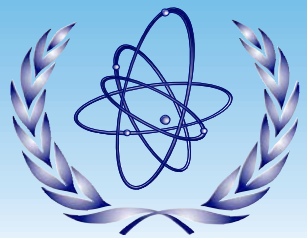


International Atomic Energy Agency

Generation IV Technology General Considerations

J. Kupitz

IAEA Consultant

Generation I

Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors

- LWR-PWR, BWR
- CANDU
- AGR

Generation III

Advanced LWRs

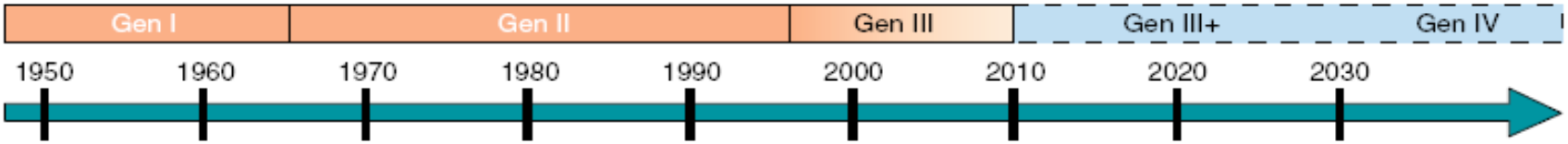
- ABWR
- System 80+

Generation III+

Evolutionary Designs Offering Improved Economics for Near-Term Deployment

Generation IV

- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant



Goals for Generation IV Nuclear Energy Systems

Sustainability–1 *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 utilization for worldwide energy production.*

Sustainability–2 *Generation IV nuclear energy systems will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden, thereby improving protection for the public health and the environment.*

Economics–1 *Generation IV nuclear energy systems will have a clear life-cycle cost advantage over other energy sources.*

Economics–2 *Generation IV nuclear energy systems will have a level of financial risk comparable to other energy projects.*

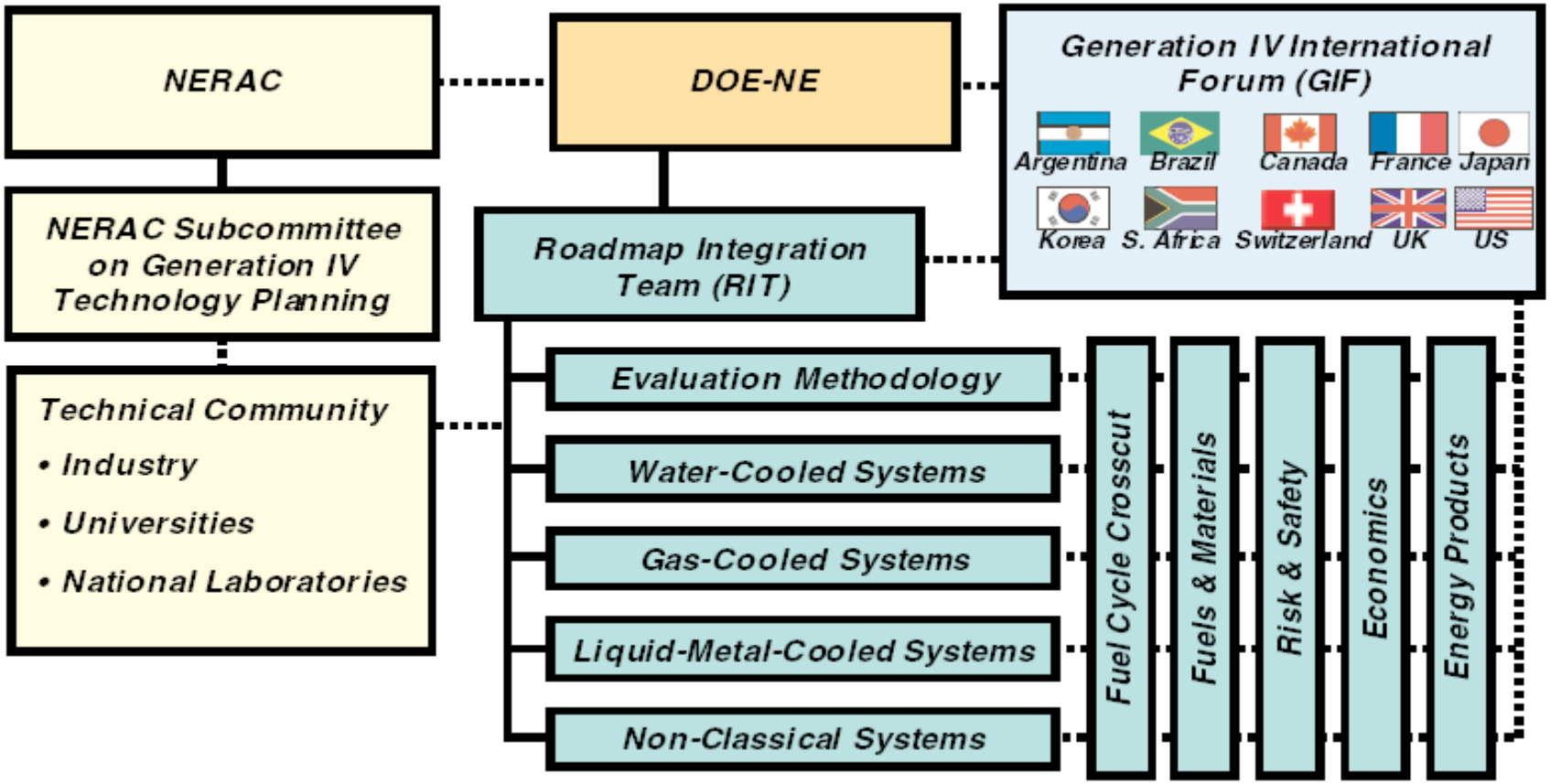
Goals for Generation IV Nuclear Energy Systems (Cont.)

