The Future of Nuclear Energy in the United States – Open or Closed Fuel Cycle?

Presented to:

University of Wisconsin

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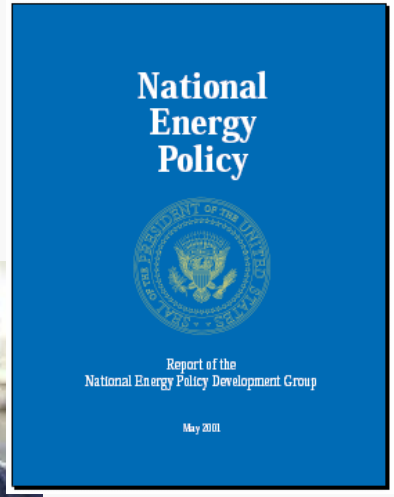
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Outline

- Summary of current administration position
- DOE programs
- 6-Lab recommendations
- International views
- Sloan Foundation/MIT report
- Discussion

Nuclear Energy: Administration View

- Nuclear power is seen in the context of energy independence
  - National Energy Policy Document (2001)
- Bargaining chip in dealing with Russia
  - Bush/Putin Summit (May 2002)
- Issues (in order)
  - Waste (Yucca Mountain)
  - Economics
  - Nonproliferation
  - Safety

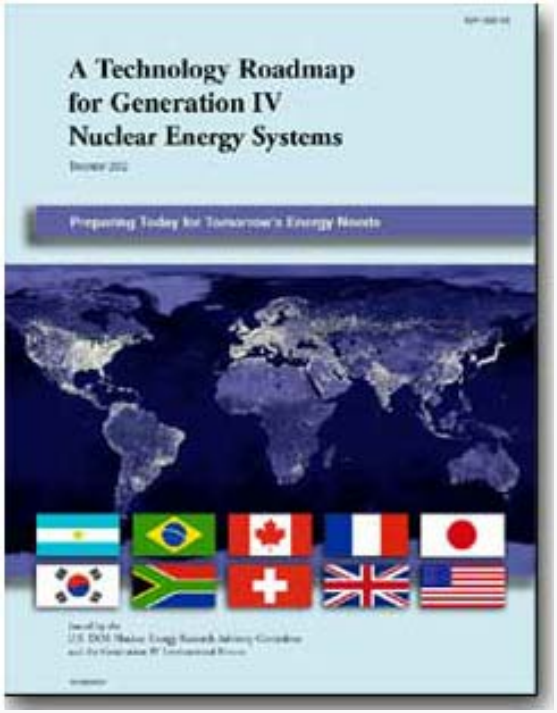


Nuclear Energy: DOE Position

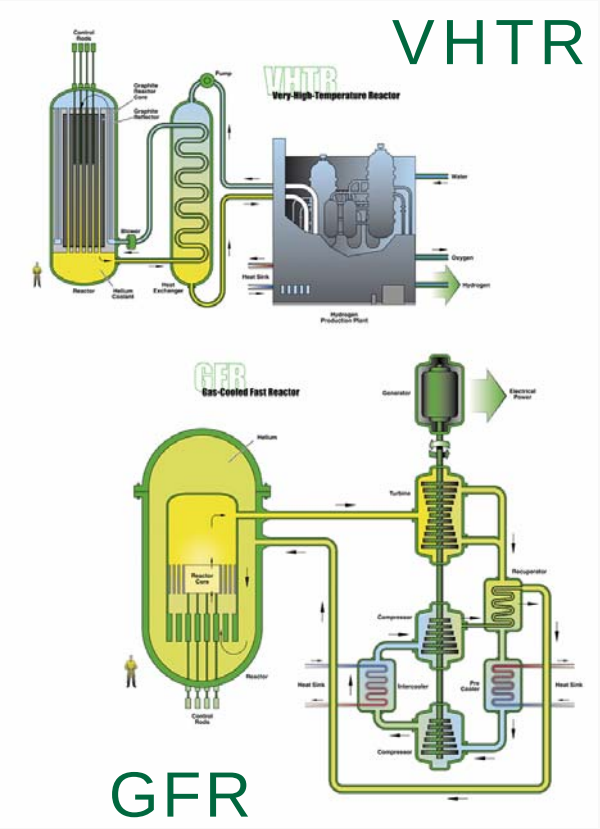
- Vocal support from leadership but little financial support
  - Advanced Fuel Cycle Initiative precursor programs had zero requests prior to FY 2003
  - FY05 request: GenIV-30M, AFCI-46M
- On the other hand, nuclear is featured in the draft 25-year DOE Strategic Plan
  - Build a new reactor by 2010 (NP2010)
  - Build a Gen IV reactor by 2020 (VHTR)

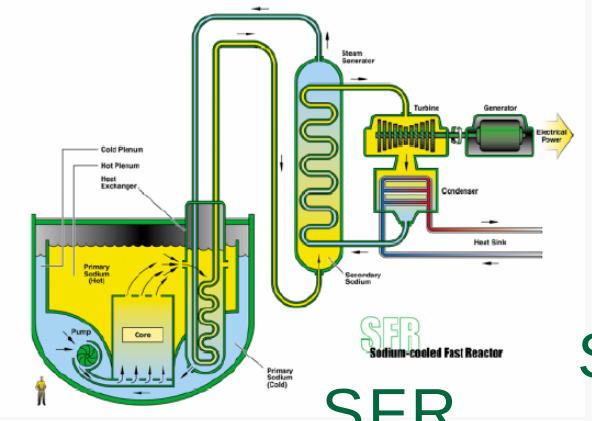
DOE Generation IV Program

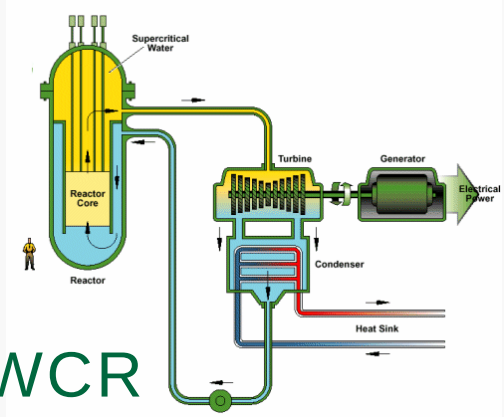
- DOE-led international program to select next generation of nuclear technology for implementation in 2030 or beyond
  - Criteria included sustainability, nonproliferation, safety, and economics
- Six concepts selected
  - High-temperature gas-cooled (VHTR)
  - Molten salt cooled (MSR)
  - Sodium, lead, and gas-cooled fast reactors (SFR, LFR, GFR)
  - Supercritical water (SCWR)
- Current emphasis is on VHTR for hydrogen production

