



# Generation IV International Forum (GIF) and Participation of Euratom

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<http://www.jrc.cec.eu.int>

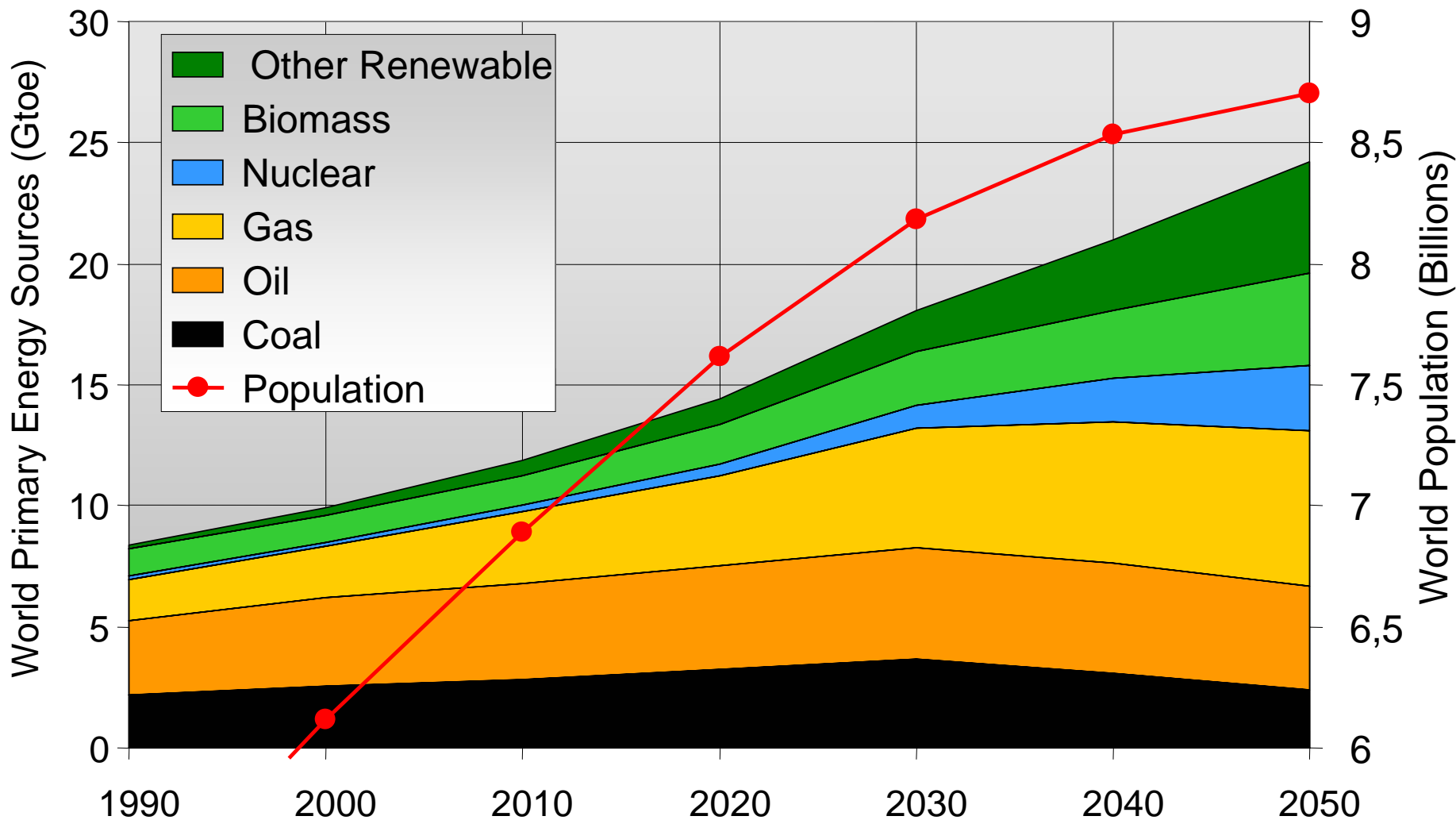


# Presentation Outline

1. Energy needs and status of the nuclear energy
2. Generation IV – Future Nuclear Systems
3. Organisation and legal framework
4. Euratom and GIF
5. German participation in GIF
6. Conclusions



# 1. Energy needs and status of the nuclear energy



Source IEA : Energy to 2050 - Scenarios for a Sustainable Future



# Nuclear Energy

at the end of the twentieth century:

- A rapid growth of power generation in the 60s and 70s, followed by a “long” consolidation period;
- Technological and industrial leadership of Europe;
- A societal dilemma leading to unforeseeable political decisions.

and now ?



# Nuclear Energy

...a few years later

- A drastic change of context :
  - Strong increase of prices of oil and gas
  - Fears associated with climate change
  - Slow evolution of public perception
- A forecast of increasing demand for nuclear power
- The necessity to prepare for such a wider deployment of nuclear energy



# Main objectives for the future

## European Commission's position

- **Nuclear option – important component of energy mix**
- **Nuclear research – fission and fusion – continuation into FP7 including innovative reactors**
- **Progress in waste management and common EU safety standards needed**
- **Euratom participation in GenIV**



# LWR: A challenge for other technologies

- From the beginning, scientists and engineers are looking to other technologies in a try to overcome the two main LWR limitations:
  - Thermodynamic yield limited by rather low temperatures;
  - Uranium burning limited by small breeding rates;
  - Limited recycling of Pu as MOX
- Two main paths have been and are still considered, high temperature reactors and fast neutron reactors.
- Direct spent fuel storage requires higher capacity of geological storage facilities.



## 2. Generation IV: Future Nuclear Systems

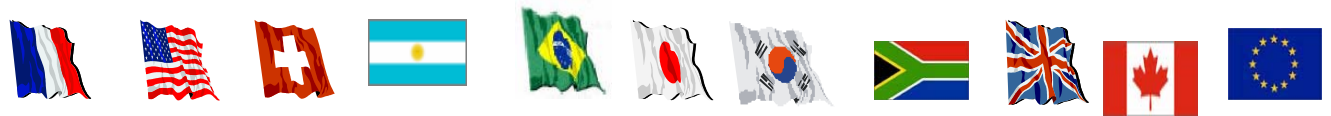
### R&D in preparation of an expansion of nuclear energy

- Prospects for energy needs show the possibility of an increasing demand for nuclear power;
- In such an hypothesis, sustainability becomes a predominant concern, which means preservation of natural resources, waste minimization and proliferation resistance, while maintaining competitiveness and higher safety levels;
- Furthermore, other application of nuclear energy than electricity production are to be considered, in particular, hydrogen production, industrial use of heat or desalination;
- The development of new systems will take time and require validation and demonstration. Therefore, the target for industrial scale applications is 2030 or later.



