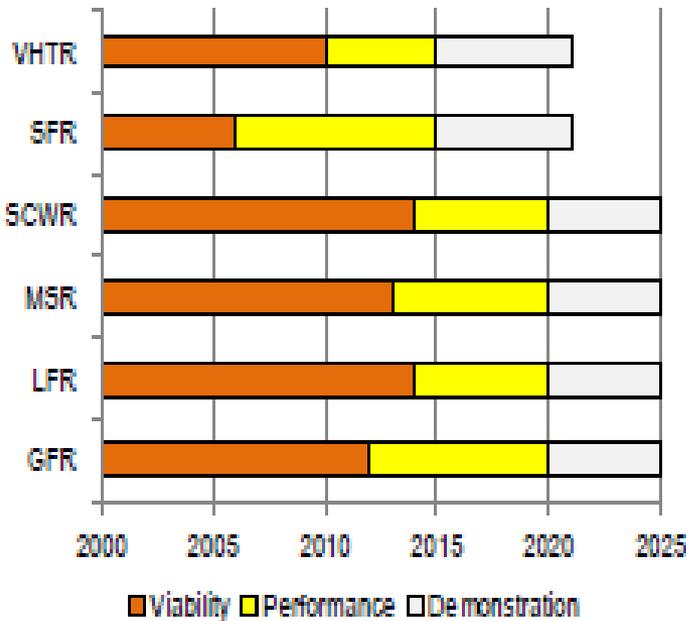
GEN IV International Forum™



Preparing Today for Tomorrow's Energy Needs

GIF roadmap 2002

GIF roadmap 2013



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# ***Technical Roadmap Update***

***↔ R&D priorities & Challenges for  
the next 10 to 15 years***

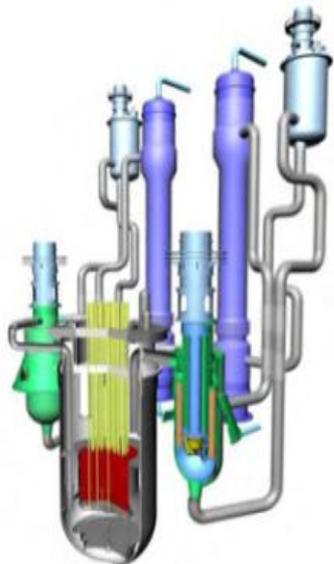
# SFR

## From Performance to Demonstration phase (2022)

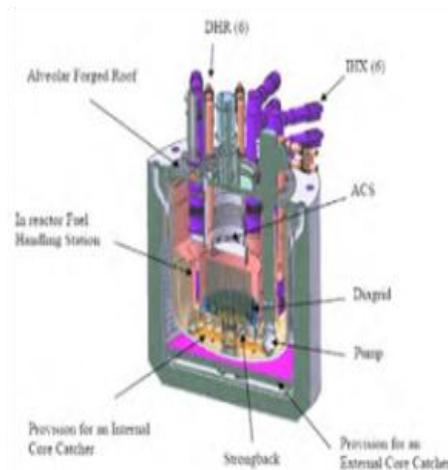
Large past experience + Several Demonstrator projects  
either in Operation/Construction\*

or at Design stage\*\*:

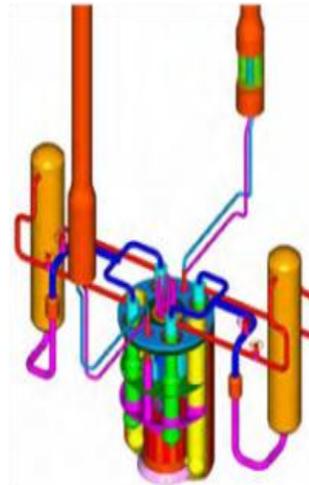
in \*China, \*Japan\*\*, \*Russia\*\*, France\*\*, Korea\*\* + India (outside GIF)



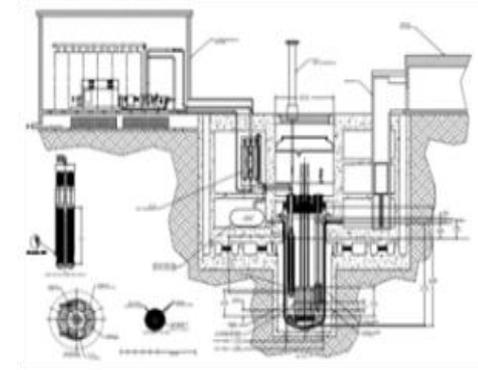
Large Loop



Large Pool



Intermediate-to-Large Loop



Small Modular

# SFR R&D priorities

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- *Safety Design Criteria (SDC) consolidation*
  - *Safety & Operation :*
    - *Improving core inherent safety and I&C,*
      - *Prevention and mitigation of severe accident with large energy releases,*
        - *Decay Heat Removal (DHR) & Ultimate heat sink, ISI&R*
          - *Prevention & mitigation of sodium fires,*
  - *Advanced fuel Development : Advanced reactors fuels & MA-bearing*
  - *Advanced cycles for energy conversion, Innovative component design*
  - *Used fuel handling scheme and technologies*
  - *System Integration & Assessment*
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# V-HTR

