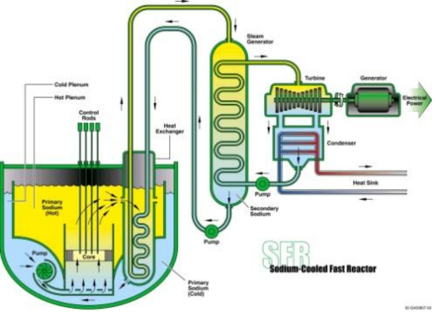


Technology Assessment & Acquisition

# Candidate Technologies
# &
# Technology Selection
# *Through Extending Quick & Dirty Technology Assessment Method*
# Nuclear Reactor Energy: Generation IV

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# Agenda

- Introduction/Background
- Gap Analysis
  - Current Issues (Technology System)
  - Current Issues (Evaluation Methodology)
- **CANDIDATE TECHNOLOGIES**
  - Technology/System Requirements
  - Candidate Technologies: Gen IV Reactors
  - Technology System Req's Matrix
  - Data Transformation
- **TECHNOLOGY SELECTION**
  - Extending Quick & Dirty Technology Assessment
  - Analysis/Technology Selection Development – Q&D TA Process, Limitations/Solutions
  - Recommendation: Final Technology Selection
- Advantages & Disadvantages (Quick & Dirty TA Method)
- Lessons Learned/Future Work
- References
- Backup

# Background: Generation IV International Forum (GIF)

- **International effort to establish feasibility & performance capabilities on next generation nuclear energy systems (began 2001)** (www.gen-4.org)

- **13 members of GIF charter**

- **Identified/selected 6 nuclear energy systems for R & D efforts & 24 metrics+** (U.S. Dept of Energy Research Advisory Committee, 2002)

- **These systems employ various reactor, energy conversion, and fuel cycle technologies**

- **GIF picked the 6 systems & goals/parameters (worldwide experts – backup)**
  - *…strategically, which system should be invested in?*
  - *…requested help in developing an evaluation methodology* (Bennett, 2002)

# Gap Analysis → Goals: Current Technology System Issues (Summary-Level)

- **Nuclear Energy System Choice Must Be:**
  - *Sustainable*
  - *Competitive (Economically)*
  - *Safe & Reliable*
  - *Proliferation Resistant & Physical Protection*

(U.S. Dept of Energy Research Advisory Committee, 2002)

# Gap Analysis → Goals: Evaluation Methodology Needs

- **Evaluation Methodology Gaps/Req's** **(Bennett, 2002)**
  - *Evaluate the potential for the systems to advance toward the Generation IV goals*
  - *Treat all Generation IV goals equally**
  - *Strive for comprehensive evaluations, but accept qualitative judgment*
  - *Allow for systems with different levels of maturity*
  - *Do not discriminate against less well developed systems*
- ***Need help in methods NOT based solely on economics**
- **Yet, published works still reflect**
  - either cost-based (Berbey, et al, 2008) (Yanagisawa, et al, 2002)
  - or concentrate on only one technology issue (Aliberti, 2006)

# Generation IV Reactors (the technology systems)

- **Thermal Reactors**
  1. Very High Temperature Reactors (VHTR) – graphite moderated core w/ once-through uranium fuel cycle. Passively safe.
  2. Supercritical Water Reactor (SCWR) – supercritical water as the working fluid. Light water reactor operating at higher temperature. High thermal efficiency and plant simplification.
  3. Molten Salt Reactor (MSR) – coolant is a molten salt.
- **Fast Reactors**
  1. Gas-Cooled Fast Reactor (GFR) – fast neutron spectrum & closed fuel cycle for more efficient conversion.
  2. Sodium-Cooled Fast Reactor (SFR) – use of liquid metal for coolant rather than water allows system to work at atmospheric pressure, reducing leakage risk. Risks of handling sodium.
  3. Lead-Cooled Fast Reactor (LFR) – low maintenance/lower cost due to longer refueling intervals.

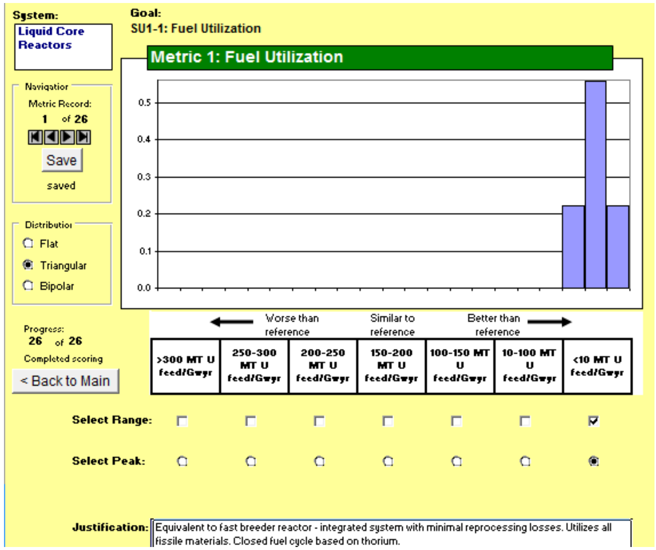
(U.S. Dept of Energy Research Advisory Committee, 2002)

Drawings in backup

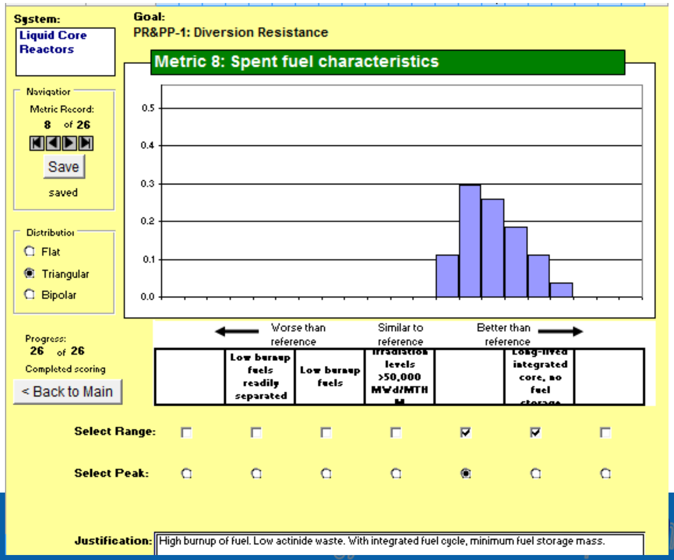
# Technology System Requirements Matrix

- GIF/Experts judged 19 total systems by quantitative & qualitative scoring (U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Supporting Documents", GIF-020-00 thru GIF-039-00, 2002)
- Generation III system as a yardstick to measure all other systems against (Nuclear Energy Research Advisory Committee, 2002)
- Requirements matrix for our study
- Original data files in backup