# The Generation IV International Forum (GIF)

- Generation IV is a framework for international co-operation in research for a future generation of nuclear energy systems on which 10 founding countries agreed and to which Euratom adhered on 30 July 2003:



FR US CH AR BR JP KR SAR UK CA EUR

- GIF overall objective is:

*"..to support research and development, within a time frame from 15 to 20 years, of concepts for one or more Generation IV Systems that will provide competitively priced and reliable supply of energy to the country(ies) where such systems may be deployed, while satisfactorily addressing nuclear safety, waste, proliferation and public perception concerns".*

- The JRC was entrusted with the co-ordination of the Community contribution to GIF.



# Interest in the six GIF Systems



VHTR	◆	◆	◆	◆	◆	◆	◆	◆	◆
GFR		◆	◆	◆	◆	◆	◆	◆	◆
SFR			◆	◆	◆			◆	◆
LFR		◆		◆	◆				◆
SCWR	◆	◆		◆	◆				◆
MSR		◆	◆						◆

July 2005

◆ signifies Co-chair in the Steering Committee

VHTR – Very-High-Temperature Reactor

GFR – Gas-Cooled Fast Reactor

SFR – Sodium-Cooled Fast Reactor

LFR – Lead-Cooled Fast Reactor

SCWR – Supercritical Water-Cooled Reactor

MSR – Molten Salt Reactor

**Note:** Argentina and Brazil are not represented as they do not participate in System Steering Committees



# Status of Fast Reactors

- Large experience with sodium technology
- Most of the development stopped in the eighties
- Difficulty with public acceptance
- R&D still needed to improve the design of SFR

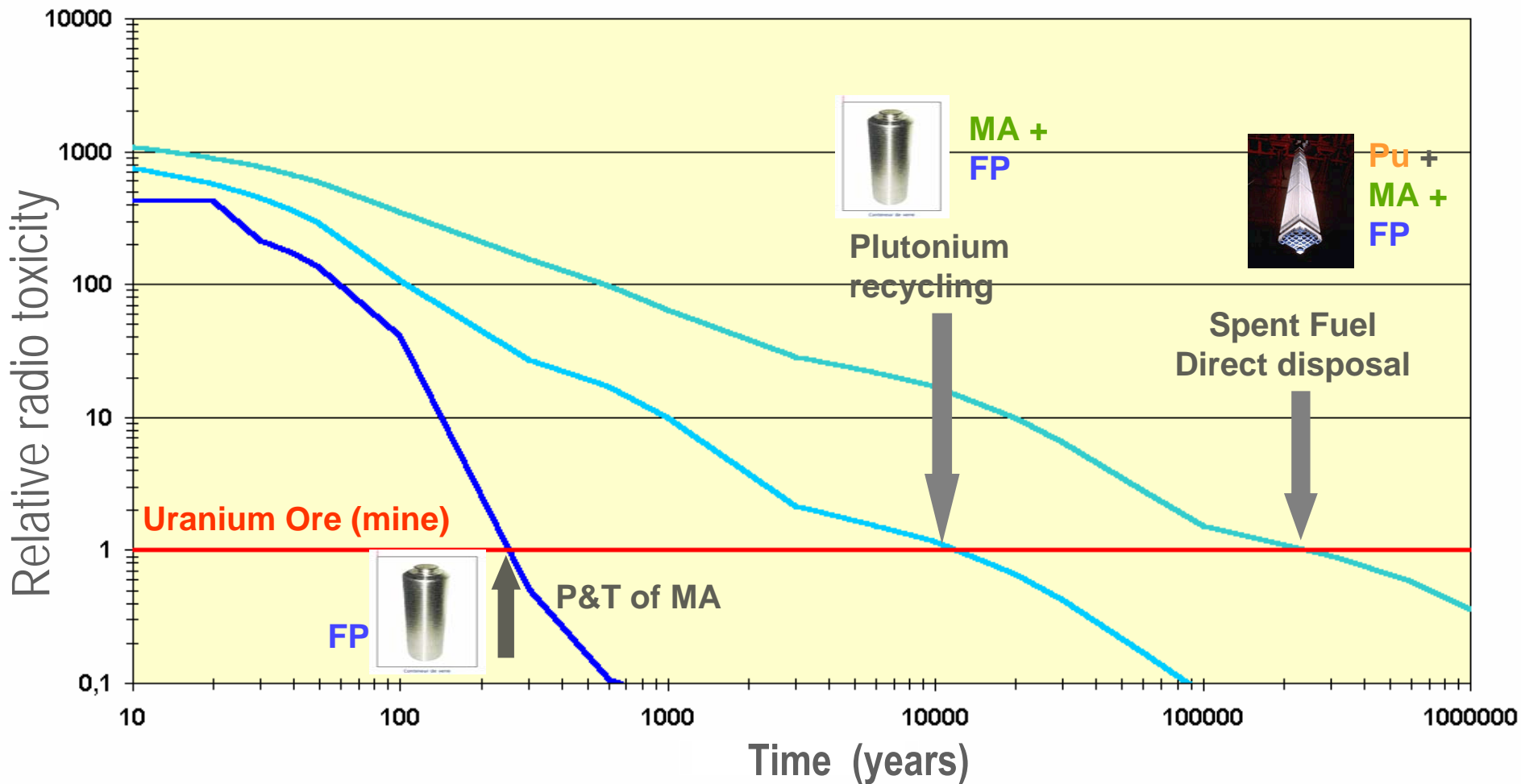
## Key advantages:

- resource optimisation (U reach with LWR only max. 2050)
- waste minimisation
- reduction of long-term radiotoxicity of waste



# Fast Reactors:

## Reduction of long-term toxicity





# Fast Reactors : Sodium Technology

- *Sodium is a very suitable coolant:*
  - liquid in a wide range of temperatures (90 – 890°C)
  - mono isotope (Na23)
  - thermodynamics parameters
  - no corrosion (when purified)
- *Large industrial experience:*
  - various industrial uses
  - 40 years of technological studies for nuclear applications
- *Well-known drawbacks:*
  - chemical reactivity (sodium fires and sodium-water reactions)
  - difficulties for handling and inspection (repairability)
  - **Challenges:** fuel with minor actinides