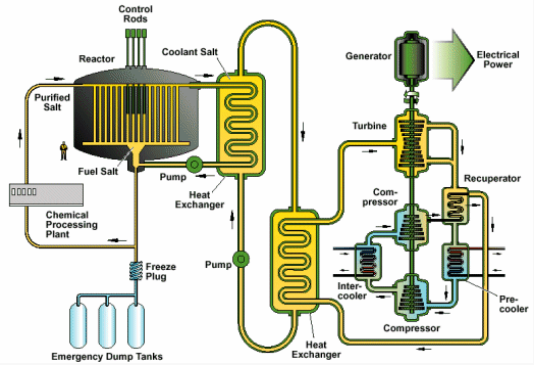


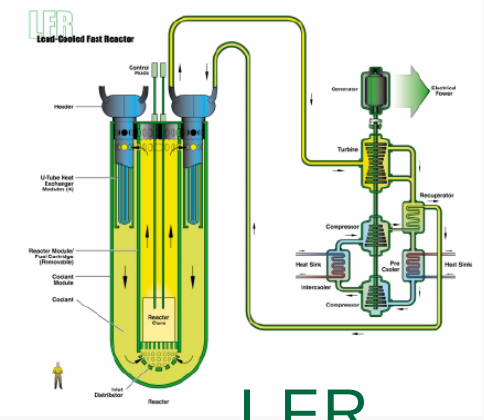
Generation IV Concepts







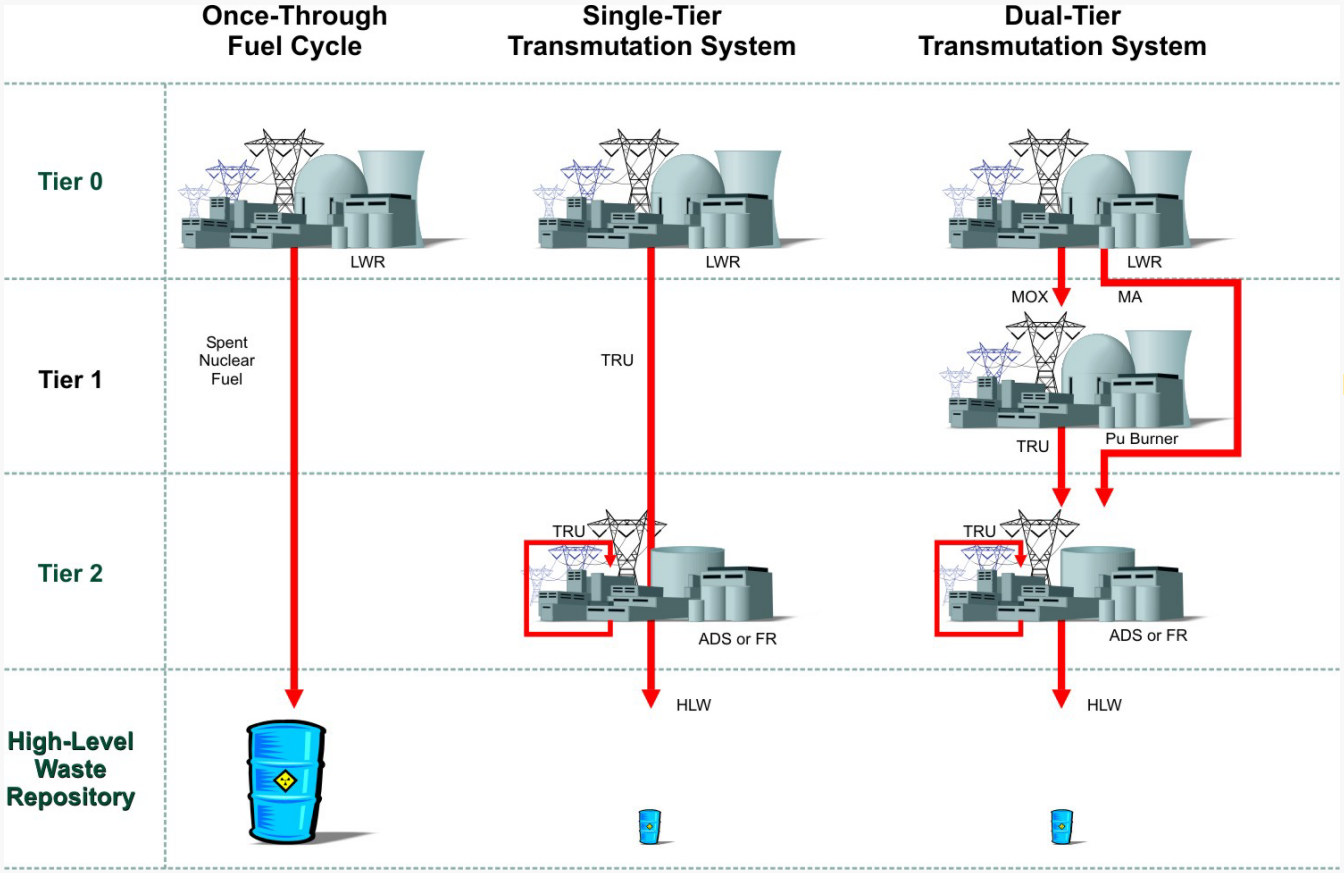




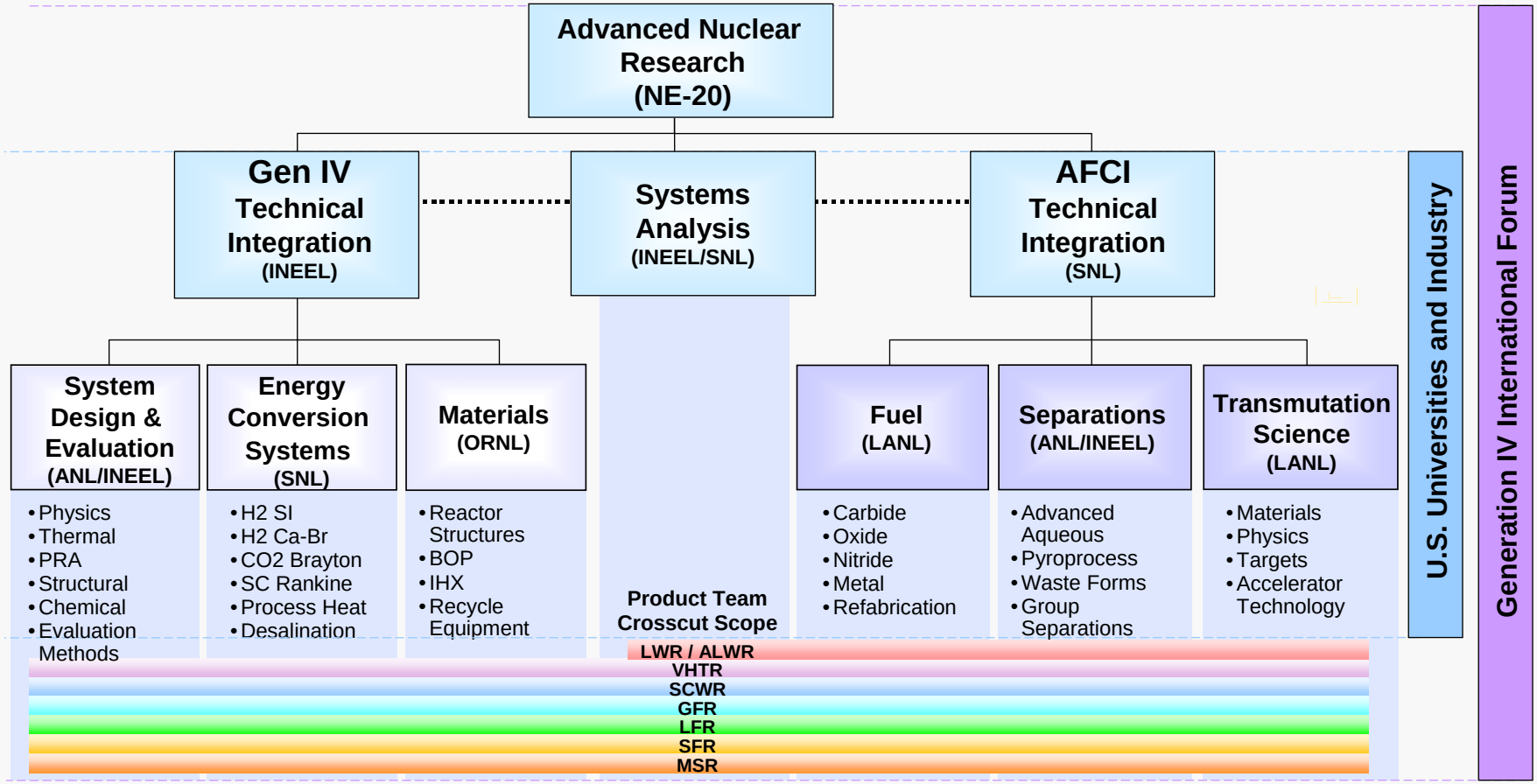
Advanced Fuel Cycle Program

- Increasingly, the focus is on whether fuel cycle technology can allow the U.S. to proceed with nuclear power without a second repository
- Decision required between 2007 and 2009

AFCI Options

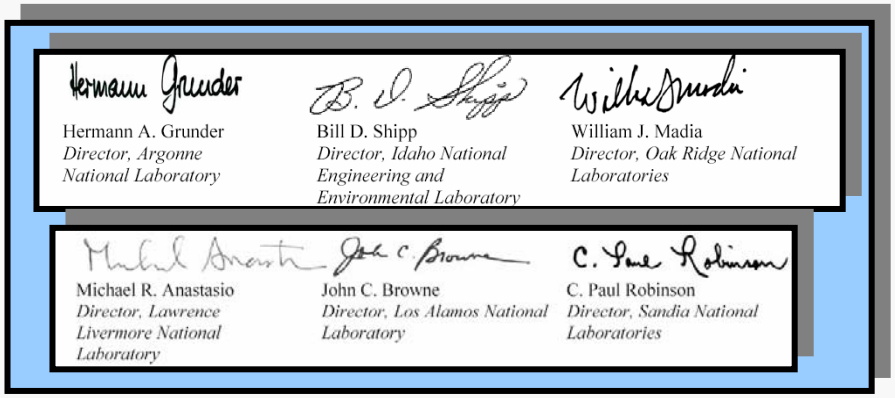


An Integrated Program: Generation IV and Advanced Fuel Cycle Initiative



Six Laboratory Directors' Nuclear Agenda

- **Initial set of recommendations to Secretary Abraham (June 2002)**
  - Develop integrated strategy that treats nuclear energy and nuclear materials as an integration system
  - Provide needed support to U.S. Industry
  - Work with Russia and the international community
  - Create new, expanded university programs
  - Accelerate, enhance present DOE fuel cycle and Generation IV efforts
- **Proposed additional $1B over 5 years to start the effort**
- **Follow-on meetings and briefings**
  - The Secretary and Under Secretary
  - Senators Deomenici and Craig
  - Vice President Cheney
- **The Secretary asked the 6 laboratories, working with Bill Magwood, to develop a nuclear energy action plan.**



The Bush-Putin Summit, July 2002

"The two governments see promise in advanced nuclear reactor and nuclear fuel technologies which would reduce significantly the volume of waste produced by civilian nuclear reactors, would be highly proliferation-resistant and could be used in the future to reduce stocks of excess weapons –grade plutonium an other dangerous nuclear materials."