*MSR Example Quantitative*




*MSR Example Qualitative*




- Fuel Utilization:
  - "The nuclear fuel cycle is the progression of steps in the utilization of fissile materials, from the initial mining of the uranium (or thorium) through the final disposition of the material removed from the reactor. " (Bodansky, 2007). Mass of fuel as MTU;
- Spent Fuel Characteristics:
  - High burn-up fuels increase difficulty of handling & chemical separations & reduce attractiveness of the recovered material for usage in weapons. Megawatt days per metric ton of heavy metal (MWd/MTHM) (Kahneman 1982)

# Data Transformation

- Converted as appropriate on a 1-7 scale & using actual performance if possible
- Where there was a spread in expert responses; used appropriate % to come up with average response
- Later TA process steps also convert to High/Med/Low where needed

| | Sustainability ( | | Sustainability Goal 2 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generation IV Nuclear Energy System | M1 Fuel Utilization | M1 Real | M2 - Mass of Waste | M2 - Real | M3 - Volume of Waste | M3 - Real | M4 - Long-term Heat Outpu | M4 - Real | M5 - Long-term Radiotoxicity | M5 - Real | M6 - Environmental Impac | M6 - Real |
| **SFR - Sodium Cooled Metal Fueled Pyroprocessing** | 7 | 5 | 7 | 2.5 | 6.7 | 4 | 7 | 0.05 | 6.7 | 15 | 5.3 | |
| **VHTR** | 4 | 175 | 6 | 7.5 | 3.7 | 18 | 3.7 | 2.5 | 4.3 | 800 | 4 | |
| **GFR - Closed Cycle** | 7 | 5 | 7 | 2.5 | 7 | 2.5 | 7 | 0.05 | 7 | 10 | 5.3 | |
| **MSR** | 7 | 5 | 7 | 2.5 | 5 | 12.5 | 5.7 | 0.4 | 5 | 300 | 4.3 | |
| **SCWR thermal spectrum** | 4 | 175 | 4.7 | 14 | 5.3 | 11 | 5 | 0.75 | 4.3 | 800 | 4.7 | |
| **LFR** | 7 | 5 | 7 | 2.5 | 6.7 | 4 | 7 | 0.05 | 6.7 | 15 | 5 | |

| | Non-Proliferation | | | afety & Reliability Goal | | | Safety & Reliability Goal 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Generation IV Nuclear Energy System | M7 - Separated Materials | M8 - Spent Fuel Characterist | M9 - Sabotage Resistance | M10 - Reliability | M11 - Worker Safety Routin | M12 - Worker/Public Safety | M13 - Reliable Rectivity | M14 - Robust Safety Featur | M15 - Dominant Phenomena | M16 - Long Fuel Response | M17 - Models with Well Chara |
| **SFR - Sodium Cooled Metal Fueled Pyroprocessing** | 4 | 5 | 5.7 | 4 | 5.3 | 4.4 | 5.7 | 5.7 | 6 | 6 | 5.7 |
| **VHTR** | 4 | 5 | 4.6 | 4 | 5.3 | 5.7 | 6 | 6 | 5.4 | 6 | 6 |
| **GFR - Closed Cycle** | 4 | 5 | 5.3 | 4 | 5 | 5.7 | 5.7 | 4.6 | 5.7 | 5.7 | 5.7 |
| **MSR** | 5.3 | 4.3 | 4.3 | 4 | 5.1 | 4.3 | 6 | 5.4 | 4.2 | 5.4 | 4.3 |
| **SCWR thermal spectrum** | 4 | 4 | 4.3 | 4 | 4.2 | 3.2 | 4 | 5.3 | 4.3 | 4.6 | 4 |
| **LFR** | 4 | 5 | 5.7 | 4 | 4 | 4.4 | 6 | 5.3 | 5.7 | 6 | 5.3 |

| | Safety & Reliability Goal 3 | | | | Economics Goals 1 & 2 | | | | | | Development Cost | | R&D Cost | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generation IV Nuclear Energy System | M18 - Source Term | M19 - Mechanisms for Energ | M20 - Long System Time | M21 - Long & Effective | M22 - Overnight Construction | M22 - Real | M23 - Production Costs | M23 - Real | M 24 - Construction | M24 - Real | M 25 - Development Costs | M25 - Real | M 26 - R & D Costs | M26 - Real |
| **SFR - Sodium Cooled Metal Fueled Pyroprocessing** | 5.7 | 5.7 | 6.7 | 6 | 5.3 | $1,250 | 4.4 | $14.50 | 6 | 30 | 2.3 | $1,250,000,000 | 3 | $600,000,000 |
| **VHTR** | 7 | 5.7 | 7 | 4 | 5.4 | $1,225 | 5 | $13 | 4.7 | 42 | 2.3 | $1,250,000,000 | 2 | $700,000,000 |
| **GFR - Closed Cycle** | 4.6 | 5.7 | 5.4 | 5 | 4.4 | $1,400 | 5 | $13 | 4.7 | 42 | 2 | $1,500,000,000 | 1 | $940,000,000 |
| **MSR** | 4.6 | 4.6 | 4.3 | 4.3 | 4 | $1,500 | 4.3 | $14.75 | 4 | 50 | 2 | $1,500,000,000 | 1 | $1,000,000,000 |
| **SCWR thermal spectrum** | 4.3 | 4 | 6 | 5.3 | 6.4 | $1,050 | 6 | $11 | 4.7 | 42 | 2.7 | $900,000,000 | 1 | $870,000,000 |
| **LFR** | 5.4 | 5.7 | 6.7 | 4.6 | 4 | $1,500 | 4 | $15 | 6 | 30 | 2 | $1,500,000,000 | 1 | $990,000,000 |