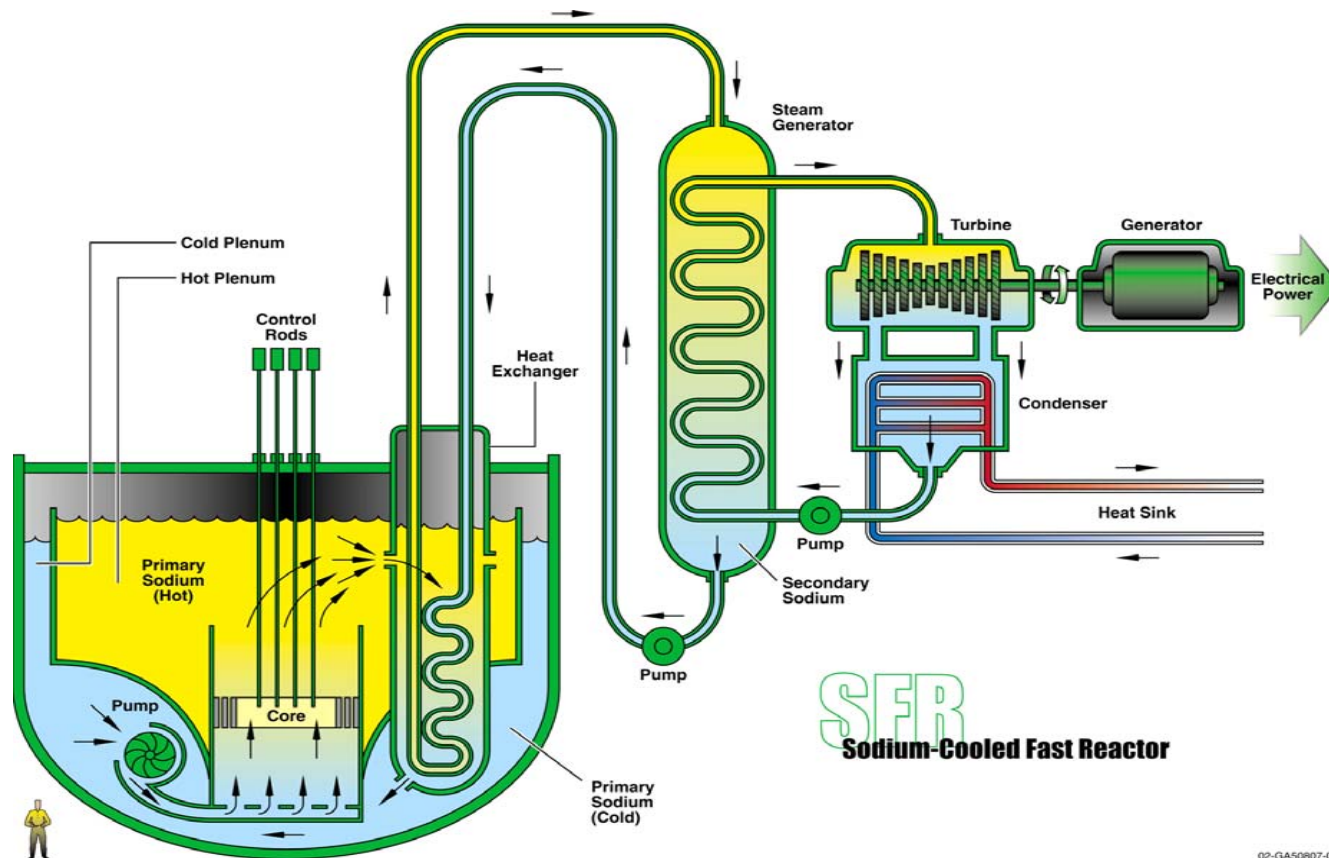
# Sodium-Cooled Fast Reactor (SFR)

## Characteristics

- Sodium coolant
- 550°C Outlet Temperature
- 600 to 1500 MWe
- Metal fuel with pyroprocessing, or
- MOX fuel with advanced aqueous processing

## Benefits

- Waste minimization and efficient use of uranium resources



SFR  
Sodium-Cooled Fast Reactor

02-GA50807-03

- A demonstration facility composed of SFR and a related fuel cycle system is under consideration as an option to be placed into operation by 2020



# Fast Reactors: Lead Technology

- A candidate to avoid the risks associated with sodium fires or sodium-water reactions
- A less favorable coolant (thermodynamics parameters, corrosion risks)
- Lead-bismuth alloy to reduce corrosion risks
- Experience limited to Russian applications in naval propulsion
- Studies going on in various countries
- Nitride fuel

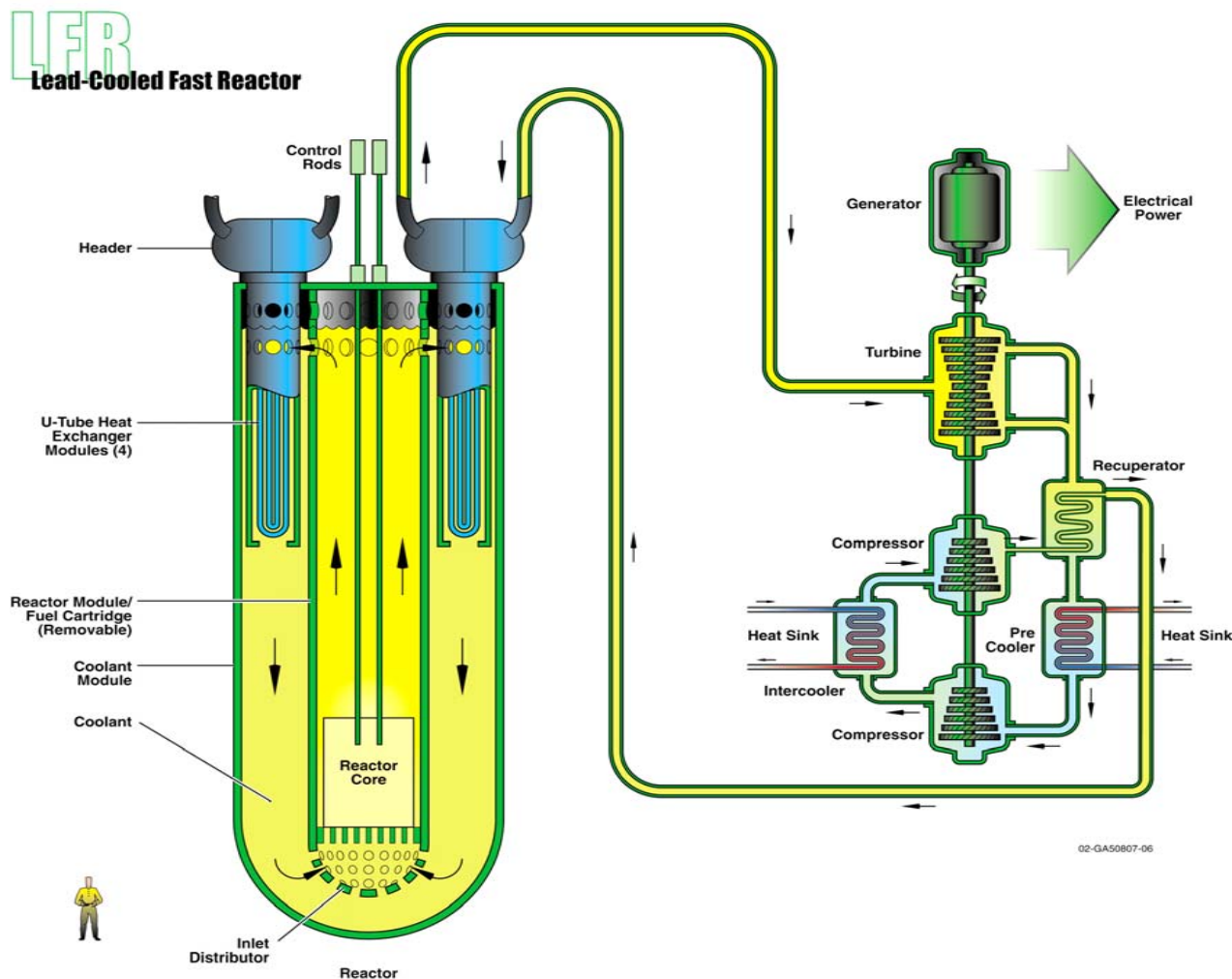
# Lead-Cooled Fast Reactor (LFR)