The summit announcement of the 60-Day Study on Advanced Nuclear Technologies reflected both U.S. national security interests and energy interests.

Six DOE laboratories (3 nuclear weapons laboratories and 3 nuclear energy laboratories) volunteered to actively support DOE in meeting the objectives of the 60-Day Study.

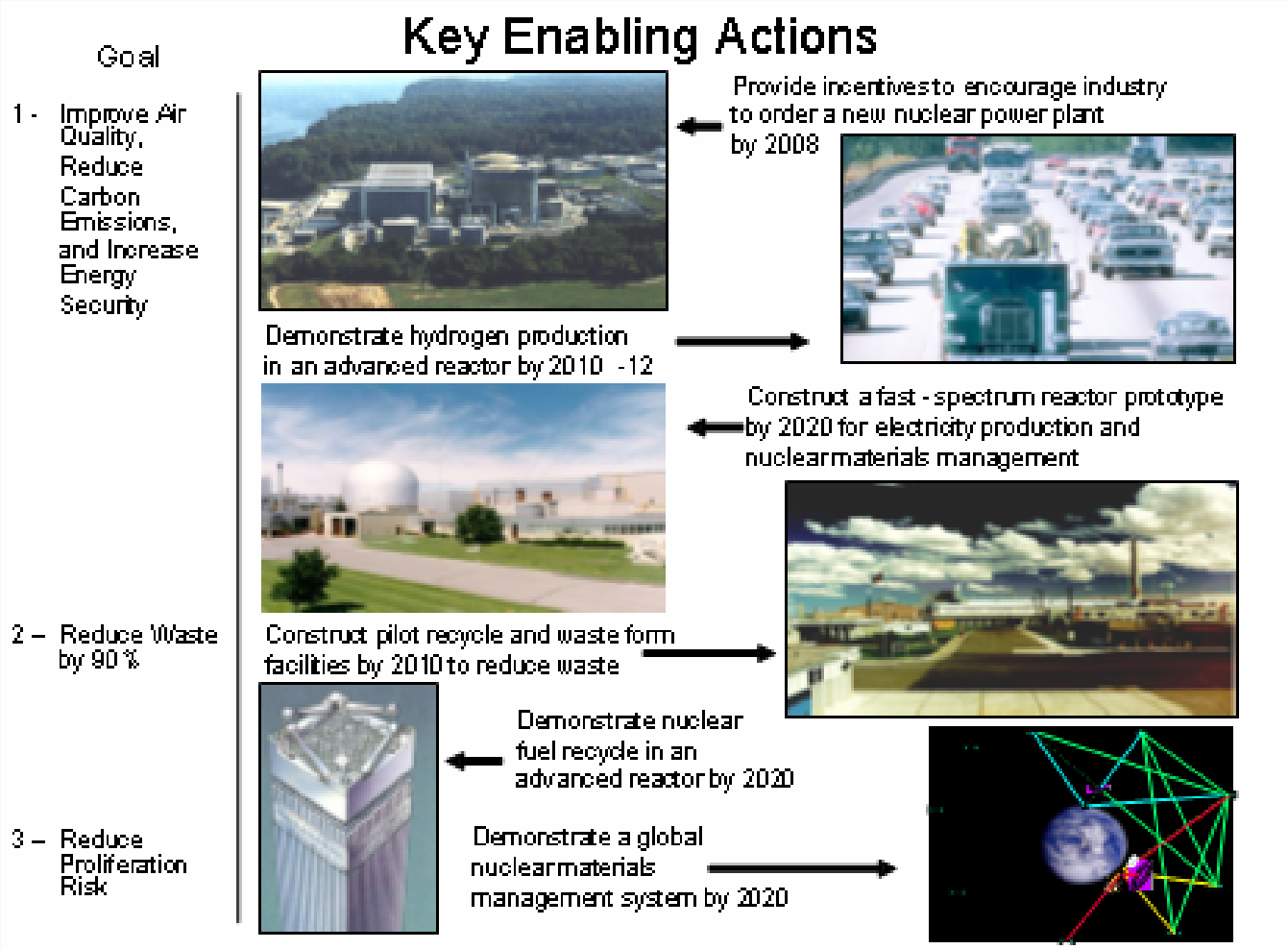
Developing a Path To Action

Three goals:

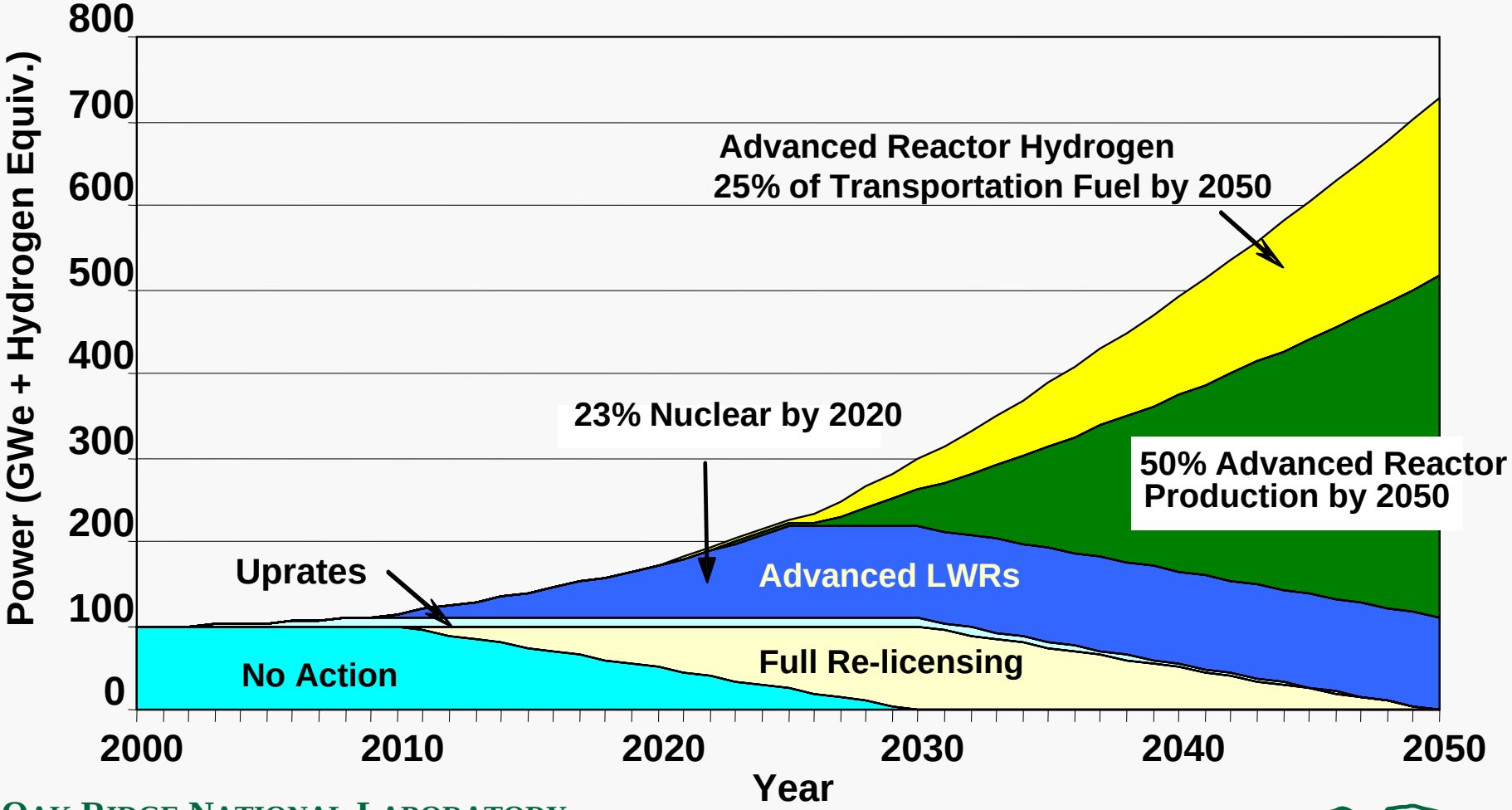
1) Reduce air pollution and increase energy security by large-scale implementation of nuclear energy
2) Achieve a greater than 90 percent reduction in reactor waste requiring geologic disposal
3) While expanding worldwide nuclear energy use, reduce the threat of nuclear weapons proliferation

