DOE Nuclear Energy Programs:
The Future of Nuclear Energy

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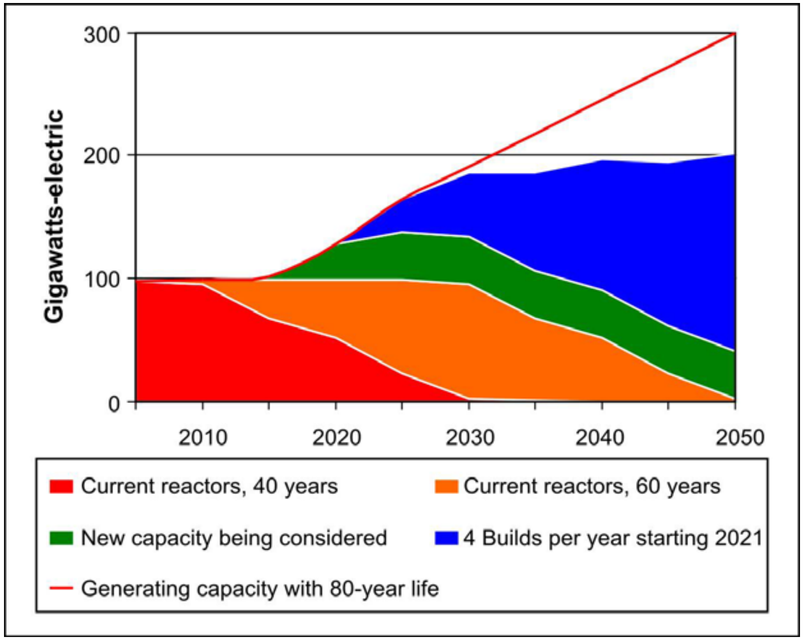
Imperative 1: Life Extension

- **Goal is to extend plant life beyond 60 years with improved performance.**
- **Challenges facing current fleet**
  - Aging and degradation of system structures and components
  - Fuel reliability and performance
  - Obsolete analog instrumentation and control technologies
  - Design and safety analysis tools based on 1980’s vintage knowledge bases and computational capabilities.



- **Necessary R&D**
  - Nuclear Materials Aging and Degradation
  - Advanced LWR Nuclear Fuel Development
  - Advanced Instrumentation, Information, and Control Systems Technologies
  - Risk-Informed Safety Margin Characterization
  - Economics and Efficiency Improvement

Imperative 2: New Builds

Goals are

- Demonstrate 10 CFR Part 52 licensing framework
- Facilitate accelerated licensing of small or medium-sized reactors
- Facilitate the development and demonstration of advanced manufacturing and construction technologies
- Develop and demonstrate next generation advanced plant concepts and technologies

Necessary R&D

- Address required changes to current licensing frameworks to accommodate new technologies and designs
- Enable new technology insertion into emerging and future designs
- Innovative concepts and advanced technologies
- Fundamental phenomena and performance data
- Advanced modeling and simulation capabilities
- New technology testing and demonstration
- Advanced manufacturing and construction technologies

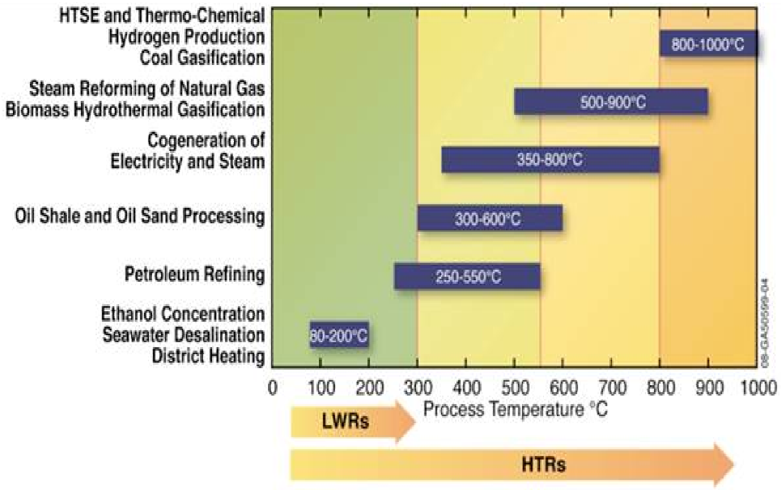
Why Small Modular Reactors?