## Characteristics

- Pb or Pb/Bi coolant
- 550°C to 800°C outlet temperature
- 120–400 MWe
- 15–30 year core life
- Cartridge core for regional fuel processing

## Benefits

- Proliferation resistance of long-life cartridge core
- Distributed electricity generation
- Hydrogen production
- High degree of passive safety





# Fast Reactors : Helium Technology

- Gas cooling is less efficient than liquid metal cooling
- Development of a gas cooled fast reactor will require a new type of fuel (burn up  $\geq 150$  GWd/t)
- Helium technology is already considered for VHTR
- Specific safety concerns need to be clarified (low thermal inertia, high power density)
- If it can be successfully designed, the result will satisfy both objectives for a sustainable development (fast neutron physics and high temperature technology)

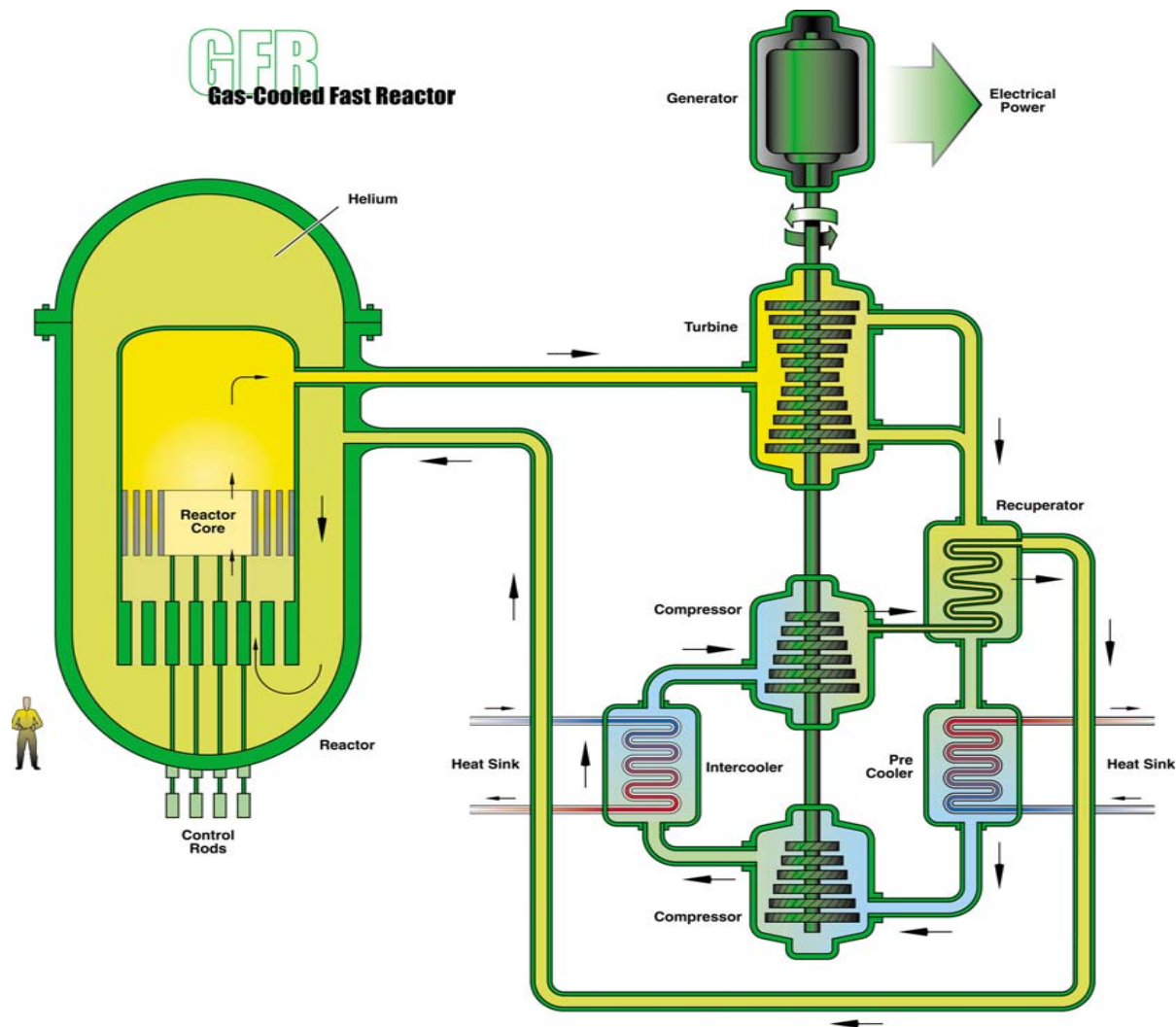
# Gas-Cooled Fast Reactor (GFR)

## Characteristics

- Helium coolant
- 850°C outlet temperature
- Direct gas-turbine cycle
- 600 MW<sub>th</sub>/288 MW<sub>e</sub>