Each goal was accompanied by a set of enabling actions and resulting impacts

The Action Plan



Goal 1: Energy Security with Environmental Quality



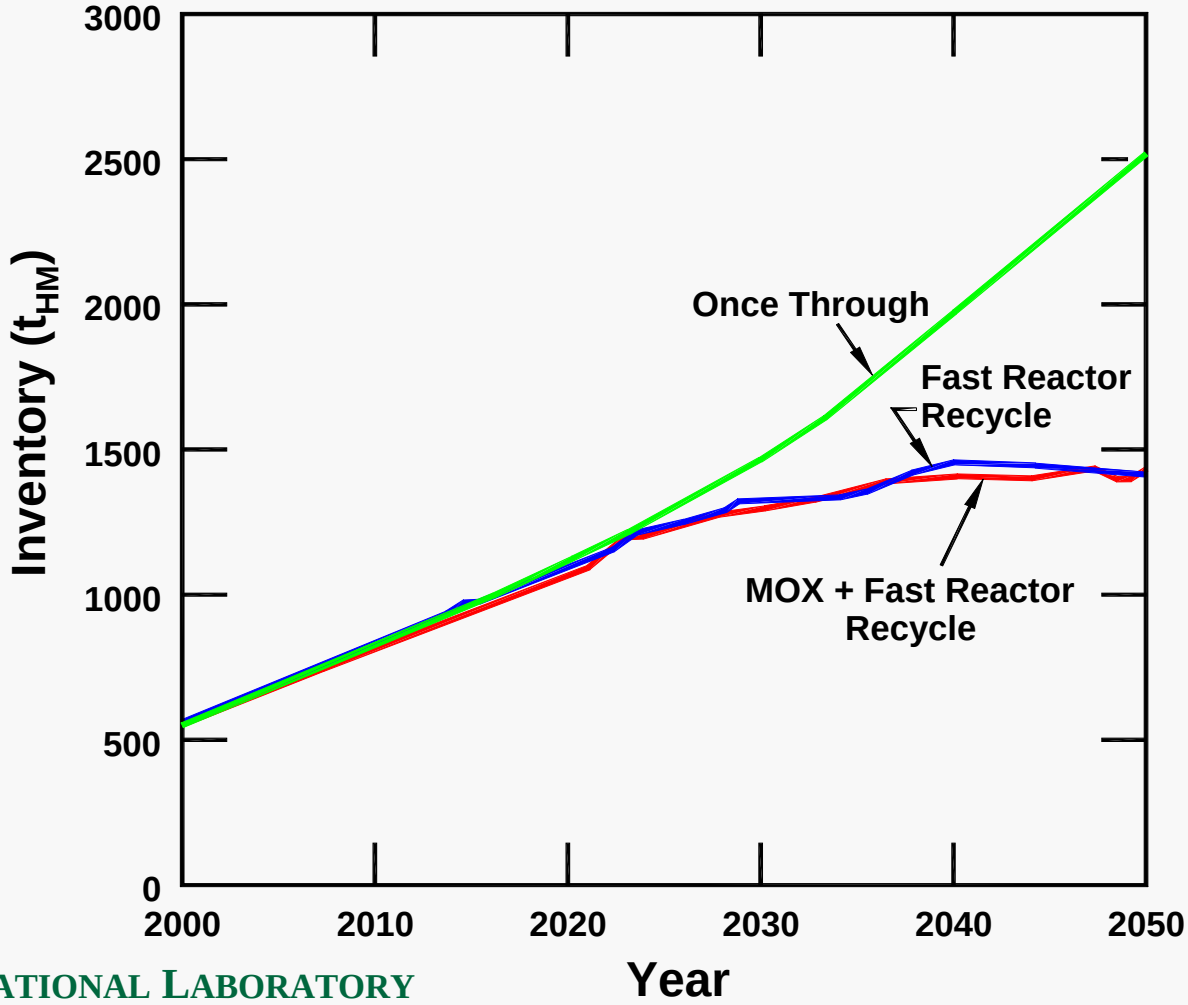
Goal 2: Reduce Nuclear Wastes

- Support the deployment of new nuclear plants with an integrated and safeguarded fuel cycle
- Reduce the volume of waste for disposal, and thus, avoid a second repository to supplement Yucca Mountain -- extinguish the waste issue before it reappears
- Preserve fuel (uranium and plutonium) resources as a hedge against the increasing price of uranium
- Reduce the toxicity of the waste for disposal
- Work with Russia on safeguards within the closed fuel cycle
- Provide sustained funding for research, $1B over 5 years

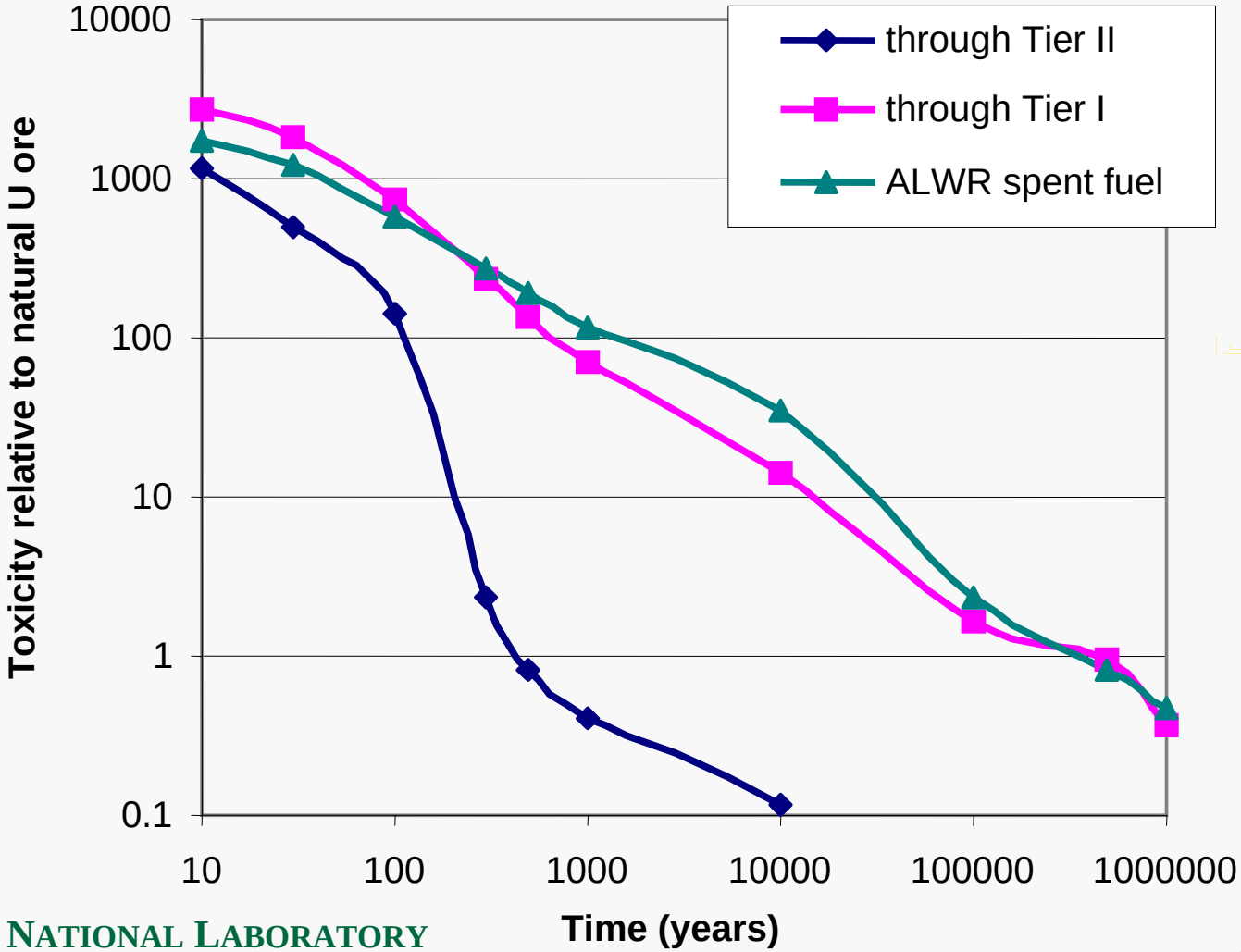
Reasons for Closing the Fuel Cycle

- Nuclear Waste Management
  - Reduce inventories of nuclear waste to be stored; remove and burn the actinides
  - Reduce the radio-toxicity of nuclear waste; reduce the need for future geologic storage sites
- Nuclear Materials Management
  - Reduce inventories of nuclear material in storage; burn excess plutonium
  - Reduce accessibility and attractiveness of material for misuse; don’t separate pure plutonium

Impact of Recycle: Inventory of TRU in the Fuel Cycle, Including in Spent Fuel



Projected Waste Toxicity, with and Without Recycle



Economics

- Despite the social benefits of the Advanced Fuel Cycle Initiative, the bottom line depends on its economics:
  - The economics of the competing fuel cycles need to be assessed carefully to assure the generating industry that the integrated fuel cycle is in their best economic interests.
  - The economics of waste disposal need to be assessed carefully to ensure that the cost of the Advanced Integrated Fuel Cycle (and its associated facilities) is indeed less than the cost of a second repository and more expensive uranium supplies.
  - The recycle options for a combined thermal/fast reactor deployment need to be assessed carefully to identify optimum deployment strategies.