- Applications for small generation increments
- Replacement of older nuclear facilities
- Flexibility in capital expenditures
- Reduced financial risk
- Simplification of siting and licensing
- Potential replacement of existing fossil resources
- Potential applications in remote locations
- Small EPZ enables process heat applications.
- Mission critical, off-grid applications
- Simplified maintenance and refueling
- Revitalize domestic nuclear industry

Imperative 3: Transition Away From Fossil Fuels

Challenges

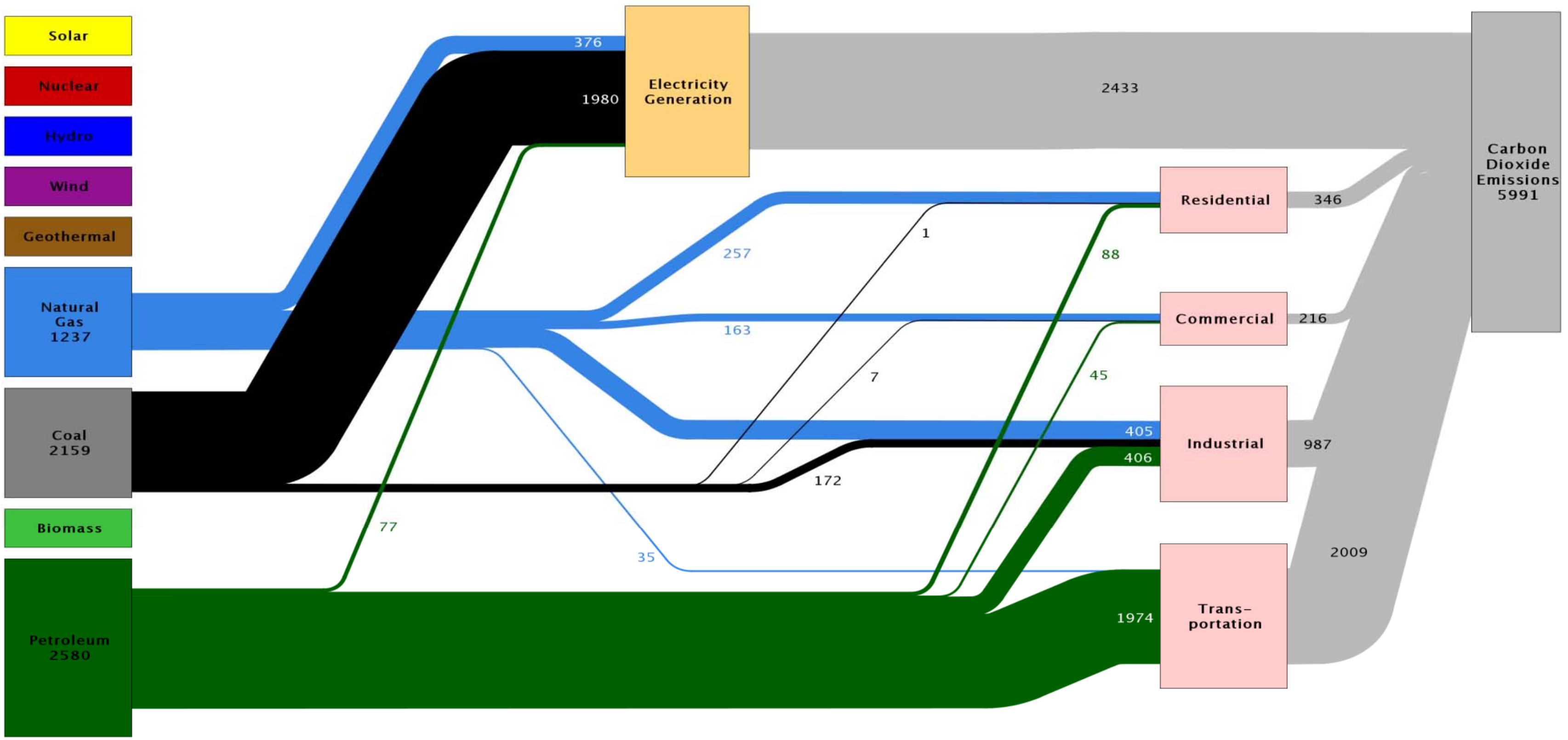
- Providing process heat to industry will require
  - Higher temperature reactors
  - Efficient heat transport systems
  - Interface systems for control and isolation
  - Development of a robust licensing case
- Institutional differences between transportation, industrial, and electric power sectors
- Use of high temperature reactors will generate used fuels that are not in the present fuel cycle