## Benefits

- Waste minimization and efficient use of uranium resources



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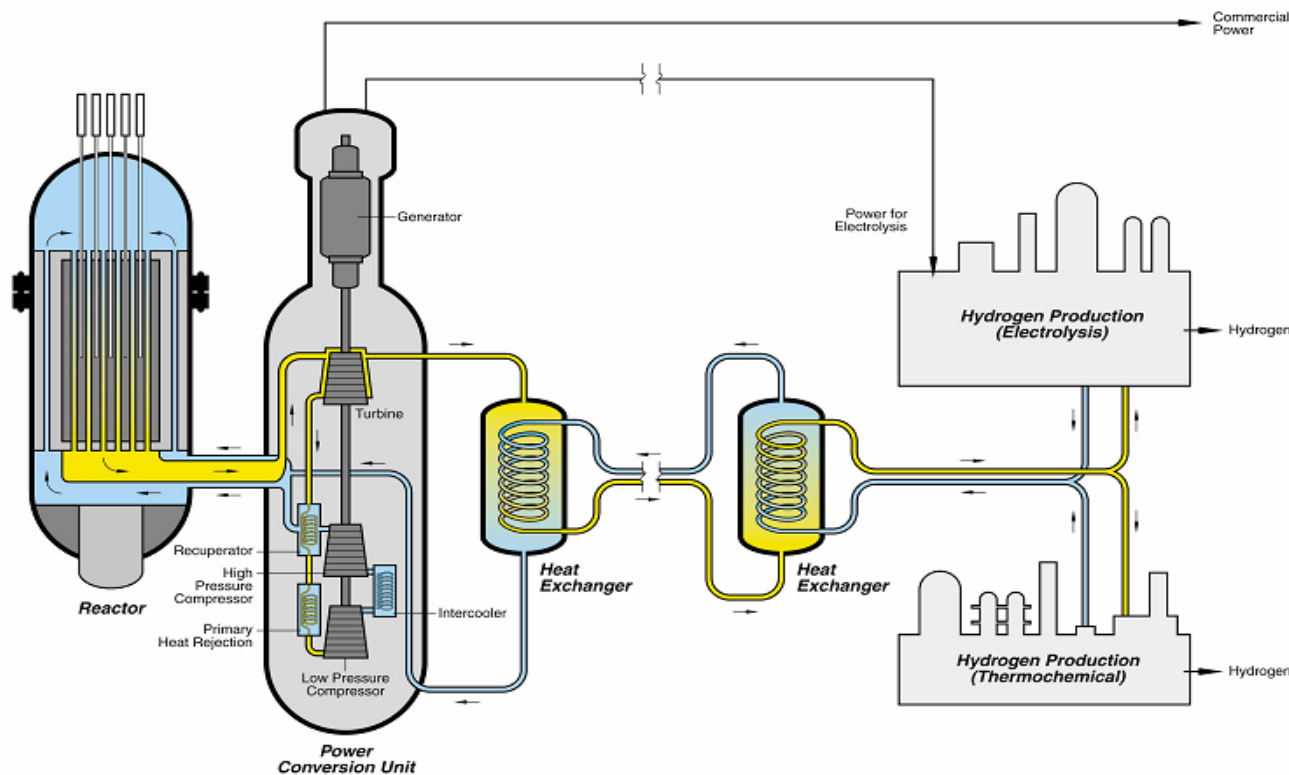
# Very-High-Temperature Reactor (VHTR)

## Characteristics

- Helium coolant
- 900-950°C outlet temp
- Water-cracking cycle

## Benefits

- **Hydrogen production**
- High degree of passive safety
- High thermal efficiency
- Process heat applications



- Preliminary design by 2011; prototype before 2020, depending on available funding
- In Europe: focus on heat applications rather than electricity and H<sub>2</sub>

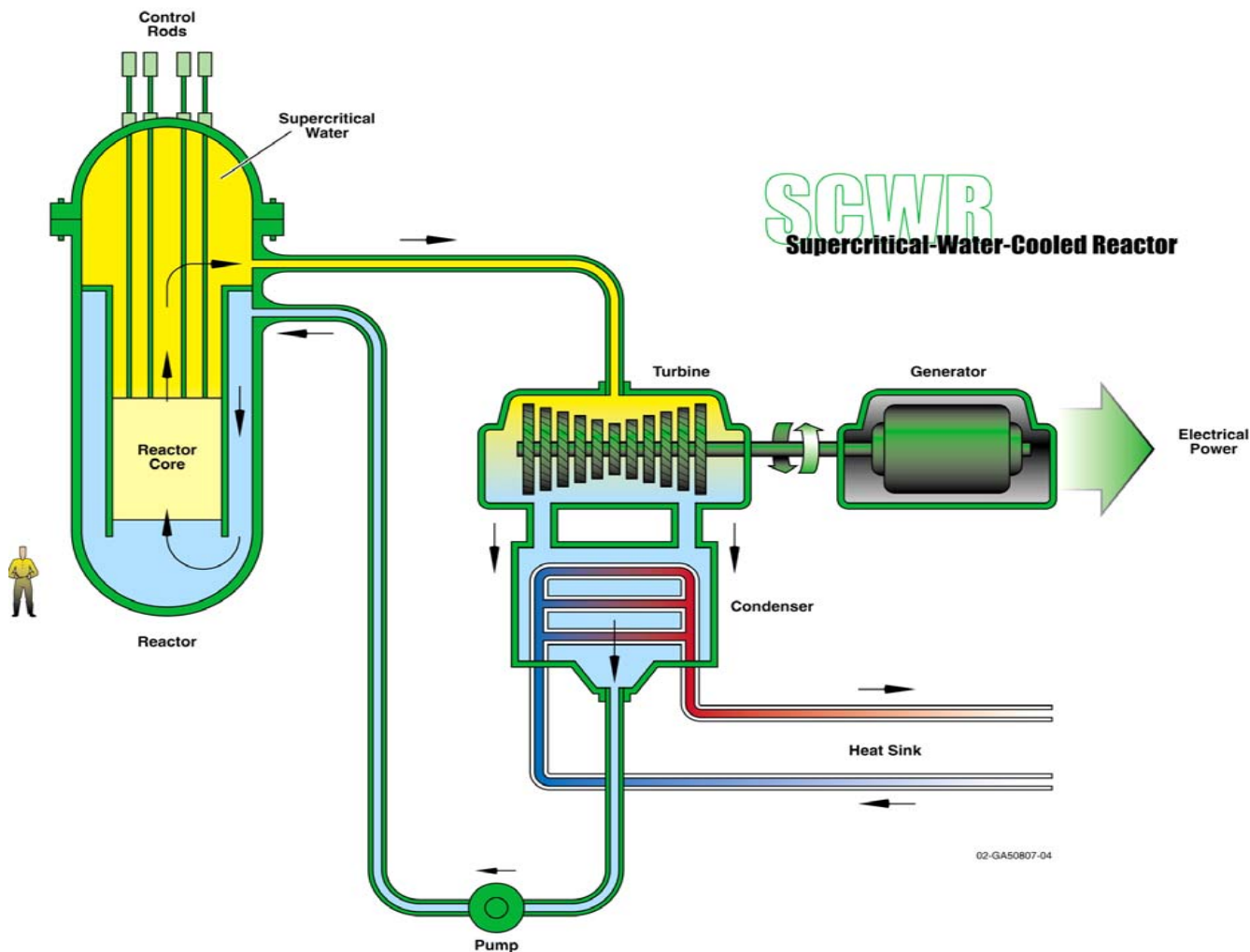
# Supercritical-Water-Cooled Reactor (SCWR)

## Characteristics

- Water coolant at supercritical conditions
- 550°C outlet temperature
- 1700 MWe
- Simplified balance of plant
- Thermal or fast spectrum