# Extending Quick & Dirty Technology Assessment

- **What Is It**
  - Multi-perspective method for technological assessment using qualitative & quantitative data (Azzone & Manzini, 2008)
  - Originally developed & applied to Italian research centre's (IRC) organizational perspective on how well it was investing in 4 technology applications
  - Note: Interesting: IRC research operations include energy → energy technologies → (nuclear fusion & fission)

- **Quick & Dirty Technology Assessment (Q&D TA) 6 Process Steps**

- **Extending**
  - Applying to 6 Gen IV Nuclear Energy technology systems (technological rather than organizational perspective)
  - → Limitations to the Q&D TA for applying to Nuclear Energy Systems; corresponding solutions outlined in assessment & selection

Azzone, G. and Manzini, R., 2008, "Quick and dirty technology assessment: The case of an Italian Research Centre", Technological Forecasting & Social Change, Vol. 75, pp. 1324-1338.

# Quick & Dirty Technology Assessment (Q&D TA) - Step 1

## 1. Identification of competences & applications

→ *Identification of Technological, Organizational, or Personal Requirement* (Linstone, 1999)

- **Limitations**
  - Q&D TA method has many competences feeding variously into 4 Technology Applications
  - All of the Gen IV Req's apply to all of the 6 systems; what could be an alternative approach to show potential development issues?
- **Solution**
  - 1st TA step: identifying tech req's & corresponding applications still apply (Chiesa, et al, 1996) (Panda & Ramanathan, 1997)
  - Linstone's TOP
- **Analysis**
  - Given technology system & long-term R&D outlook;
  - not surprising how many technological req's –
  - resources will be concentrated on technology development & overlapping development interests (cross-cutting R&D) → which is what is happening (Nuclear Energy Research Advisory Committee, 2002)
  - At this point organizational is concentrated on costs → as a technological system matures, this could change

| GENERATION IV GOALS | Technological/ Organizational/ Personal |
|---|---|
| **Sustainability Goal 1** | |
| M1 Fuel Utilization | Technological |
| **Sustainability Goal 2** | |
| M2 - Mass of Waste | Technological |
| M3 - Volume of Waste | Technological |
| M4 - Long-term Heat Output | Technological |
| M5 - Long-term Radiotoxicity | Technological |
| M6 - Environmental Impact | |
| **Non-Proliferation** | |
| M7 - Separated Materials | Technological |
| M8 - Spent Fuel Characteristics | Technological |
| M9 - Sabotage Resistance | Technological |
| **Safety & Reliability Goal 1** | |
| M10 - Reliability | Technological |
| M11 - Worker Safety Routine Exposures | Personal |
| M12 - Worker/Public Safety Accidents | Personal |
| **Safety & Reliability Goal 2** | |
| M13 - Reliable Reactivity Control | Technological |
| M14 - Robust Safety Features | Technological |
| M15 - Dominant Phenomena Have Low Uncertainty | Technological |
| M16 - Long Fuel Response Time | Technological |
| M17 - Models with Well Characterized Uncertainty | Technological |
| **Safety & Reliability Goal 3** | |
| M18 - Source Term | Technological |
| M19 - Mechanisms for Energy Release | Technological |
| M20 - Long System Time Constraints | Technological |
| M21 - Long & Effective Holdup | Technological |
| **Economics Goals 1 & 2** | |
| M22 - Overnight Construction Costs | Organizational |
| M23 - Production Costs | Organizational |
| M 24 - Construction Duration | Organizational |
| **Development Costs** | |
| M 25 - Development Costs | Organizational |
| **R&D Costs** | |
| M 26 - R & D Costs | Organizational |

# Quick & Dirty Technology Assessment (Q&D TA) - Step 2

2. Analysis – Internal Relevance of competences & applications

*→ Internal Inputs & Outputs*

## Limitations

- Q&D TA method included normalized %; easy cutoffs bet. High/lows
- this step probably would have worked better with all original 19 nuclear energy systems

## Solution

- Technology System Inputs/Outputs (Anderson 2002, 2008) (Martino, 1993)
- Eyeball real numbers & provide low-med-high estimate (Jolly, 2008)

## Analysis

- VHTR & SCWR are non-breeder reactors.; system incapable of using all fissile material as fuel: either must be reprocessed for fuel usage or goes to waste (U238 isotope cannot be fissioned). Breeders are able to transform U238 into Plutonium. (Simon, 1984)
- All other systems capable of full fuel utilization – the mixture of thorium &/or uranium is fully used with minimal waste
- The complexities of fuel containment & reactor systems create the differences between the other 4 systems
- *Which system looks optimal?*
- SFR: Sodium-Cooled Fast Reactor: Breeder efficient fuel usage; operates at atmospheric pressure → so low escapage risk, less has to go into design for containment (Hishida, 2007) (Hyung-Kook, 2008)

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| GENERATION IV GOALS | INTERNAL: INPUT |
|---|---|
| **Economics Goals 1 & 2** | |
| M22 - Overnight Construction Costs | Input |
| M23 - Production Costs | Input |
| M 24 - Construction Duration | Input |
| **Development Costs** | |
| M 25 - Development Costs | Input |
| **R&D Costs** | |
| M 26 - R & D Costs | Input |

| GENERATION IV GOALS | INTERNAL: OUTPUT |
|---|---|
| **Sustainability Goal 1** | |
| M1 Fuel Utilization Output (low) | |
| **Sustainability Goal 2** | |
| M2 - Mass of Waste Output (low) | |
| M3 - Volume of Waste Output (low) | |
| M4 - Long-term Heat Output Output (low) | |
| M5 - Long-term Radiotoxicity Output (low) | |

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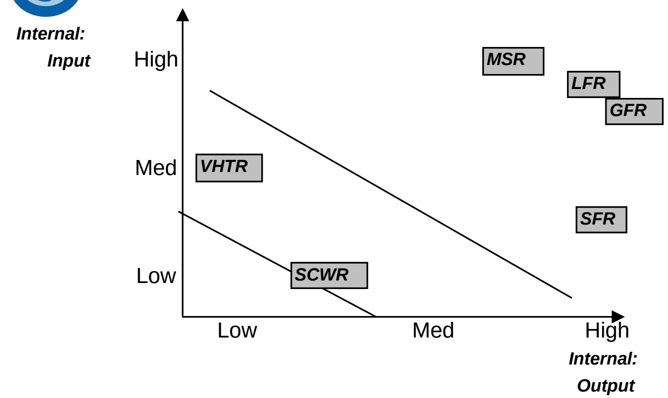