Necessary R&D

- Develop reactors of the appropriate size and outlet temperature
- Develop associated fuels, graphite and high temperature structural materials
- Develop heat transfer and interface systems
- Develop energy conversion technologies
- Develop modeling and simulation capabilities to evaluate interactions between reactors and the chemical plants or refineries which they would serve

U.S. Carbon Dioxide Emissions- 2007



Estimated U.S. Carbon Dioxide Emissions in 2007:
~5991 Million Metric Tons

Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

Imperative 4: Sustainable Fuel Cycles

Objectives

- In the near term, define and analyze fuel cycle technologies to develop options that increase the sustainability of nuclear energy
- In the medium term, select the preferred fuel cycle option(s) for further development
- By 2040, be prepared to demonstrate the selected fuel cycle options at engineering scale

Necessary R&D

- Reduce transuranic production
- Implement science-based development program for fuel recycling
- Obtain mechanistic understanding of waste form behavior
- Perform fundamental analysis of fuel fabrication processes, and fuel/clad performance
- Evaluate very high burnup systems that require minimal or no chemical separations
- Develop transmutation systems needed to supplement partial recycling in thermal reactors
- Enable real time nuclear material accountancy and control
- Analyze storage and disposal system performance in a variety of environments

Imperative 4: Sustainable Fuel Cycles (continued)

Once-Through

- No recycling or conditioning of used fuel
- Low uranium utilization
- Appropriate for a low cost uranium future
- Appropriate when repository space and/or actinide loadings are not show stoppers