Goal 3: Reduce Proliferation Risk

- Prevent the spread of nuclear weapons
- Constrain (reduce?) nuclear weapons growth in declared states
- Avoid the spread of nuclear weapons to non-declared states and sub-national groups

Controlling and managing nuclear materials is the essential element for success

Enhancing Proliferation Resistance

- Technical
  - Unattended monitoring – both local and remote
  - Mass tracking system extensions
  - Advanced measurement technologies
  - Transportation monitoring
  - Computer-based simulation and assessment
- Institutional
  - Multilateral control of enrichment, reprocessing, transport, and disposal
  - Advanced physical protection international safeguards and communication systems with universal adherence to the Additional Protocol
  - Formal methods for assessment of the effectiveness of physical protection and international safeguards

Advanced Technology Requirements

- Simplified reactors (perhaps sealed-core) in locations with higher proliferation risk– limited or no on-site refueling
- Advanced reactors, as part of closed fuel cycles, in developed countries with supporting technical infrastructure and lower proliferation risk – destroy unwanted isotopes
- Limited number of enrichment and fuel fabrication centers
- Limited number of reprocessing and repository centers

Advanced Technology Requirements *(continued)*

- Extrinsic and intrinsic advanced technologies for monitoring, tracking and response
- Integrated nuclear material management accounting system – transparency
- Integrated physical protection and international safeguards
- International management framework that closes loopholes and provides for enforcement
- Develop and demonstrate advanced Gen IV reactors for both electricity and hydrogen production

Advanced Technology Requirements *(continued)*

- Develop and demonstrate closed fuel cycle technology to produce an economically, socially, and politically sustainable fuel cycle of the future
- Demonstrate technology to set the world standard in proliferation prevention
- The plan also recommends significant effort in four areas needed to rebuild the US nuclear infrastructure
  - University nuclear education
  - National laboratory resources
  - Base nuclear technology development
  - Information preservation

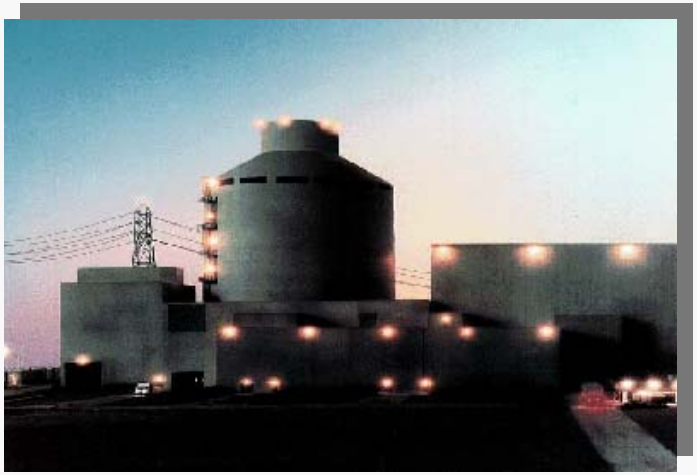
Summary: 6-Lab Recommendations

- Provide significant incentives for near term deployment of new US plants
- Develop and demonstrate advanced Gen IV reactors for both electricity and hydrogen production
- Develop and demonstrate closed fuel cycle technology to produce an economically, socially, and politically sustainable fuel cycle of the future
- Demonstrate technology to set the world standard in proliferation prevention
- The plan also recommends significant effort in four areas needed to rebuild the US nuclear infrastructure
  - University nuclear education
  - National laboratory resources
  - Base nuclear technology development
  - Information preservation

A Personal View of the Future for Nuclear Energy in the US

- There is cause for optimism, scarcely unbridled, but genuine
- Compare the situation today with that of 5 years ago
  - International advanced nuclear programs being developed
  - Reprocessing is being openly discussed again
  - Dialogue with Russia has started

U.S. Industry Views



- Vendors
  - Product oriented (i.e., short-term)
  - Focused on NP2010 to the exclusion of nearly everything else
- Utilities
  - Difficult to get support for long-term research because of market focus
- Hydrogen may provide the avenue
- Bottom line:

Modern Market Economics
Make Building a Nuclear Plant Difficult

International Views: France

- France has 80% of its electricity from nuclear power
- Already reprocessing (PUREX)
- French goal is to cap inventories of separated Pu by 2006
- The Law of 1991, authorized a 15-year program to investigate alternatives to repository
- Recent French/Congressional report supports nuclear R&D

International Views: Russia

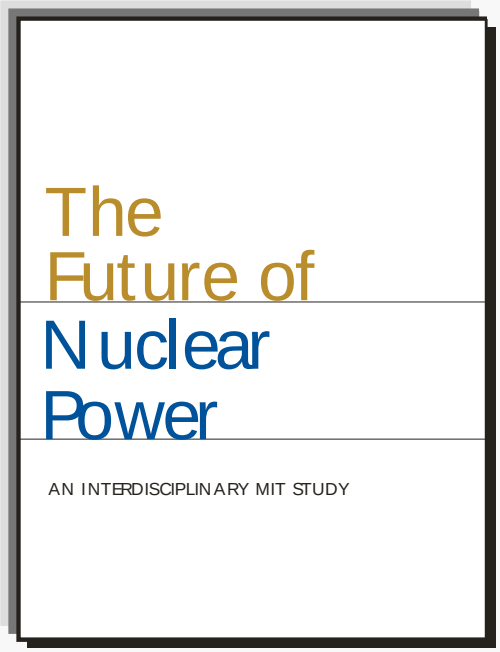
- Russia is committed to nuclear power and recycling
- It has a very large infrastructure to support
- Russian policy is to export hydrocarbons for hard currency and use nuclear at home
- Eagerly seeking fast reactor cooperation with the West, especially U.S.

International Views: Japan

- Japan has no feasible repository site and no hydrocarbons
- As a result, Japan is committed to nuclear power and recycling
  - ? Scandals?