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***Internal: Input Analysis***

| Generation IV Nuclear Energy System | M22 - Overnight Construction Costs | M23 - Production Costs | M 24 - Construction Duration (Months) | M 25 - Development Costs | M 26 - R & D Costs | |
|---|---|---|---|---|---|---|
| **SFR** | $1,250 | $14.50 | 30 | $1,250,000,000 | $600,000,000 | Med-Low |
| **VHTR** | $1,225 | $13 | 42 | $1,250,000,000 | $700,000,000 | Med |
| **GFR** | $1,400 | $13 | 42 | $1,500,000,000 | $940,000,000 | Med-High |
| **MSR** | $1,500 | $14.75 | 50 | $1,500,000,000 | $1,000,000,000 | High |
| **SCWR** | $1,050 | $11 | 42 | $900,000,000 | $870,000,000 | Low |
| **LFR** | $1,500 | $15 | 30 | $1,500,000,000 | $990,000,000 | High-Med |

***Internal: Output Analysis (note: small magnitude is HIGH output )***

| Generation IV Nuclear Energy System | M1 Fuel Utilization | M2 - Mass of Waste | M3 - Volume of Waste | M4 - Long-term Heat Output | M5 - Long-term Radiotoxicity | |
|---|---|---|---|---|---|---|
| **SFR** | 5 | 2.5 | 4 | 0.05 | 15 | High |
| **VHTR** | 175 | 7.5 | 18 | 2.5 | 800 | Low |
| **GFR** | 5 | 2.5 | 2.5 | 0.05 | 10 | **High** |
| **MSR** | 5 | 2.5 | 12.5 | 0.4 | 300 | Med-High |
| **SCWR** | 175 | 14 | 11 | 0.75 | 800 | Low-Med |
| **LFR** | 5 | 2.5 | 4 | 0.05 | 15 | High |

# Quick & Dirty Technology Assessment (Q&D TA) - Step 3

3. External relevance of competences & applications

- ## Description

(Azzone, 2008) (Jeong & Kim, 1997) (Martin, 1995)

- Potential of Future Developments
  - An external analysis of technology first should be analyzed for potential of future developments – which is dependent on maturity & physical limits of the technology
- Economic and Social Relevance
  - Along with technology potential, the economic & social relevance can be compared; these are dependent on the range of potential applications/technologies & the potential economic/social impact

# Quick & Dirty Technology Assessment (Q&D TA) - Step 3 (Con't…)

## 3. External relevance of competences & applications

| GENERATION IV GOALS | EXTERNAL: ECONOMIC & SOCIAL RELEVANCE |
|---|---|
| M6 - Environmental Impact | X |
| **Non-Proliferation** | |
| M7 - Separated Materials | X |
| M8 - Spent Fuel Characteristics | X |
| M9 - Sabotage Resistance | X |
| **Safety & Reliability Goal 1** | |
| M10 - Reliability | X |
| M11 - Worker Safety Routine Exposures | X |
| M12 - Worker/Public Safety Accidents | X |
| M21 - Long & Effective Holdup | X |

| Generation IV Nuclear Energy System | M6 - Environmental Impact | M7 - Separated Materials | M8 - Spent Fuel Characteristi | M9 - Sabotage Resistance | M10 - Reliability | M11 - Worker Safety Routin | M12 - Worker/Public Safety | M21 - Long & Effective | Avg | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SFR - Sodium Cooled Metal Fueled Pyroprocessing** | 5.3 | 4 | 5 | 5.7 | 4 | 5.3 | 4.4 | 6 | **4.963** | **High** |
| **VHTR** | 4 | 4 | 5 | 4.6 | 4 | 5.3 | 5.7 | 4 | **4.575** | **Med-High** |
| **GFR - Closed Cycle** | 5.3 | 4 | 5 | 5.3 | 4 | 5 | 5.7 | 5 | **4.913** | **High** |
| **MSR** | 4.3 | 5.3 | 4.3 | 4.3 | 4 | 5.1 | 4.3 | 4.3 | **4.488** | **Med-High** |
| **SCWR thermal spectrum** | 4.7 | 4 | 4 | 4.3 | 4 | 4.2 | 3.2 | 5.3 | **4.213** | **Med** |
| **LFR** | 5 | 4 | 5 | 5.7 | 4 | 4 | 4.4 | 4.6 | **4.588** | **Med-High** |

1

| GENERATION IV GOALS | EXTERNAL: POTENTIAL for FUTURE DEVELOPMENT |
|---|---|
| **Safety & Reliability Goal 2** | |
| M13 - Reliable Reactivity Control | X |
| M14 - Robust Safety Features | X |
| M15 - Dominant Phenomena Have Low Uncertainty | X |
| M16 - Long Fuel Response Time | X |
| M17 - Models with Well Characterized Uncertainty | X |
| **Safety & Reliability Goal 3** | |
| M18 - Source Term | X |
| M19 - Mechanisms for Energy Release | X |
| M20 - Long System Time Constraints | X |

2

| Generation IV Nuclear Energy System | M13 - Reliable Rectivity Control | M14 - Robust Safety Featur | M15 - Dominant Phenomena | M16 - Long Fuel Response | M17 - Models with Well Chara | M18 - Source Term | M19 - Mechanisms for Energ | M20 - Long System Time | Avg | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SFR - Sodium Cooled Metal Fueled Pyroprocessing** | 5.7 | 5.7 | 6 | 6 | 5.7 | 5.7 | 5.7 | 6.7 | **5.9** | **High** |
| **VHTR** | 6 | 6 | 5.4 | 6 | 6 | 7 | 5.7 | 7 | **6.138** | **High** |
| **GFR - Closed Cycle** | 5.7 | 4.6 | 5.7 | 5.7 | 5.7 | 4.6 | 5.7 | 5.4 | **5.388** | **Med-High** |
| **MSR** | 6 | 5.4 | 4.2 | 5.4 | 4.3 | 4.6 | 4.6 | 4.3 | **4.85** | **Med** |
| **SCWR thermal spectrum** | 4 | 5.3 | 4.3 | 4.6 | 4 | 4.3 | 4 | 6 | **4.563** | **Med** |
| **LFR** | 6 | 5.3 | 5.7 | 6 | 5.3 | 5.4 | 5.7 | 6.7 | **5.763** | **Med-High** |