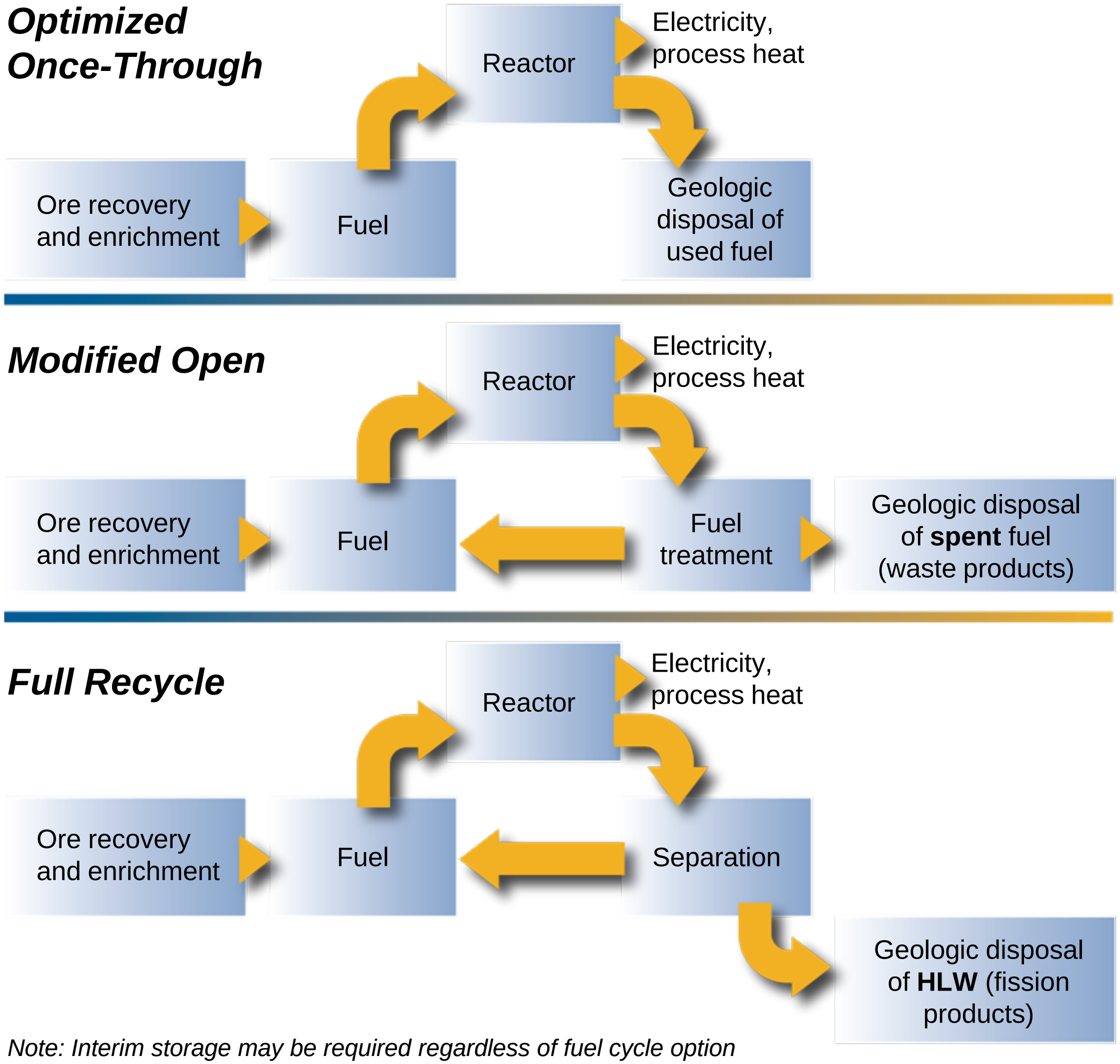
Full Recycle

- Multiple reprocessing steps and transmutation of actinides (e.g., GNEP)
- “Complete” uranium utilization (with breeder)
- Appropriate for a high cost uranium future
- Appropriate when repository space and/or actinide loadings are show stoppers

Modified Open Cycle

- Very limited used fuel conditioning or processing (e.g., recladding)
- High uranium utilization (i.e., used fuel is spent fuel)
- Appropriate for a high cost uranium future
- Appropriate when repository space is a show stopper
- Appropriate when actinide loading is not a show stopper

Three Potential Fuel Cycle Options



Optimized Once-Through

Ore recovery and enrichment

Fuel

Reactor

Electricity, process heat

Geologic disposal of used fuel

Modified Open

Ore recovery and enrichment

Fuel

Reactor

Electricity, process heat

Fuel treatment

Geologic disposal of **spent** fuel (waste products)

Full Recycle

Ore recovery and enrichment

Fuel

Reactor

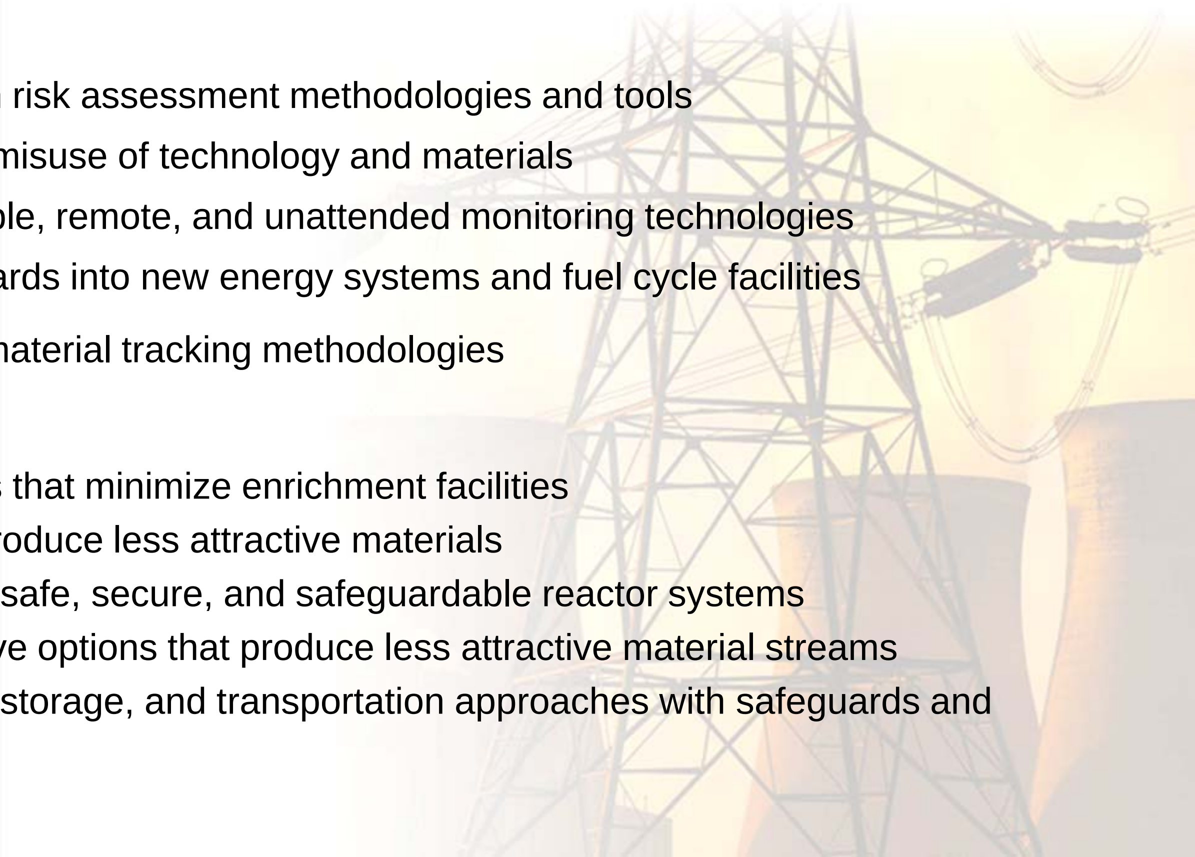
Electricity, process heat

Separation

Geologic disposal of **HLW** (fission products)