Safety and Reliability–1 *Generation IV nuclear energy systems operations will excel in safety and reliability.*

Safety and Reliability–2 *Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.*

Safety and Reliability–3 *Generation IV nuclear energy systems will eliminate the need for offsite emergency response.*

Proliferation Resistance and Physical Protection–1 *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.*

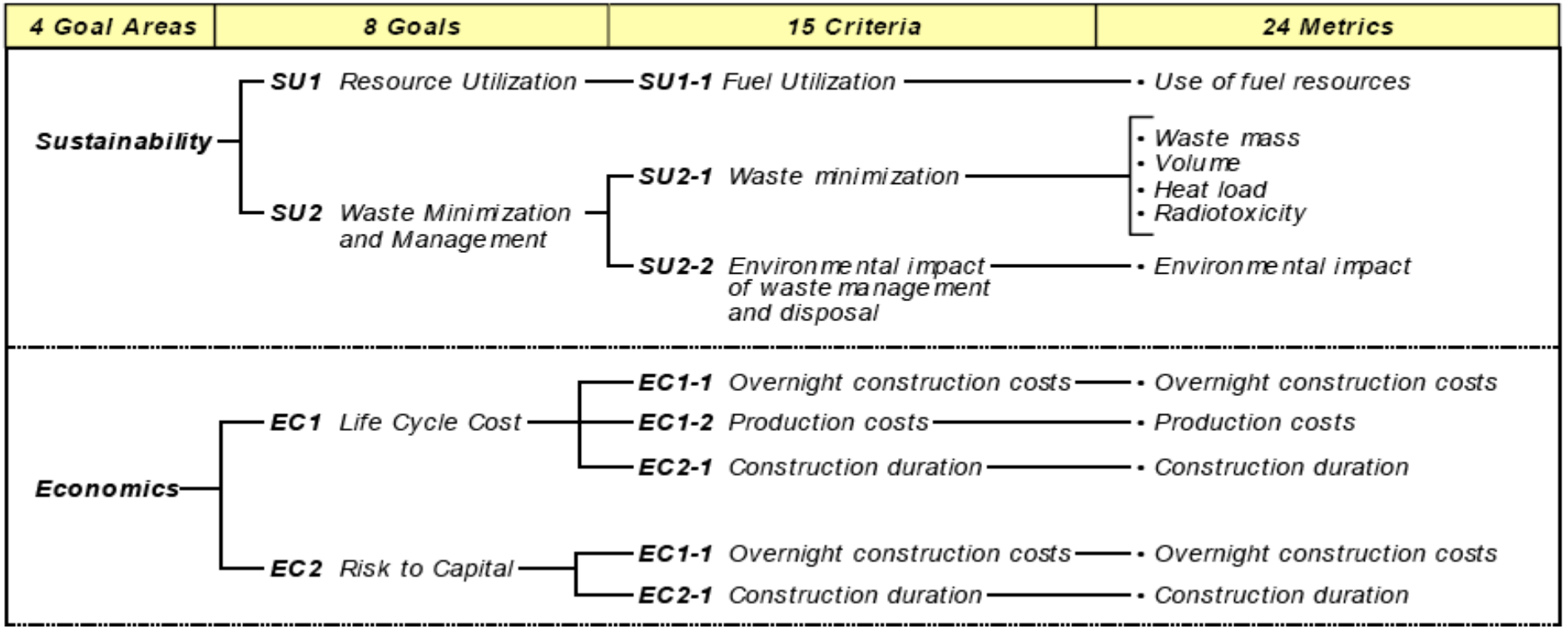

NERAC
DOE-NE
Generation IV International Forum (GIF)
Argentina
Brazil
Canada
France
Japan
Korea