# Quick & Dirty Technology Assessment (Q&D TA) - Step 3 (Con't…)

3. External relevance of competences & applications

*→ External Review of Economic/Social Relevance & Potential for Future Development*

- **Limitations**
  - Expert judgment at this summarized level of granularity
- **Solution**
  - Determine which goals fit into each category; then utilize/avg the expert judgments provided for each
- **Analysis**
  - These **two categories were excellent for reviewing nuclear energy systems** – in fact, accounted for remaining goals not included in inputs/outputs
  - Allowed for full spectrum of metrics/expert's judgments
  - SFR high again
  - Was a little surprised that with only 6 systems for comparison, differentiation still showing – good news

3

| Economic & Social Relevance | Potential for Future Development: Med | Med-High | High |
|---|---|---|---|
| High | | GFR | SFR |
| Med-High | MSR | LFR | VHTR |
| Med | SCWR | | |

# Quick & Dirty Technology Assessment (Q&D TA) - Step 4

4. Technological Positioning

*→ Technological Positioning*

- **Description**
  - This step is meant to determine the level of excellence of the technology…with respect to the state of art in the field (Azzone, 2008) (Pappas, 1984) (Coburn, 2002)
  - Not a trivial exercise (Walsh, S., and Linton, J.D., 2002)
  - **In Q&D TA, the authors asked a group of experts to rank by H/M/L; this was already done for this nuclear system study** from original data set since the judging was conducted compared to a Gen III system.
- **Limitations**
  - Q&D TA Italian Research Centre ended with more distinct variations – with 20 variables, rather than 6
- **Solution**
  - As expert judgments were feeds into the internal and external perspectives; these were pulled together into an overall technological positioning of each system
- **Analysis**
  - **SFR shows high; and the two non-breeder systems are the lowest with respect to positioning to the state of art**
  - Future work would include listing strengths/weaknesses of each system here

Technological Positioning of Each System

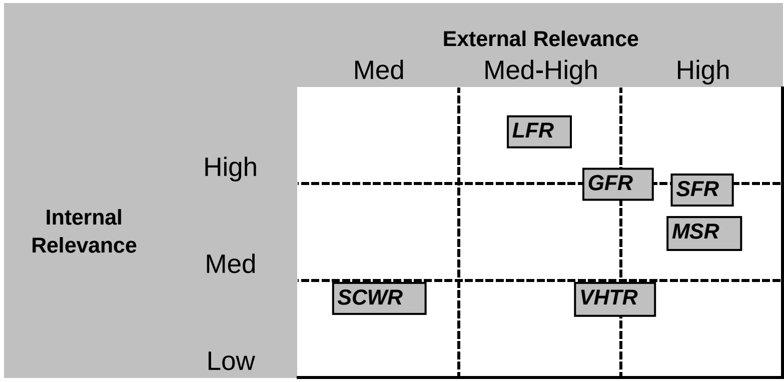
| Generation IV Nuclear Energy System | Overall Evaluation (L-M-H) |
|---|---|
| **SFR** | High |
| **VHTR** | Med |
| **GFR** | Med-High |
| **MSR** | Med-High |
| **SCWR** | Med-Low |
| **LFR** | Med-High |

# Quick & Dirty Technology Assessment (Q&D TA) - Step 5

5. Processing of the data and information

→ *Processing of data & information*

- **Description**
  - Processing data/information in this step can be challenging; “to deliver significant results, the processing of data must always be guided by the aims [goals] of the assessment” (Azzone, 2008)
  - ***Goal: Ability to distinguish which Gen IV system best meets Nuclear Energy Goals***
  - ***Goal: An evaluation method meeting the workgroup’s goals***
- **Limitations**
  - No major ones
- **Solution**
  - Similar to Q&D TA; matched up the internal & external relevances
  - Scored results-to-date against evaluation methodology requirements
- **Analysis**
  - When matched up against external factors, SFR now more clearly shows as compelling system
  - Evaluation Method: Fairly good fit with requirements, some improvements could be made




**Customer Requirements (Evaluation Methodology) Met?**

- *Evaluate the potential for the systems to advance toward the Generation IV goals (Score=.9)*
- *Treat all Generation IV goals equally* (Score=.5; economic?)*
- *Strive for comprehensive evaluations, but accept qualitative judgment (Score=1)*
- *Allow for systems with different levels of maturity (Score=1)*
- *Do not discriminate against less well developed systems (Score=1)*

# Quick & Dirty Technology Assessment (Q&D TA) - Step 6

6. Summary of Results

→ *Summary of Results*

- **Analysis**
  - Similar to the Q&D TA, the methodology appears to have satisfactorily met the objectives of the TA
  - At the end of the assessment, it was much easier to understand how to differentiate between the systems/which ones to focus on with SFR system as a promising nuclear energy source
  - Inputs clearly highlighted as well as outputs provides a rough estimate of efficiency
  - Social relevance & technological development potential appeared to round out analysis of the important technology system requirements
    - could aid in buy-in for where investment R&D should be spent

# Advantages & Disadvantages (Q&D TA Method)

- **Advantages**
  - Flexible, both for multiple perspectives as well as for adapting/addressing limitations
  - Qualitative & Quantitative
  - Did it allow for equal treatment of goals?