Note: Interim storage may be required regardless of fuel cycle option

Imperative 5: Understand and minimize proliferation risk

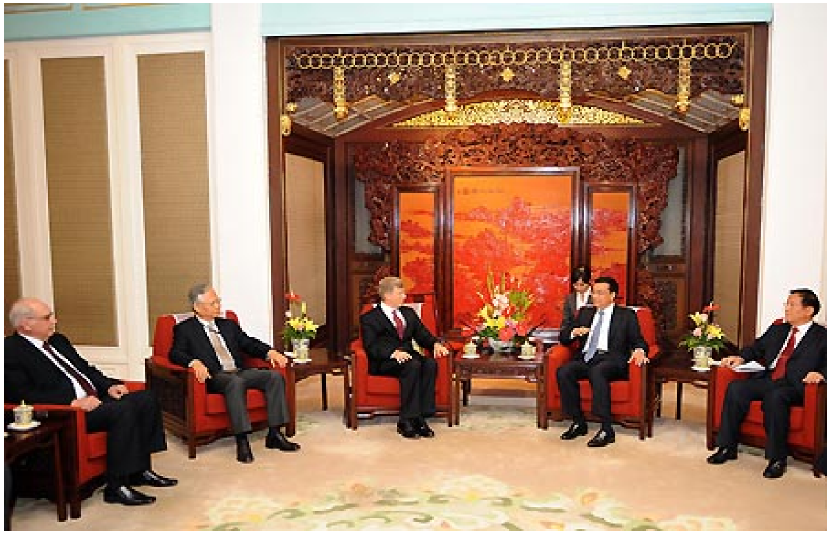


- **Limiting proliferation and security threats requires protecting materials, facilities, sensitive technologies and expertise**
- **Challenges**
  - Development of proliferation risk assessment methodologies and tools
  - Minimizing the potential for misuse of technology and materials
  - Development of highly reliable, remote, and unattended monitoring technologies
  - Designing improved safeguards into new energy systems and fuel cycle facilities
  - Development of advanced material tracking methodologies
- **Necessary R&D**
  - Development of approaches that minimize enrichment facilities
  - Development of fuels that produce less attractive materials
  - Development of intrinsically safe, secure, and safeguardable reactor systems
  - Development of cost-effective options that produce less attractive material streams
  - Development of fabrication, storage, and transportation approaches with safeguards and security benefits

International Cooperation

- **Most NE programs have international components.**

- **International collaborations enable us to**
  - increase our capabilities
  - support the U.S. nuclear industry
  - advance the President’s new framework for civilian nuclear cooperation including cradle-to-grave nuclear fuel services.



Rationale for Proliferation Concerns

»	EXISTING NP STATES	ASPIRING NP STATES
CONTROL OF CORRUPTION	68	46
POLITICAL STABILITY	58	40
GOVERNMENT EFFECTIVENESS	72	49
REGULATORY QUALITY	72	50
DEMOCRACY SCORE	78	21

- **Miller and Sagan, Pg 7, *Daedalus*, Fall 2009: using data from World Bank, *World Governance Indicators***

Laboratory Operations

- **Responsible for NE-owned facilities (most of INL and some buildings at ORNL) and site-wide safeguards and security activities at INL**
  - Activities are focused on enabling the NE RD&D mission.
  - Advanced Test Reactor (ATR) National Scientific User Facility is part of program.
- **Responsible for maintaining and advancing infrastructure, personnel skills, and knowledge bases to be ready to meet the need for radioisotope power sources.**
  - DOE infrastructure is located at INL, ORNL, and LANL.
- **Funding levels are**
  - Idaho Facilities Management $173M
  - ORNL, LANL, and Research Reactor Infrastructure $30M
  - Space and Defense Power Systems $42M
  - Safeguards and Security $83M

Challenges

- Four distinct issues affect reaching these goals:

1) Public Perception of Nuclear Energy
2) Capital Cost of New Plants
3) Solving the Nuclear Waste Problem
4) Non-proliferation