S. Africa
Switzerland
UK
US
NERAC Subcommittee on Generation IV Technology Planning
Roadmap Integration Team (RIT)
Technical Community
• Industry
• Universities
• National Laboratories
Evaluation Methodology
Water-Cooled Systems
Gas-Cooled Systems
Liquid-Metal-Cooled Systems
Non-Classical Systems
Fuel Cycle Crosscut
Fuels & Materials
Risk & Safety
Economics
Energy Products

Evaluation and Selection Methodology

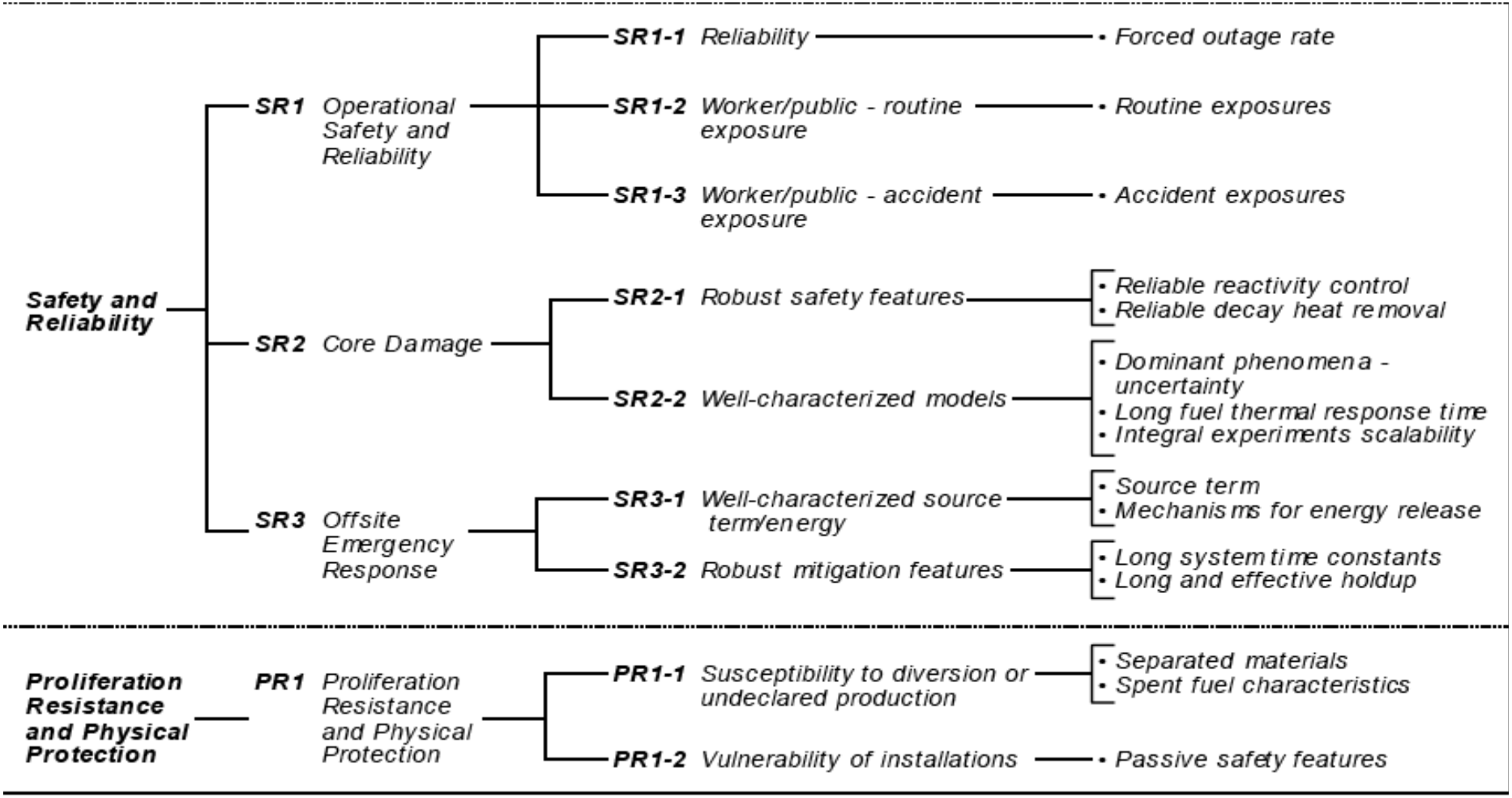
The selection of the systems to be developed as Generation IV was accomplished in the following steps:

1. Definition and evaluation of candidate systems
2. Review of evaluations and discussion of desired missions (national priorities) for the systems
3. Final review of evaluations and performance to missions
4. Final decision on selections to Generation IV and identification of near-term deployable designs.

Roll Up of Metrics, Criteria, Goals and Goal Areas



(Cont.)


Safety and Reliability
SR1 Operational Safety and Reliability
SR1-1 Reliability
• Forced outage rate
SR1-2 Worker/public - routine exposure
• Routine exposures
SR1-3 Worker/public - accident exposure
• Accident exposures
SR2 Core Damage
SR2-1 Robust safety features
• Reliable reactivity control
• Reliable decay heat removal
SR2-2 Well-characterized models
• Dominant phenomena - uncertainty
• Long fuel thermal response time
• Integral experiments scalability
SR3 Offsite Emergency Response
SR3-1 Well-characterized source term/energy
• Source term
• Mechanisms for energy release
SR3-2 Robust mitigation features
• Long system time constants
• Long and effective holdup
Proliferation Resistance and Physical Protection
PR1 Proliferation Resistance and Physical Protection
PR1-1 Susceptibility to diversion or undeclared production
• Separated materials
• Spent fuel characteristics
PR1-2 Vulnerability of installations
• Passive safety features

Generation IV Nuclear Energy Systems

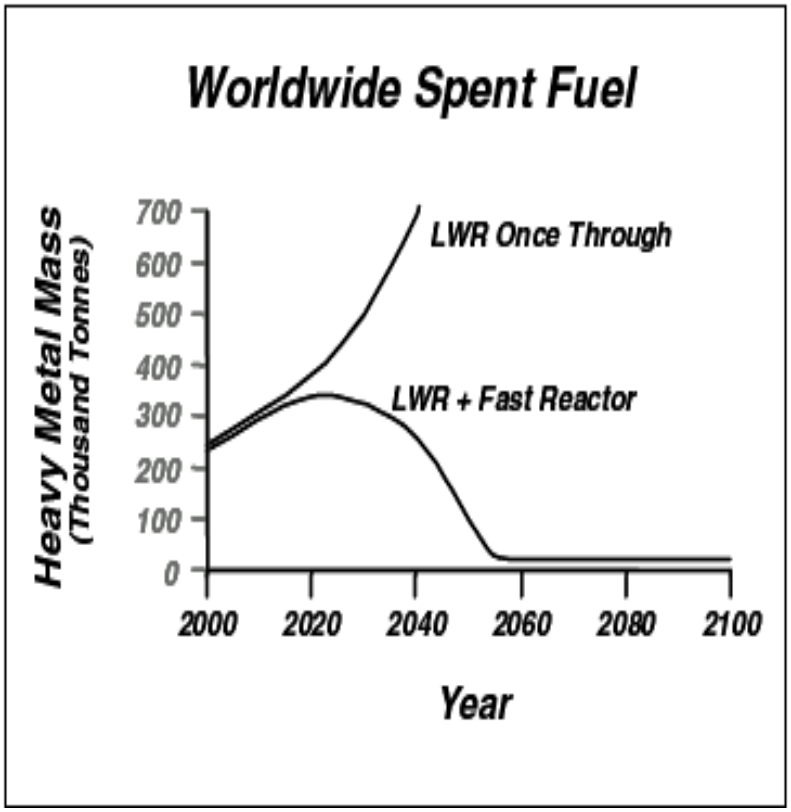
The Generation IV roadmap process described in the previous section culminated in the selection of six Generation IV systems. The motivation for the selection of six systems is to