- **Disadvantages**
  - Requires qualitative: in both cases (Italian Research Centre & Nuclear Energy Systems) expert judgment needed – this is a lot of work to gather

# Recommendations

- According to this extension of Q&D TA, investment should be directed to SFR nuclear energy system
- A further study of priorities/objectives weighted by country/investor could provide some further differences … thereby potentially making another system of higher priority
- Q&D TA methodology should be implemented with updated information about each system as the method is flexible enough to overcome limitations

# Lessons Learned/Future Work

- **Lessons Learned**
  - Improved perspective on TA for technology component vs system vs organization technology research perspective
  - Difficultly in judging TA not only for larger systems, but also for long-term R&D
  - Work-arounds, as needed, to address limitations of Q&D TA method → expanded ability to address obstacles (vs. a method with fewer obstacles)
  - Could have avoided some mis-steps by just starting with Q&D TA steps rather than try and fit into class sequence exactly
  - May not win the battle if a researcher tries to use 100% quantitative only – not for larger technological systems & long-term R&D (must find ways to deal effectively with qualitative judgments)

- **Future Work Needed**
  - More analysis/study of nuclear systems & individual technology components themselves (Q&D TA helped to focus)
  - Further study on methods already employed to analyze past nuclear energy options/other energy
  - Apply Q&D TA to all 19 nuclear energy systems & compare results to 6 original ones chosen by GIF
  - Possible to use only quantitative scoring numbers for all requirements?
  - Update expert score sheets with latest information/research/developments on the different nuclear systems

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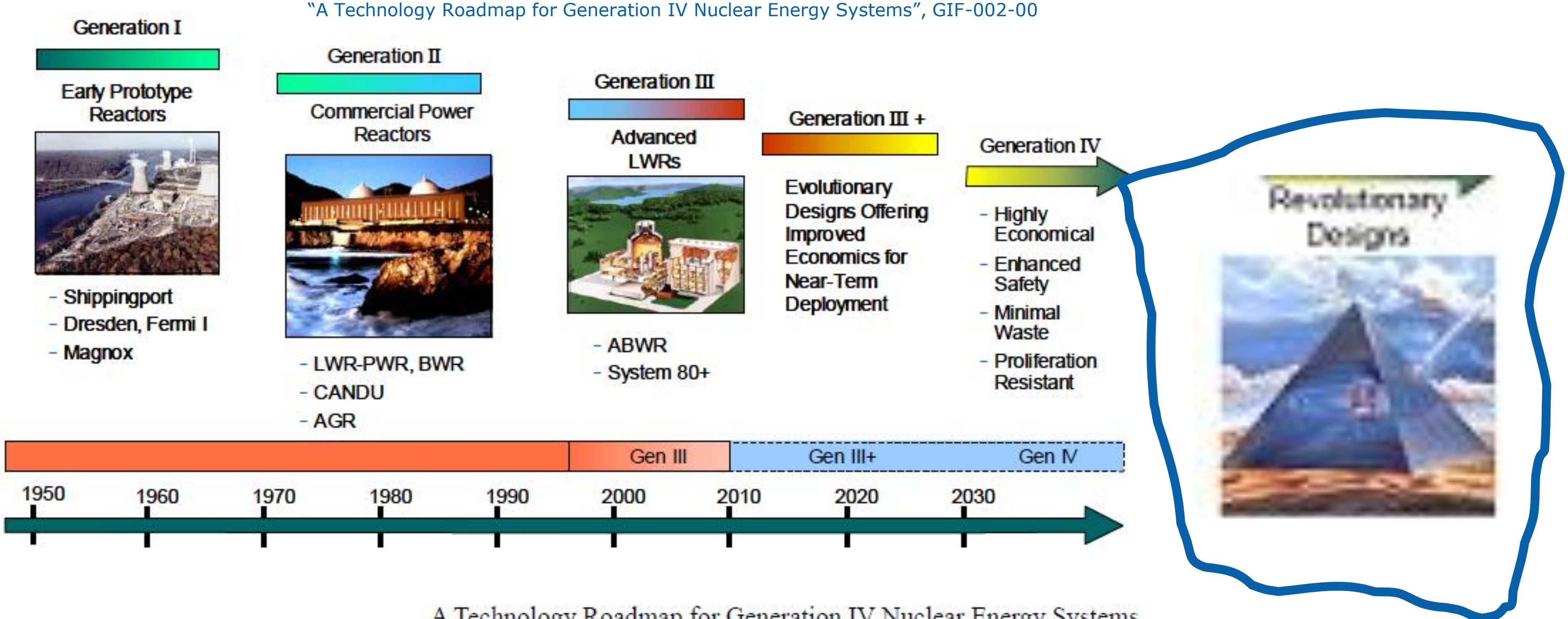
# Backup

# History of Nuclear Reactors

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, "A Technology Roadmap for Generation IV Nuclear Energy Systems", GIF-002-00