## From Performance to Demonstration phase (2025)

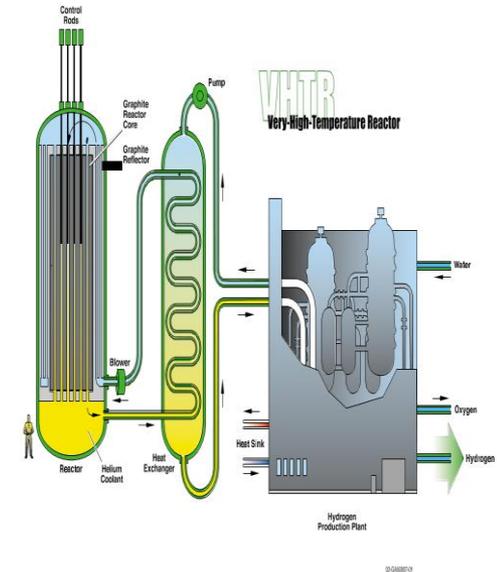
**Leading projects: HTR-PM, Construction in China**  
**NGNP, R&D & Design study in USA**  
**HTTR study in Japan**

➤ Near term R&D ⇔  $750^{\circ}\text{C} < T < 900\text{-}950^{\circ}\text{C}$

- Qualification of Ni alloys & of new grades of graphite
- Thermalhydraulic safety demonstration (LOCA, Passive DHR, ...)
- Qualification of UCO TRISO fuel (1 250°C; burnup  $\leq 150$  GWd/tHM)

➤ Longer term R&D ⇔  $T \geq 950\text{-}1000^{\circ}\text{C}$

- Require developments of advanced materials (SiC/SiC composites, graphite, ...) and fuels at high burnup up to 200 GWd/tHM)
- Key component development for heat users and H<sub>2</sub> production: Intermediate Heat Exchanger, ...



# SCWR

## Just entering Performance phase, Demonstration phase foreseen in 2025

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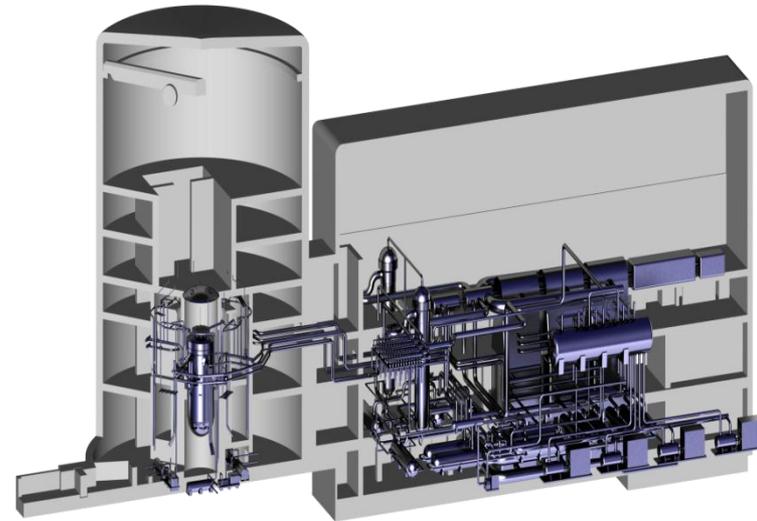
**2017, possible decision about a SCWR demonstrator**

➤ **2014 - 2017**

- **Out-of pile, small scale fuel assembly test; cladding material selection**
- **Pre-conceptual design phase completion**
- **Qualification of computational tools**

➤ **2017 - 2022**

- **In-pile, small scale fuel & assembly tests**



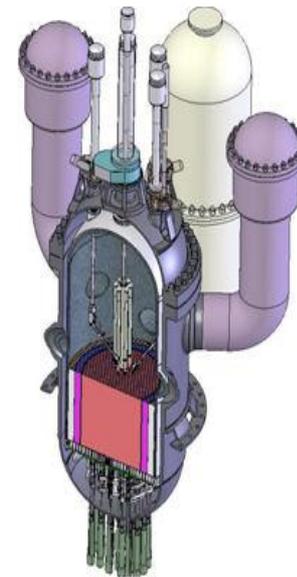
# GFR Viability phase

**Design studies for an experimental reactor under consideration:  
ALLEGRO**

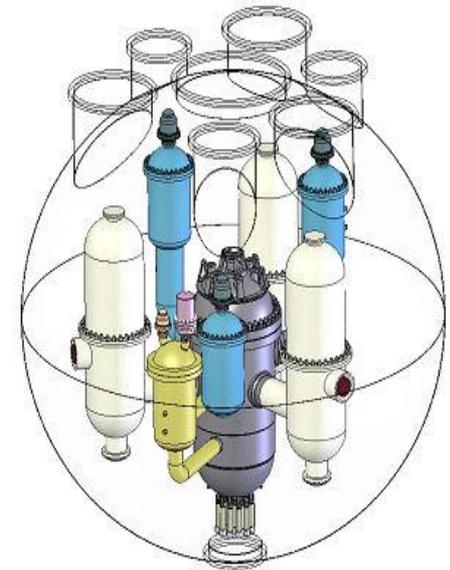
➤ **2 main KEY VIABILITY issues:**

**1, Design for safe LOCA management system & robust DHR system without external power supply,**

**2, Developing suitable Fuel technologies (out-of-pile test + irradiation experiments)**



GFR - reactor, decay heat loops, main heat exchangers and fuel handling equipment