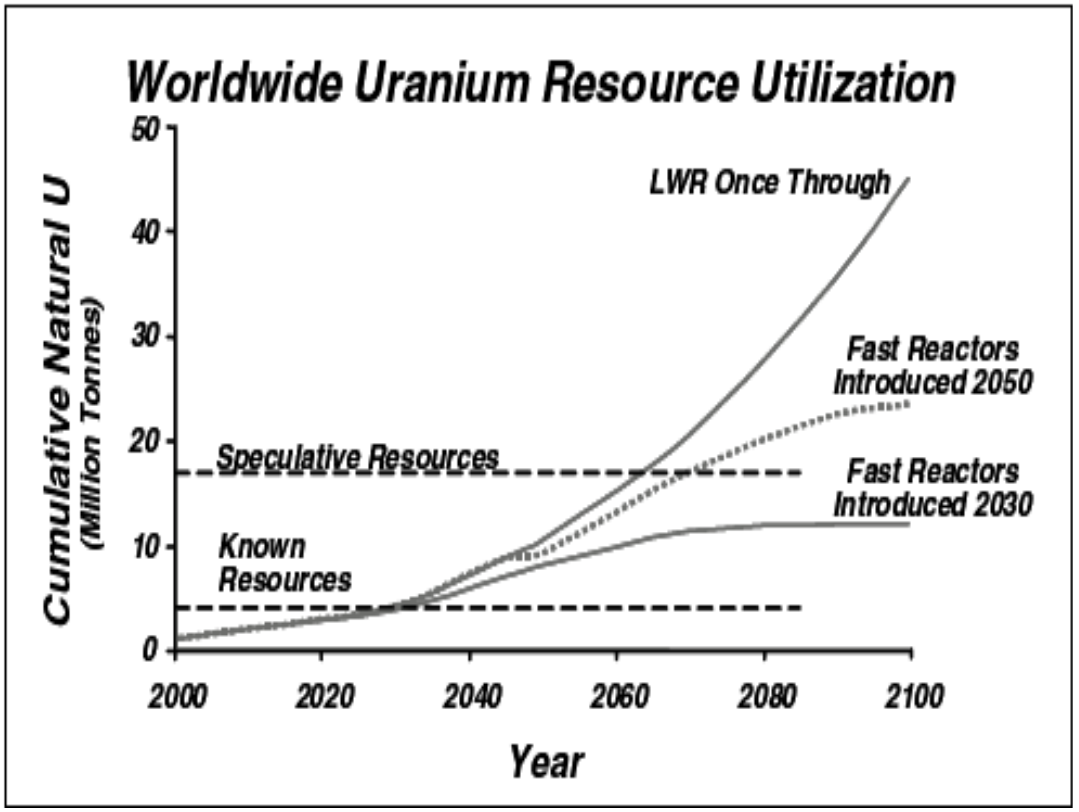
- Identify systems that make significant advances toward the technology goals
- Ensure that the important missions of electricity generation, hydrogen and process heat production, and actinide management may be adequately addressed by Generation IV systems
- Provide some overlapping coverage of capabilities, because not all of the systems may ultimately be viable or attain their performance objectives and attract commercial deployment
- Accommodate the range of national priorities and interests of the GIF countries.

Generation IV System	Acronym
Gas-Cooled Fast Reactor System	GFR
Lead-Cooled Fast Reactor System	LFR
Molten Salt Reactor System	MSR
Sodium-Cooled Fast Reactor System	SFR
Supercritical-Water-Cooled Reactor System	SCWR
Very-High-Temperature Reactor System	VHTR

