11.30am

Nuclear Energy: Where do we go from here?

Keith Bradley
Argonne National Laboratories

Abstract

For the past several decades, nuclear energy has proven to be one of the most reliable and cost-effective methods of producing base-load power in both the US and abroad. A growing interest in reducing Man's so-called carbon footprint suggested a resurgence in modern nuclear power — a renaissance period. But the renaissance has stalled. But the considerable merits of nuclear power remain robust and provide considerable technical opportunities for cutting-edge R&D. A snapshot of the current state of nuclear energy research and a discussion of the numerous opportunities will be provided.

Biography

Keith Bradley is Technical Director, Advanced Modeling and Simulation - Nuclear Engineering Division, Argonne National Laboratory (http://www.ne.anl.gov/). Keith Bradley has nearly 30 years of experience in national security and advanced nuclear energy research and development. Currently, he manages a complex-wide program in advanced modeling and simulation for the DOE Office of Nuclear Energy. The program develops next-generation predictive simulation capability to advance nuclear power. Most of Bradley’s career has been spent in the area of national security, with particular emphasis on nuclear capabilities and threats. Previously he worked at Lawrence Livermore and Los Alamos National Laboratories, studying the physics of nuclear weapons, technology development for nuclear nonproliferation, and R&D to advance and protect civilian nuclear fuel cycles. Bradley also worked closely with teams who were developing next-generation simulation tools, and was subsequently chosen to lead a similar program for the Office of Nuclear Energy.

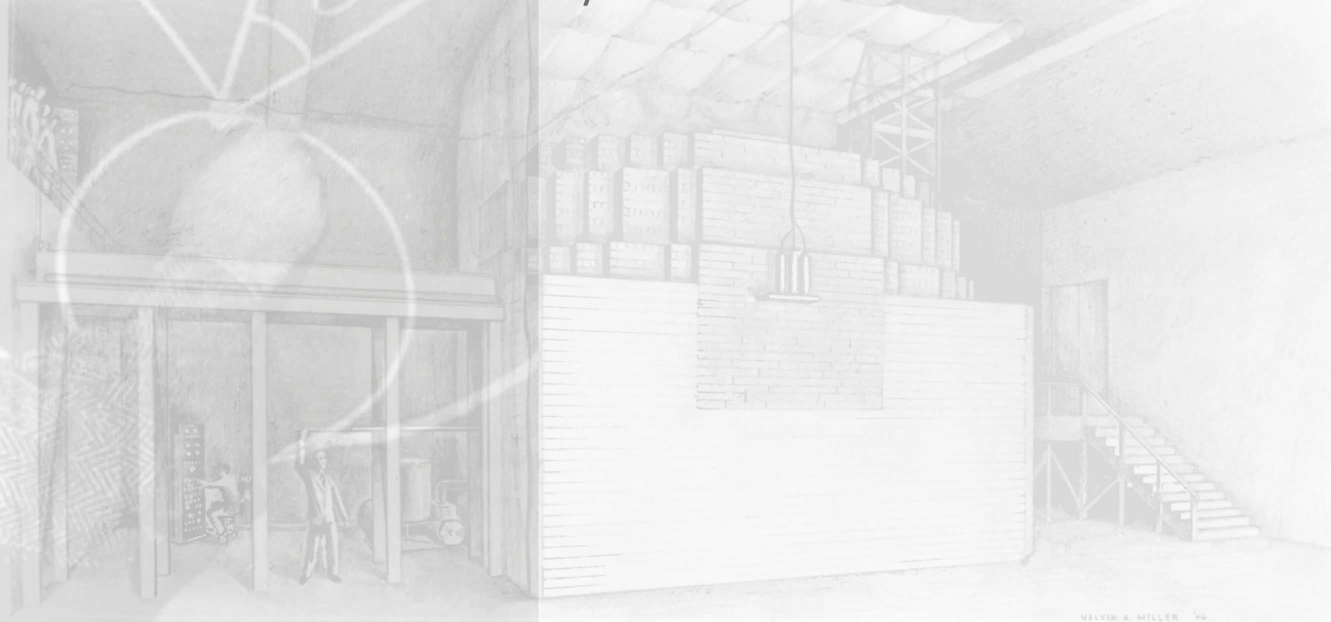
Nuclear Power: Where do we go from here?

Keith S. Bradley, Ph. D.
National Technical Director for Modeling & Simulation
U.S. Department of Energy, Office of Nuclear Energy

USC Smart Energy Summit
Los Angeles, California
January 27, 2012

Why Argonne?