## Benefits

- Efficiency near 45% with excellent economics
- Prototype about 2020



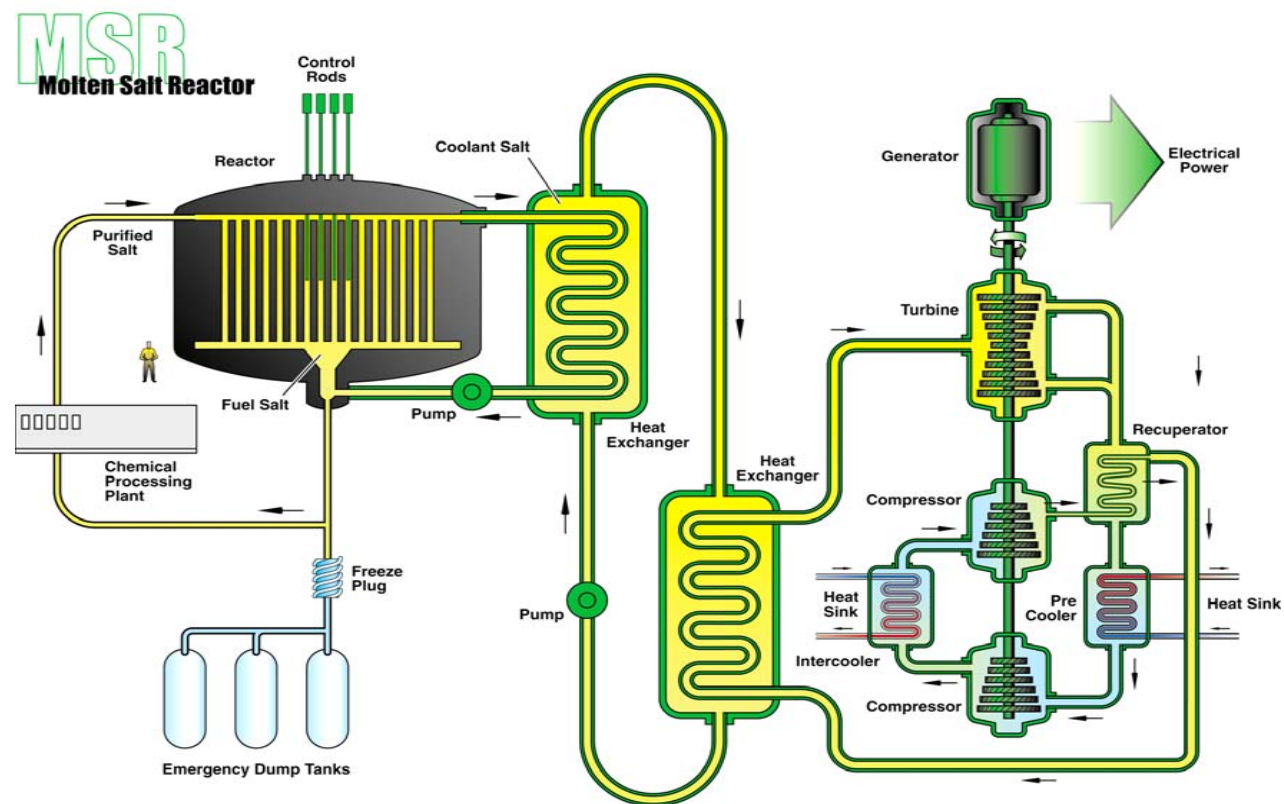
# Molten Salt Reactor (MSR)

## Characteristics

- Fuel: liquid fluorides of Na, Zr, U and Pu
- 700–800°C outlet temperature
- 1000 MWe
- Low pressure (<0.5 MPa)

## Benefits

- 'Final burn' transmutation
- Avoids fuel development
- Proliferation resistance through low fissile material inventory



02-GA50807-02



# MSR R&D Areas

- Very innovative
- Molten salt properties and salt control (REDOX, impurities)
- Resistance of structural materials in molten salt environments (fluorides, chlorides)
- Specific components, esp. heat exchangers
- Graphite life
- Bubbling extraction of gaseous FPs and noble metals
- FP online extraction
- Tritium control



# Status of Research on GIF Systems (I)

## VHTR

EURATOM contributions:

1. **Indirect** through FP6 projects, e.g. RAPHAEL, ExtreMat (materials research for applications in extreme environments, approved) Integrated Projects

Co-ordination of indirect contributions via HTR-TN (JRC-IE is operating agent)

2. **Direct** JRC contributions (IE + ITU)

- On *fuel* (IE + ITU):

- Irradiation tests, out-of-pile characterization, waste minimization (IE)
- Fuel development and safety testing (ITU)

- On *materials* (IE):

- For both direct and indirect cycle power conversion and combined heat and power applications:
  - Safety analyses (neutronics, thermal hydraulics)
  - Materials tests (in-pile and out-of-pile)
  - System studies, alternative closed fuel cycles: Th-U and symbiotic fuel cycles with FBR
  - graphite waste minimization
  - data management

## SCWR

EURATOM contributions:

1. **Indirect** through FP6 submitted proposal (I3) on Material Testing Reactor

2. **Direct** JRC contributions

- at IE:

Two new rigs installed to test materials for SCWR in supercritical water  
Analytical safety studies (core behaviour in normal and accidental situations), spectrum hardening

- at ITU:

structure material testing

## LFR

at IE:

- Feasibility studies
- Fuel cycle studies
- Safety studies (e.g.: dissolution of fission products in liquid metal)
- Feed-back on design options



# Status of Research on GIF Systems (II)

## SFR

EURATOM contributions:

1. **Indirect** through FP6 ITSR (Innovative Technology for SFR) proposal, not yet decided
2. **Direct** JRC contributions
  - at ITU

METAFIX: irradiation of metallic fuels in PHENIX (in collaboration with CRIEPI and CEA)

FUTURIX: participation of the JRC in the irradiation experiment, with the fabrication of 2 fuels

NIMPHE: nitride fuels studies (post-irradiation examination)

## MSR

EURATOM contributions:

1. **Indirect** through FP6 proposal under preparation (LICORNE) as a follow-up to the FP5 MOST Project
2. **Direct** JRC contributions
  - at ITU
    - Phase diagram studies underway

## GFR

EURATOM contributions:

1. **Indirect** through FP6 project GCFR (approved)
2. **Direct** JRC contributions
  - at IE:
    - Design studies
  - at ITU
    - Fuel and fuel cycle development (review started)



# Status of Research on GIF Systems (III)

## Other FP6 Projects useful for GIF

- 2 projects on H<sub>2</sub> production: approved
- Certain fusion activities, e.g. on materials
- PuMA (Pu and MA burning in HTRs): proposed
- GCR-Minwaste (minimization of waste): proposed
- ELSY (EU LFR design): proposed

## Bilateral collaborations useful to GIF R&D:

- USA: General Atomics (finished)
- China: INET (ongoing)
- South Africa: PBMR (starting)
- Japan: JAEA (pending), CRIEPI (ongoing)
- + EURATOM –DOE/Canada/China etc.