MIT/Sloan Foundation Study

- To make a difference in CO_2, it will require nuclear energy at least maintaining market share
  - 1500 GWe globally by mid-century
    - (1) If you adopt nuclear power, you should use a lot of it
    - (2) Current nuclear architecture is flawed and needs rethinking
    - (3) There is time (50 years) to do the research on advanced fuel cycles
    - (4) Interim storage is required
    - (5) Different ideas of geologic disposal need investigation
    - (6) Once through fuel cycle is cheaper and safer



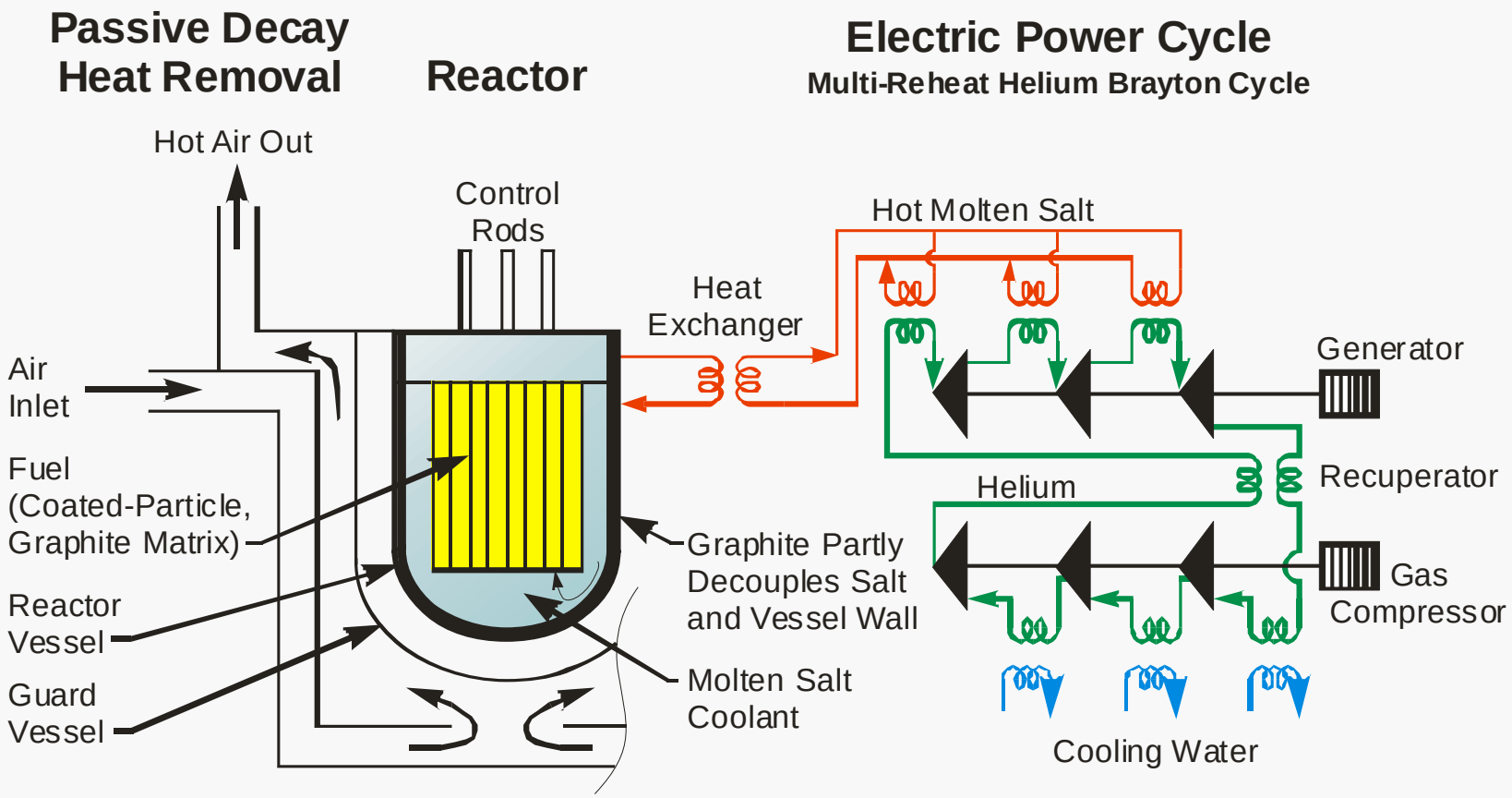
Responses to MIT Study (Informal and Formal)

- Too optimistic on uranium supplies
  - Support a renewed assessment
- European economics different from U.S.
  - Conclusions do **not** generalize
- MIT report has “back-end” costs wrong
  - Comparing theory with practice (MOX in France)
  - Reprocessing through MOX is only “a very small cost penalty”
- Partitioning and transmutation will change public attitudes (e.g. in France)
  - Elimination of actinides **essential**
  - Deep boreholes a nonstarter due to uncertainty
- Reprocessing is demonstrably safe (France/UK)

Personal Views on the Fuel Cycle

- Advanced reactor and fuel cycle R&D will be carried out on an international basis with both,
  - Traditional partners and Russia,
  - Possibly through an ITER-like project?
- Focus in the U.S. will be on 2nd repository decision
- U.S. policy will remain as no accumulation of separated plutonium (beyond working inventories)
- Geological isolation/repository science/high-level waste storage options will be further researched now we are over the hump on Yucca Mountain
- A “grown-up” fuel cycle position is necessary unless the nuclear enterprise in the U.S. is to choke on its own waste

AHTR: The Advanced High-Temperature Reactor Concept



ORNL Strategic Approach to Fission Power

- Focus on our strengths
  - High temperature reactors
  - Thermal reactors
  - Space reactors
  - Fuel cycle and associated technologies
- Support regional initiatives
  - Especially through education
- Identify and make key hires

Summary

- **U.S. has moved hesitantly towards active consideration of a closed cycle**
- **DOE and national laboratories continue to pursue this goal**
- **Exciting R&D is being performed in fission power and the fuel cycle**
- **Opposition is waking up!**