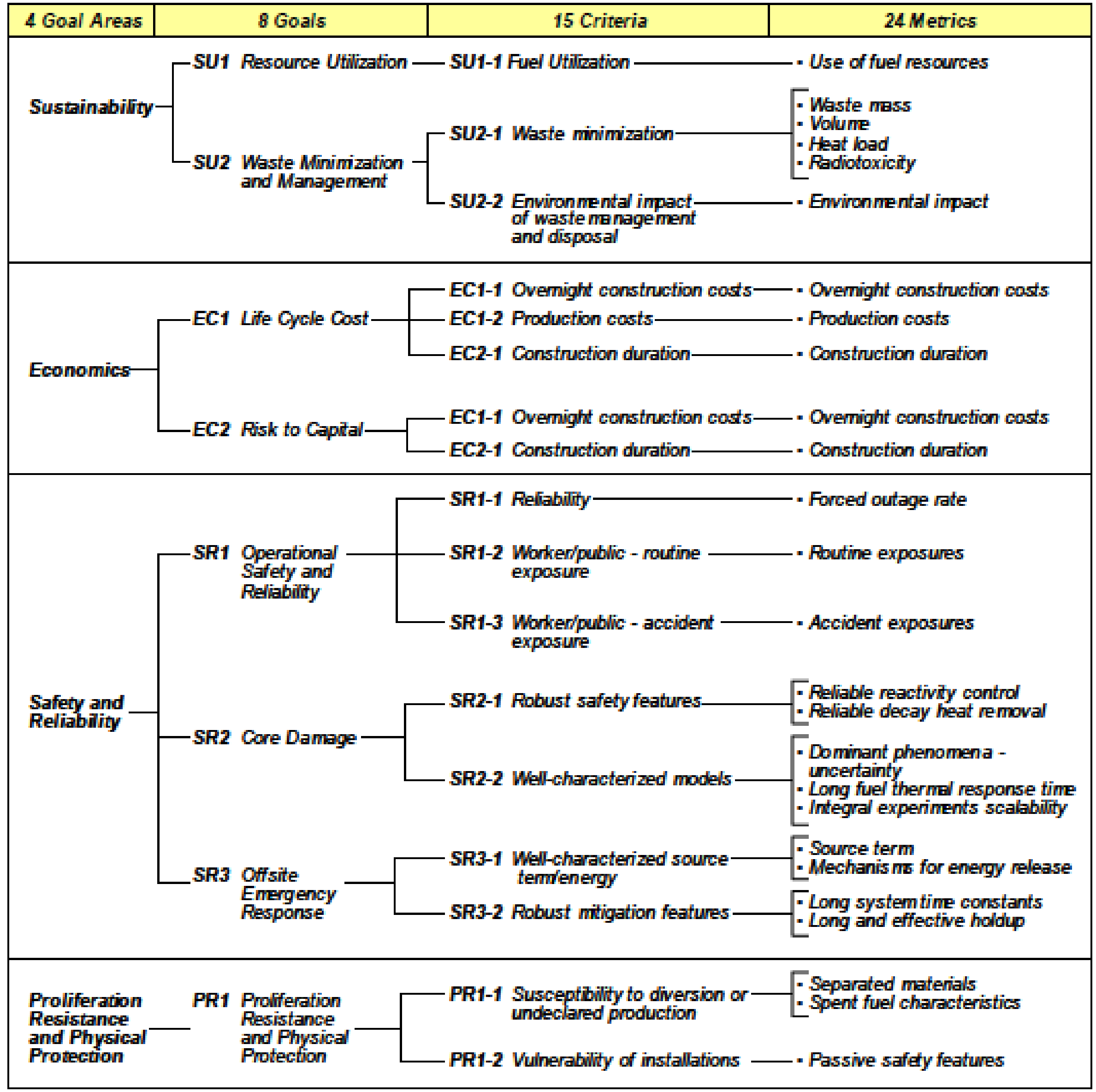

A Technology Roadmap for Generation IV Nuclear Energy Systems

- LWR: Light water reactors
- PWR: Pressurized water reactors
- BWR: Boiling water reactors
- AGR: Advanced gas-cooled reactor
- ABWR: Advanced boiling water reactor
- CANDU: CANada deuterium uranium. All current reactors in Canada are this type
- System 80+: Pressurized water reactor design. The + refers to an evolutionary design (improved costs & safety)

www.nuclear.energy.gov/genIV/neGenIV1.html accessed 10/24/09 U.S. Dept of Energy Office of Nuclear Energy, Science & Technology

- 24 metrics

Roll Up of Metrics, Criteria, Goals and Goal Areas




U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, “A Technology Roadmap for Generation IV Nuclear Energy Systems”, GIF-002-00, 2002.

# Current Problems → Requirements/Needs

- ***Sustainable Nuclear Energy -*** sustainability goals focus on waste management and resource utilization.
  - Extending the nuclear fuel supply into future centuries by recycling used fuel to recover its energy content, and by converting 238U to new fuel
  - Having a positive impact on the environment through the displacement of polluting energy and transportation sources by nuclear electricity generation and nuclear-produced hydrogen
  - Allowing geologic waste repositories to accept the waste of many more plant-years of nuclear plant operation through substantial reduction in the amount of wastes and their decay heat
  - Greatly simplifying the scientific analysis and demonstration of safe repository performance for very long time periods (beyond 1000 years), by a large reduction in the lifetime and toxicity of the residual radioactive wastes sent to repositories for final geologic disposal.

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, “A Technology Roadmap for Generation IV Nuclear Energy Systems”, GIF-002-00, 2002.

# Current Problems → Requirements/Needs

- ***Competitive Nuclear Energy* - ** Economics goals consider competitive costs and financial risks of nuclear energy systems.
  - Achieving economic life-cycle and energy production costs through a number of innovative advances in plant and fuel cycle efficiency, design simplifications, and plant sizes
  - Reducing economic risk to nuclear projects through the development of plants built using innovative fabrication and construction techniques, and possibly modular designs
  - Allowing the distributed production of hydrogen, fresh water, district heating, and other energy products to be produced where needed  (*SIZE*)

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, "A Technology Roadmap for Generation IV Nuclear Energy Systems", GIF-002-00, 2002.

# Current Problems → Requirements/Needs

- ***Safe and Reliable Systems*** - Safety and reliability goals consider safe and reliable operation, improved accident management and minimization of consequences, investment protection, and reduced need for off-site emergency response.
  - Increasing the use of <u>inherent safety features</u>, robust designs, and <u>transparent</u> safety features that can be understood by <u>non-experts</u>
  - <u>Enhancing public confidence</u> in the safety of nuclear energy

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, "A Technology Roadmap for Generation IV Nuclear Energy Systems", GIF-002-00, 2002.

# Current Problems → Requirements/Needs

- ***Proliferation Resistance and Physical Protection -*** controlling and securing nuclear material and nuclear facilities.
  - Providing continued effective proliferation resistance of nuclear energy systems through improved design features and other measures
  - Increasing physical protection against terrorism by increasing the robustness of new facilities

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, "A Technology Roadmap for Generation IV Nuclear Energy Systems", GIF-002-00, 2002.