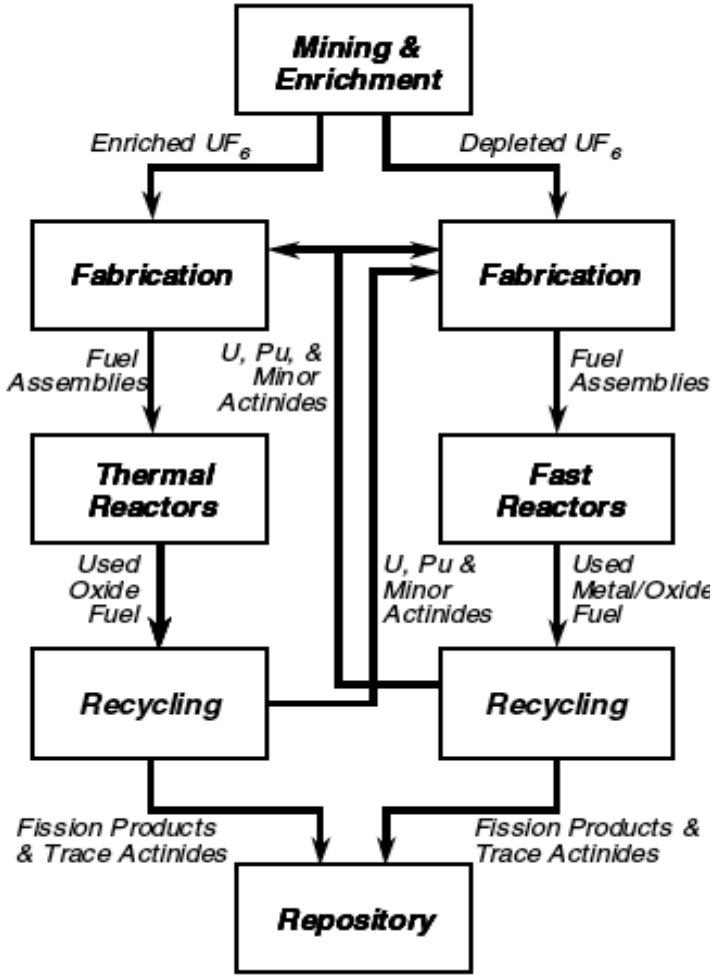
Findings of Roadmap

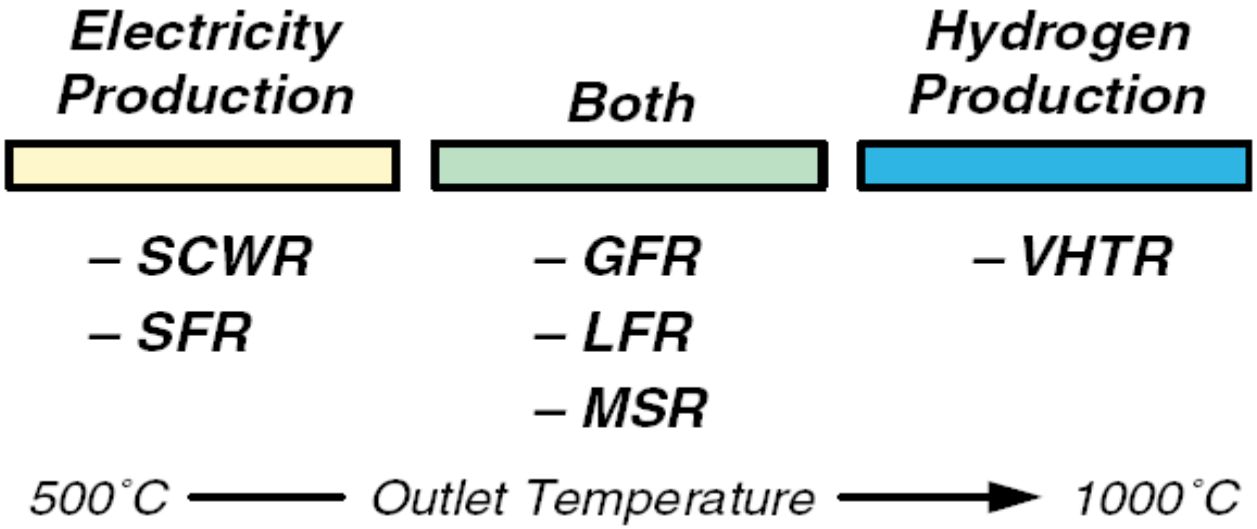
a) Fuel Cycles and Sustainability
b) Missions and Economics of Gen. IV