GFR - spherical guard vessel

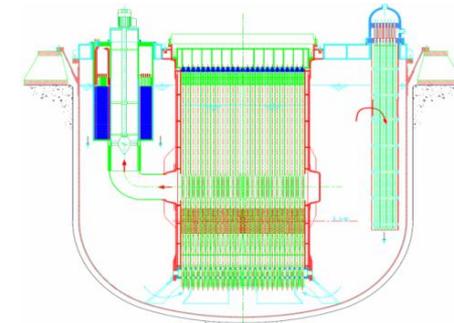
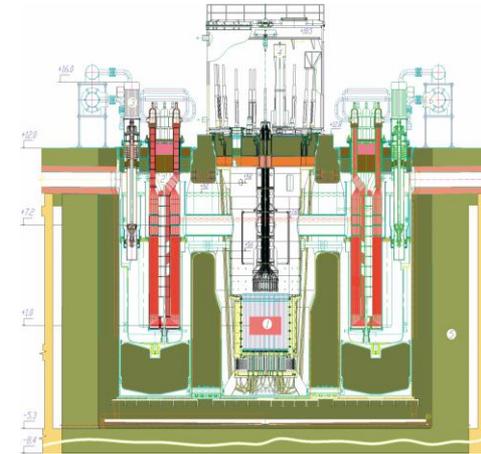
# LFR

## From Performance to Demonstration phase (2021)

**Demonstrators: in Russia PSVBR-100 (Pb-Bi) and BREST-300, ALFRED project (120 MW) in Europe**

**Key R&D challenges include:**

- **Selection of Materials resistant to erosion-corrosion for fuel cladding and reactor structures & components**
- **Material / Lead chemistry management for  $T > 480-500^{\circ}\text{C}$**
- **Fuel developments: MOX; Nitride fuel; MAs bearing fuels;**
- **Fuel handling technology and operation. Core instrumentation. Advanced modeling and simulation...**

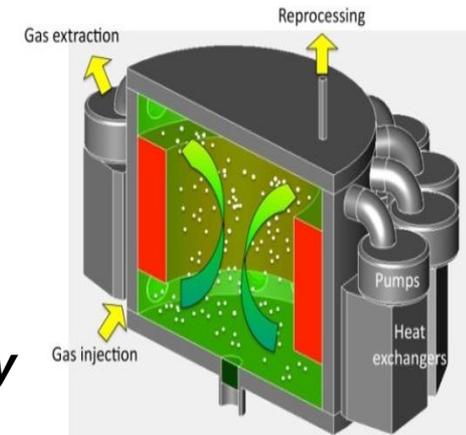


# MSR Viability Phase

*In baseline, the Molten Salt Fast Reactor, MSFR (a liquid fuel concept); In addition: Fluoride salt-cooled High-temperature Reactor, FHR (solid fuel)*

**2 conceptual designs : MOSART (Molten Salt Actinide Recycler & Transmuter); MSFR**

- **Management and salt control (2012-2014)**
  - **Liquid salt chemistry: multi –component solubility limits versus  $T^{\circ}\text{C}$  & salt composition**
- **Confirmation of bubbling efficiency (2014-2015)**
- **Heat exchanger viability (2015-2017)**
- **Validation of reprocessing flow sheets at laboratory scale**
- **Definition of safety analysis methodology and specification of accident scenarios.**



# GIF 3 Methodology Working Groups

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- **Economic Modeling WG (EMWG)**
    - *Development & application of integrated economic model to assess various reactor systems (GEN 3 & 4)*
  - **Risk and Safety WG, (RSWG)**
    - *Draw teachings from Fukushima accident and accordingly update methodologies:*
      - » *Integrated Safety Assessment Methodology, ISAM*
      - » *Safety approach by Design & assessment of Gen IV systems*
  - **Proliferation Resistance and Physical protection, PRPP**
    - *Enabling safeguards by Design & giving assistance to system developers*
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# Conclusions

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- ❑ *Update of the Technical Roadmap has confirmed the GIF original choice on strategic Goals & Systems selection.*
  
- ❑ *However most of the GIF Goals are very challenging and, after the Fukushima accident, a stronger & more effective International cooperation is required to be able to reach all of them particularly those regarding Safety & Economic competitiveness*
  
- ❑ *In this frame, the update of R&D priorities does permit the International community to concentrate Human resources & budgets on the most challenging ones*