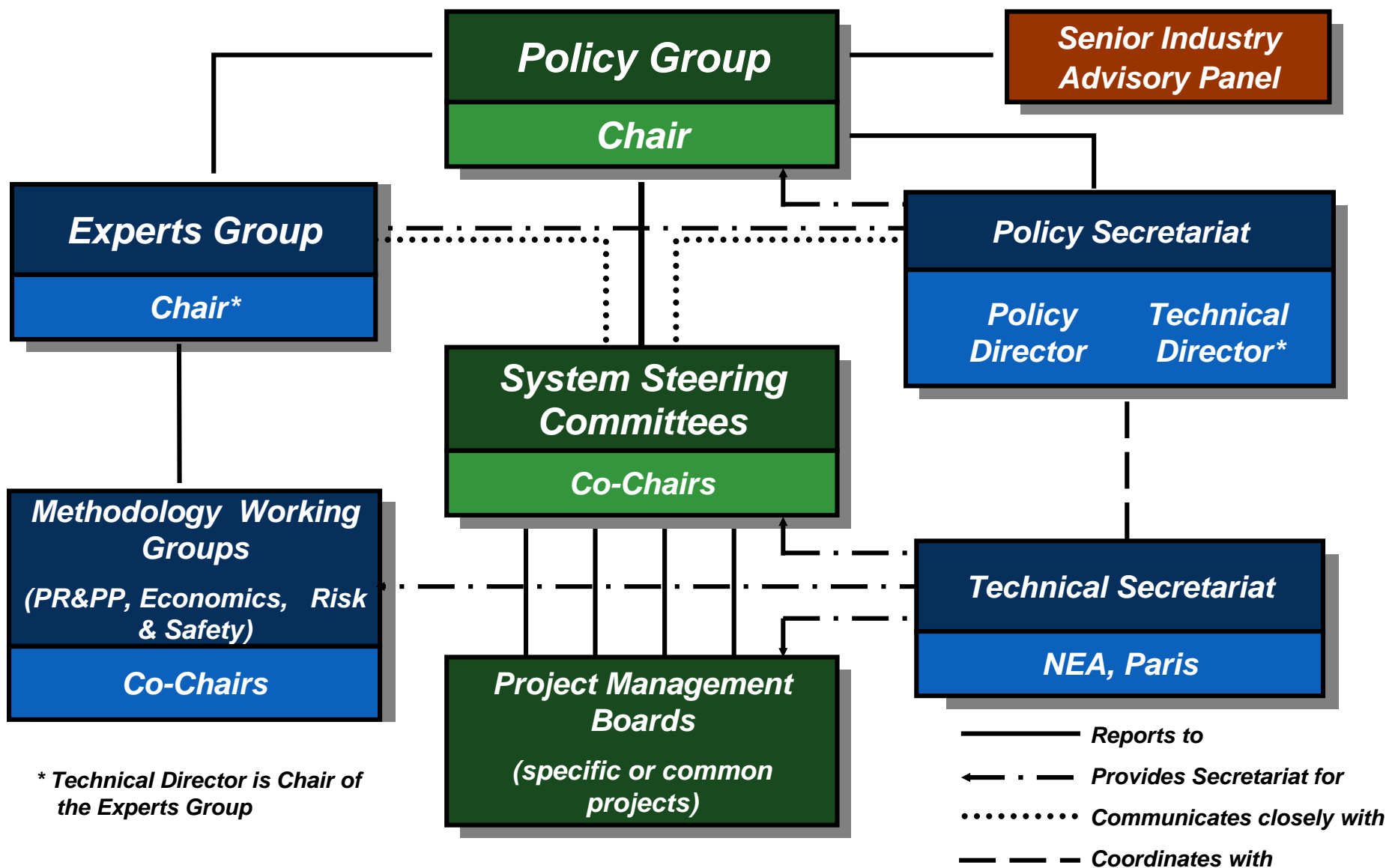


# The role of reprocessing

- Long-term sustainability requires reprocessing (fuel availability, number of geological repositories)
- Advanced aqueous reprocessing
  - Separation of Pu and minor actinides; ready for prototype demonstration (small scale testing at JRC-ITU)
- Advanced dry reprocessing
  - Previous experience with EBR metal fuel (Idaho); R&D in several countries; small prototype in Japanese-European co-operation at JRC-ITU
- Challenge for new fuel to be developed for GFR: highly refractive/ leak-tight yet dissolvable



# 3. GIF Organization and legal framework



\* *Technical Director is Chair of the Experts Group*



# GIF Legal Architecture

- **GIF activities governed by three-level legal agreements:**
  - **Framework Agreement in force (2005)**
    - Signatories: CA, FR, JP, UK, US + CH (13 April 2005) + KR (31 August 2005)
  - **System Arrangements – under discussion / finalisation**
  - **Project Arrangements – under discussion**
- **Initial GIF Documents:**
  - *Political*: the GIF Charter (2001)
  - *Technical*: The GIF Technology Roadmap (2002)



# The Framework Agreement

- Legally binding text governing the overall functioning of GIF
- Entered into force on 28 February 2005.
- **Objective:**  
“..to establish a framework for international collaboration to foster and facilitate achievement of the purpose and vision of the GIF”.
- **Potential Parties** to the FA: Governments (or their ministries or agencies) for GIF Member States and Euratom
- The Framework Agreement describes the role of the other arrangements in the GIF system (System and Project Arrangements)
- **IPR provisions** will be dealt with at the appropriate level (mainly at project level)



# The System Arrangements (SAs)

- **Euratom will sign the System Arrangements**
- Currently, two SAs are under finalisation: for VHTR and for SFR
- **Content of the Template System Arrangement:**
  - Collaboration to be undertaken
  - Management of the research and the development activities undertaken to realize the objective of GIF
  - Financial arrangements
  - Protection, use and disclosure of background proprietary information
  - Adequate and effective protection and allocation of intellectual property created or furnished in the course of the collaboration, including provision for the resolution of disputes concerning intellectual property rights



# The Project Arrangements (PAs)

- **R&D within each System will be performed in one or more projects** (co-ordinated by a Project Management Board)
  - ➔ each System Arrangement implemented through one or several project agreements/arrangements
- **Signatories to the PAs: R&D organisations, industry from GIF Members**
- **Integration of the work within each system will be done by a “Design and Integration Project”**
- **IPR provisions included at this level.**
- **Statute of the PAs: contracts?**
- **Negotiations on PA content started recently: SFR Advanced Fuel PA (17-18 November in Washington)**



# Senior Industry Advisory Panel

- **Objective:** provide advice on long-term strategic issues, including regulatory, commercial or technical issues.
- Comprises 12 senior nuclear industry representatives from the GIF countries
- Panel members sought from nuclear system vendors, architect/engineering companies, nuclear utilities, fuel vendors, waste management or other nuclear energy technology companies, but not from trade organizations.
- Met for the first time on 21 September 2005 in the margin of the Policy Group meeting in Manchester
- **Euratom** is seeking, on a regular basis, advice/input from its representatives on various GIF documents and decisions.