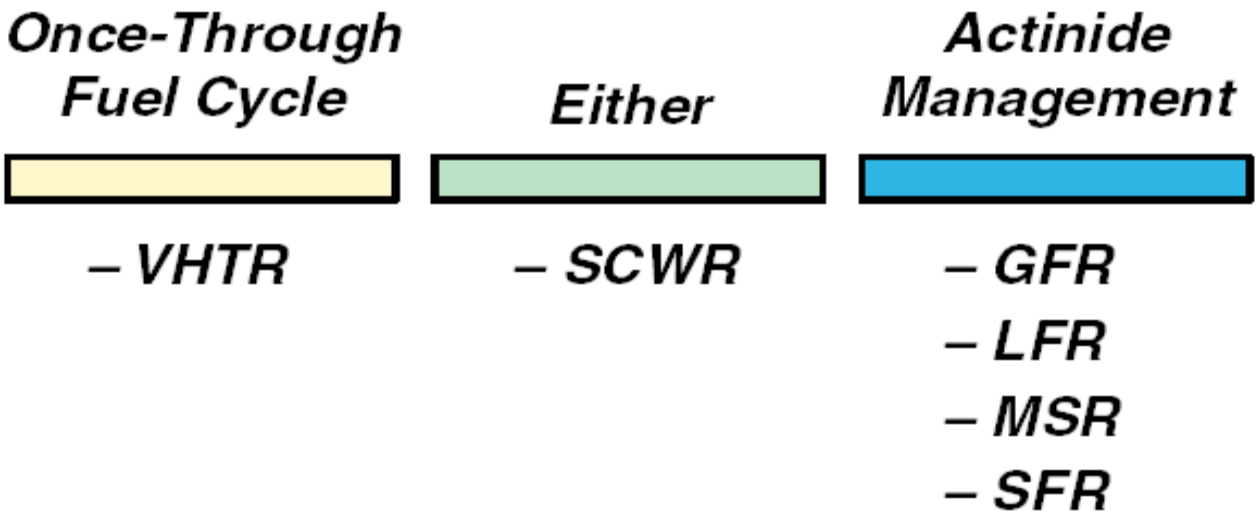

Worldwide Spent Fuel
Heavy Metal Mass
(Thousand Tonnes)
700
600
500
400
300
200
100
0
LWR Once Through
LWR + Fast Reactor
2000
2020
2040
2060
2080
2100
Year


Worldwide Uranium Resource Utilization
Cumulative Natural U
(Million Tonnes)
50
40
30
20
10
0
LWR Once Through
Fast Reactors
Introduced 2050
Speculative Resources
Fast Reactors
Introduced 2030
Known
Resources
2000
2020
2040
2060
2080
2100
Year

Symbiotic Fuel Cycles




Electricity Production
Both
Hydrogen Production
– SCWR
– SFR
– GFR
– LFR
– MSR
– VHTR
500˚C
Outlet Temperature
1000˚C


Once-Through Fuel Cycle
Either
Actinide Management
– VHTR
– SCWR
– GFR
– LFR
– MSR
– SFR

Large Monolithic	Mid-size	Small Modular
– LFR*	– GFR	– LFR*
– MSR	– VHTR	
– SFR*	– SFR*	
– SCWR		

* Range of options

- ABWR (Advanced Boiling Water Reactor)
- AP1000 (Advanced Pressurized Water Reactor 1000)
- ESBWR (European Simplified Boiling Water Reactor)
- GT-MHR (Gas Turbine–Modular High Temperature Reactor)
- PBMR (Pebble Bed Modular Reactor)
- SWR-1000 (Siedewasser Reactor-1000).

U.S. Near-Term Deployment (by 2010)
ABWR
AP1000
ESBWR
GT-MHR
PBMR
SWR-1000

International Near-Term Deployment

Advanced Boiling Water Reactors

- ABWR II (Advanced Boiling Water Reactor II)
- ESBWR (European Simplified Boiling Water Reactor)
- HC-BWR (High Conversion Boiling Water Reactor)
- SWR-1000 (Siedewasser Reactor-1000)

Advanced Pressure Tube Reactor

- ACR-700 (Advanced CANDU Reactor 700)

Advanced Pressurized Water Reactors

- AP600 (Advanced Pressurized Water Reactor 600)
- AP1000 (Advanced Pressurized Water Reactor 1000)
- APR1400 (Advanced Power Reactor 1400)

International Near-Term Deployment (by 2015)
ABWR II
ACR-700
AP600
AP1000
APR1400
APWR+
CAREM
EPR
ESBWR
GT-MHR
HC-BWR
IMR
IRIS
PBMR
SMART
SWR-1000

International Near-Term Deployment (cont.)