# Original 6 Nuclear System Data Files

http://gif.inel.gov/roadmap/pdfs/000_contents.pdf

gfr VHTR MSR SCWR SFR

U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, “A Technology Roadmap for Generation IV Nuclear Energy Systems and Supporting Documents”, GIF-020-00 thru GIF-039-00, 2002

# GIF Evaluation Methodology Group (2002)



## Evaluation Methodology Group (EMG)

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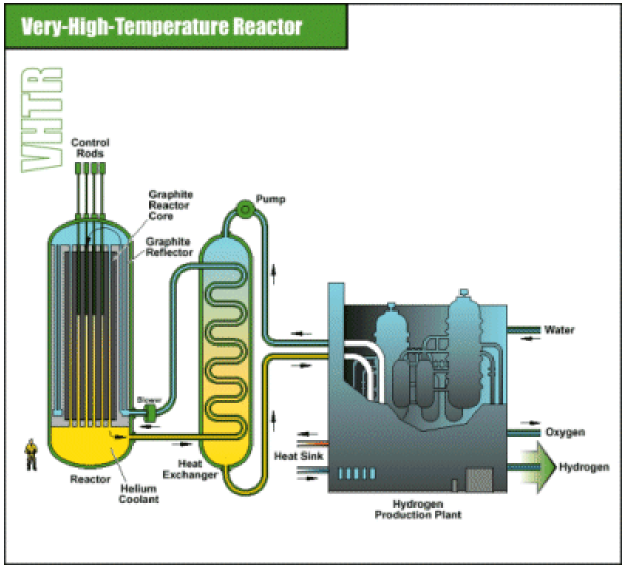
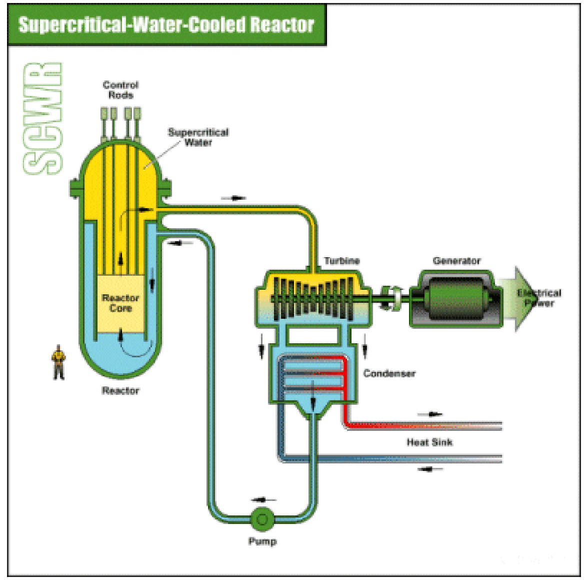
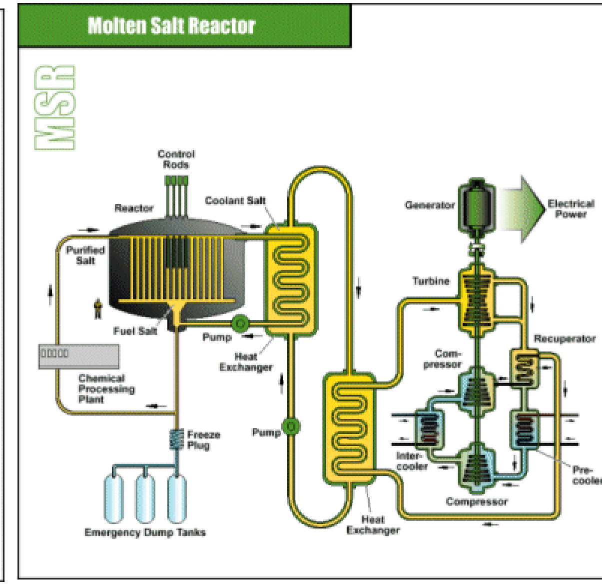
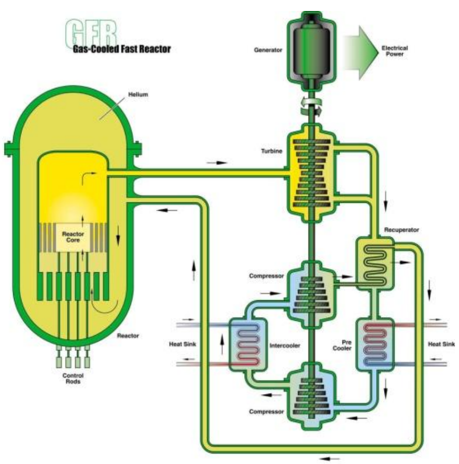
U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, "A Technology Roadmap for Generation IV Nuclear Energy Systems", GIF-002-00, 2002.

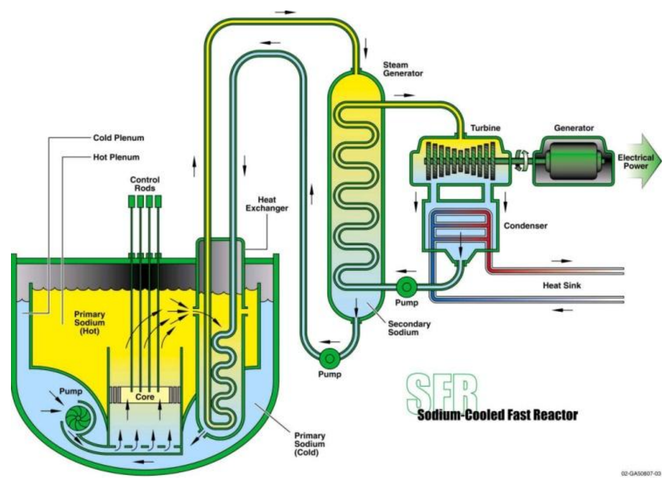
# GIF 6 Nuclear Energy System Alternatives

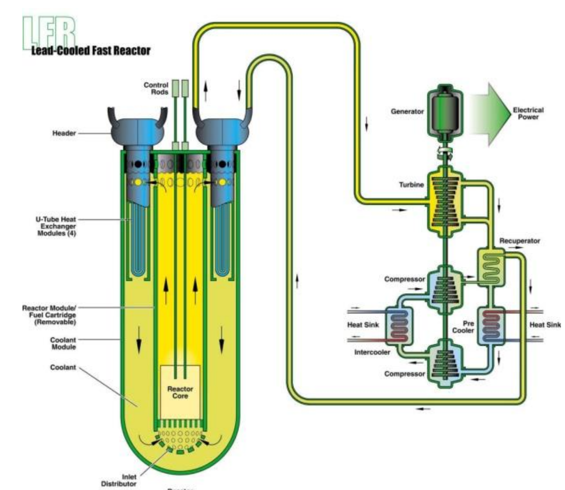



U.S. Dept of Energy Research Advisory Committee and Generation IV International Forum, Dec 2002, “A Technology Roadmap for Generation IV Nuclear Energy Systems”, GIF-002-00, 2002.