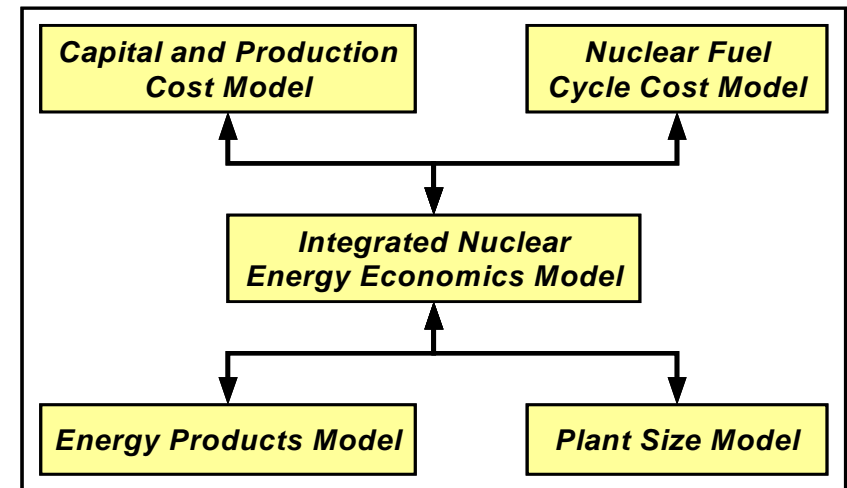
# GIF Methodology Working Groups

- **Economic Modeling Working Group**
- **Proliferation Resistance and Physical Protection**
- **Risk & Safety Working Group**
- Under consideration: **Sustainability Working Group**
- Each is chartered to work on crosscutting methodologies that can be used to evaluate the Generation IV systems

# Economic Modeling Working Group

- Develop economic models for evaluation of Generation IV systems with respect to goals established by GIF
  - Establish and execute plan to develop an integrated model and its constituent models

- Capital/production cost model
- Nuclear fuel cycle cost model
- Plant size model
- Energy products model



- Provide the models, documentation and other economic information to the GIF decision bodies



# Proliferation Resistance & Physical Protection Working Group

- **GIF Technology Roadmap:** *“Generation IV nuclear energy systems will increase the assurance that they are very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.”*
- **Major Tasks**
  - **Develop and demonstrate a methodology** for the systematic evaluation of Generation IV nuclear energy systems with respect to proliferation resistance and physical protection
  - Characterize relevant proliferation and security threats
  - Specify measures for expressing a system’s proliferation resistance and physical protection
  - Develop a methodology to assess/quantify the measures
    - Methodology will be implemented in a software-based evaluation tool (called the “Implementation Guide”)



# Risk and Safety Working Group

The **primary objective** is to assure a harmonized approach on long-term safety, risk and regulatory issues in development of the next generation systems, with focus on:

- 1) *Defining safety and quality goals and evaluation methodology*
- 2) *Facilitating integrated consideration of safety, proliferation resistance and physical protection goals*
- 3) *Assisting the Experts Group in advising the Policy Group on interactions with the nuclear safety regulatory community, and other relevant interests including IAEA*
- 4) *Interacting with the Generation IV Steering Committees and Project Management Boards to provide insights for the definition of the R&D*



## 4. Euratom and the co-ordination of the participation to GIF

- **The Council should give soon the green light to the accession of Euratom to the GIF Framework Agreement**
- Euratom organises regularly (at least twice a year) "Euratom Co-ordination Meetings" on GIF issues (the most recent took place on 18 October in Brussels)
- Maintains close contact with Euratom representatives in various GIF bodies giving guidance and receiving feedback
- Consults regularly partners from MS and ACs on its positions
- Gives an incentive to the participation of R&D organisations at national level (representation in GIF SSCs, WG and advisory panels)
- Disseminates largely GIF information (through workshops, presentations, CIRCA web-based newsgroup managed from the European Commission)



# The approach of a Member State: Finland

Finland has created a GEN4FIN Working Group to co-ordinate at national level GIF-related R&D, via Euratom GIF membership.

## Members of GEN4FIN Working Group

All major parties involved in nuclear technology are represented:

- **TKK** Helsinki University of Technology
- **LUT** Lappeenranta University of Technology
- **VTT** Technical Research Centre of Finland
- **FNS** Fortum Nuclear Services (Engineering unit of the NP Utility company)
- **TVO** Teollisuuden Voima Oy (The Olkiluoto NP Utility company)
- **Prizz** PrizzTech Oy (A project and technology development company)
- **STUK** Nuclear Safety Authority of Finland
- **TEKES** Finnish Centre for Technology Development
- **KTM** Ministry of Trade and Industry



## 5. German participation to GIF

- Euratom representative in the Senior Industry Advisory Panel: **Dr Gerd Jäger, RWE**
- Euratom representative in the SCWR Steering Committee: **Prof. Thomas Schulenberg, FZK**
- Euratom representative in the VHTR Steering Committee:  
**Dr Werner von Lensa, FZJ**



# Euratom representation in GIF main bodies

**Policy Group:** Roland Schenkel, DG JRC, EC  
Pablo Fernández-Ruiz, DG RTD, EC

**Experts Group:** Pierre Frigola, DG JRC, EC  
Simon Webster, DG RTD, EC

## System Steering Committees:

**VHTR:** Werner von Lensa, FZJ

**GFR:** Didier Haas, ITU, EC

**SCWR:** Prof. Thomas Schulenberg, FZK

**LFR:** Luciano Cinotti, Ansaldo

**MSR:** Miroslav Hron, NRI – Rez

**SFR:** Jean-François Babelot, ITU, EC (*observer*)

**Senior Industry Advisory Panel:** Dr Gerd Jäger, RWE  
Dr Adolfo García-Rodríguez, Empresarios Agrupados

**EMWG:** Prof. Risto Tarjanne, University of Laaperantaa

**PPRPP WG:** Giacomo Cojazzi, JRC-Ispra, EC

**RSWG:** Vesselina Ranguelova, IE, EC  
Antti Daavittila, VTT, Finland



## 6. Conclusions - Euratom membership will:

- make significant scientific/technical contribution to GIF (20 - 30 M€/year)
- play a constructive role towards achievement of GIF R&D objectives
- provide a platform for participation from interested research organizations (including industry) from EU Member States not part of GIF and CCs
- align parts of European nuclear research to objectives of GIF
- offer an exciting and challenging field for European scientists and students in a worldwide R&D initiative.