- APWR+ (Advanced Pressurized Water Reactor Plus)
- EPR (European Pressurized Water Reactor)

Integral Primary System Reactors

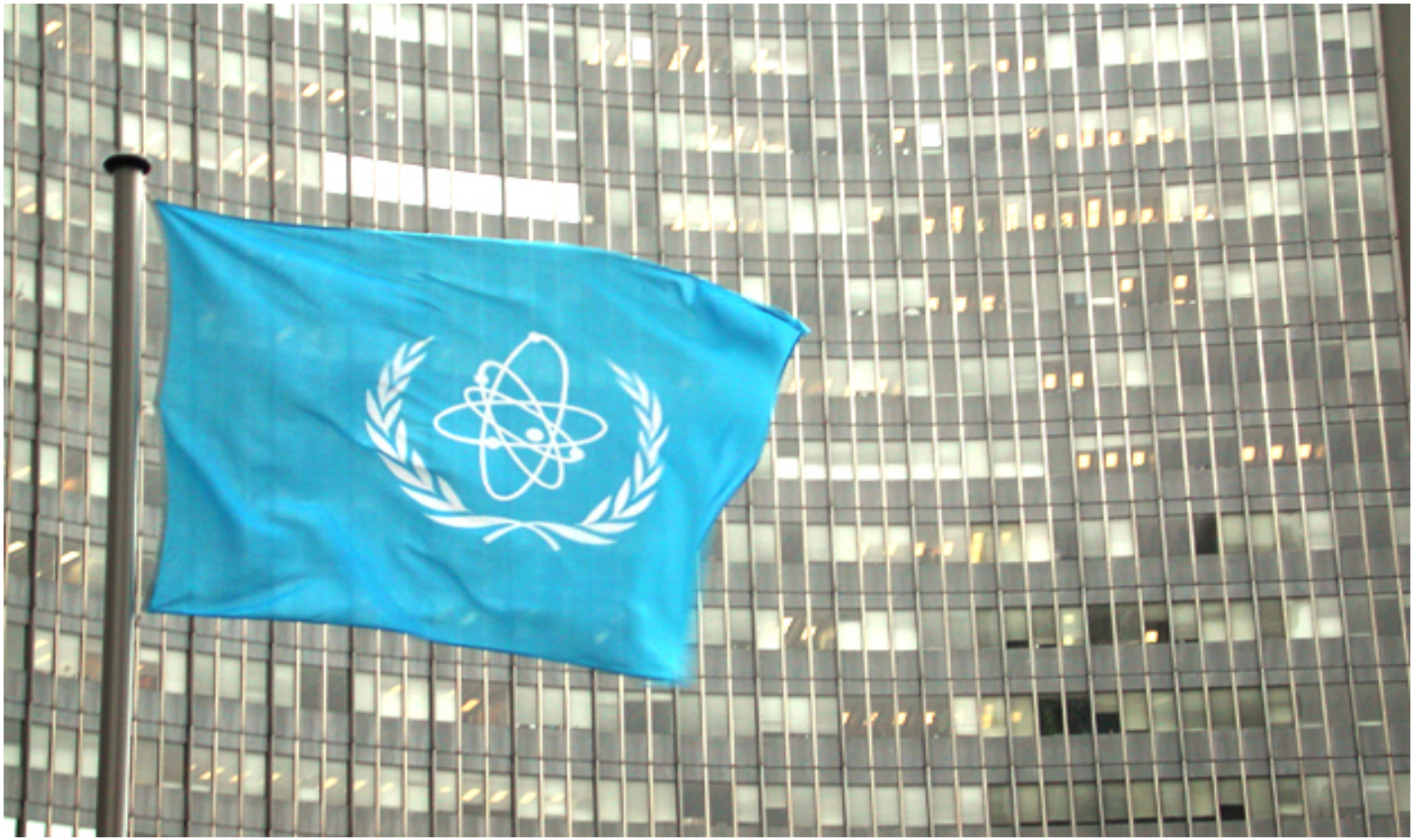
- CAREM (Central Argentina de Elementos Modulares)
- IMR (International Modular Reactor)
- IRIS (International Reactor Innovative and Secure)
- SMART (System-Integrated Modular Advanced Reactor)

Modular High Temperature Gas-Cooled Reactors

- GT-MHR (Gas Turbine-Modular High Temperature Reactor)
- PBMR (Pebble Bed Modular Reactor)

Generation IV Deployment

Generation IV System	*Best Case Deployment Date*
SFR	2015
VHTR	2020
GFR	2025
MSR	2025
SCWR	2025
LFR	2025



…atoms for peace