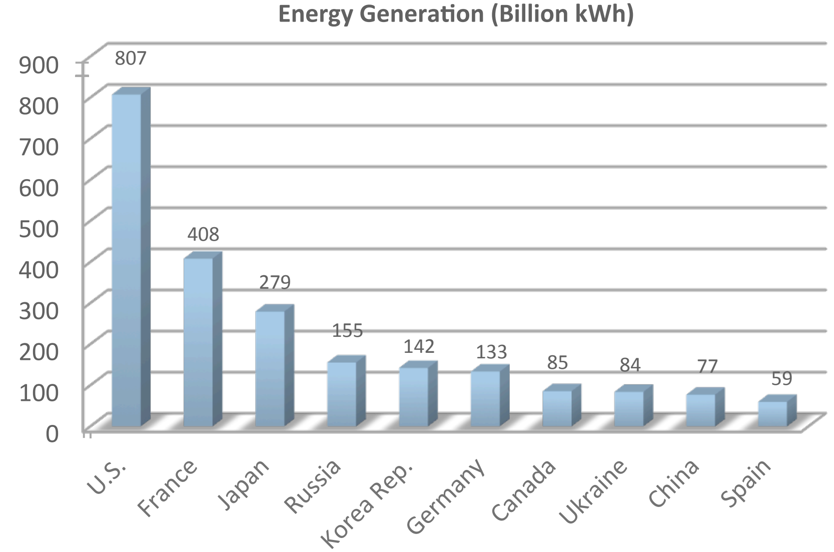
- On December 2, 1942 Enrico Fermi and colleagues created first controlled nuclear chain reaction at University of Chicago (Chicago Pile-1 or CP-1)
- 3 months later, that “reactor” was moved to Argonne Forest Section … later to be officially named Argonne National Laboratory (1946)
- Argonne was the nation’s first national laboratory



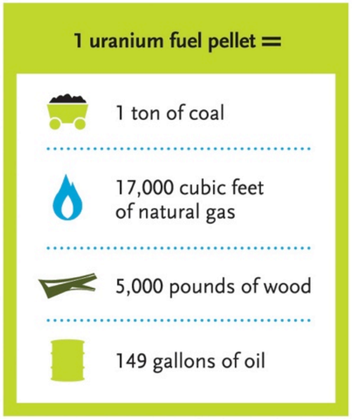
Chicago Pile I (CP-I), World's First Reactor

Some Interesting Facts about US Nuclear Power

- 104 operating reactors producing ~20% of nation's electricity
- Current capacity factor 91%
- Generating it by other fuel sources would require (per year)
  - 13.7 million barrels of oil, or
  - 3.4 million short tons of coal, or
  - 65.8 billion cubic feet of natural gas
- Eldest operating plant began in 1969 (Oyster Creek, New Jersey)
- Newest operating plant began in 1996 (Watts Bar 1, Tennessee)
- Westinghouse and GE are now owned by Japanese companies



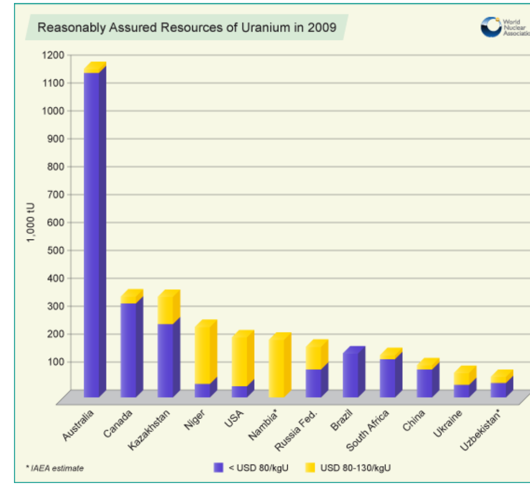
Power Production Equivalents



Source: Nuclear Energy Institute

Attributes of Nuclear Power

- Clean
- Safe
- Reliable
- Base Load Provider
- Sustainable
- PROFITABLE



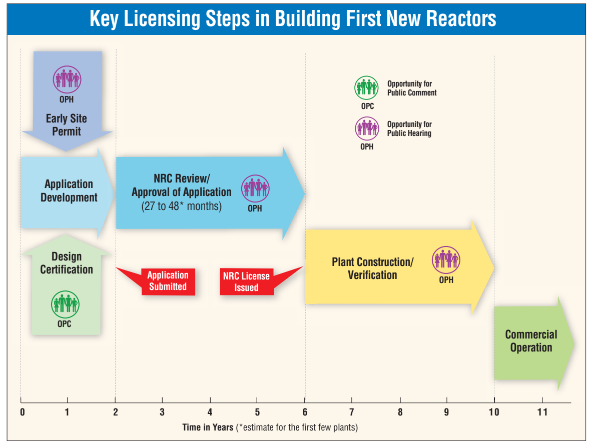
Summary of severe* accidents in energy chains for electricity 1969-2000

	OECD		Non-OECD	
Energy chain	**Fatalities**	**Fatalities/TWy**	**Fatalities**	**Fatalities/TWy**
Coal	2259	157	18,000	597
Natural gas	1043	85	1000	111
Hydro	14	3	30,000	10,285
Nuclear	0	0	31	48

Data from Paul Scherrer Institut, in OECD 2010. * severe = more than 5 fatalities

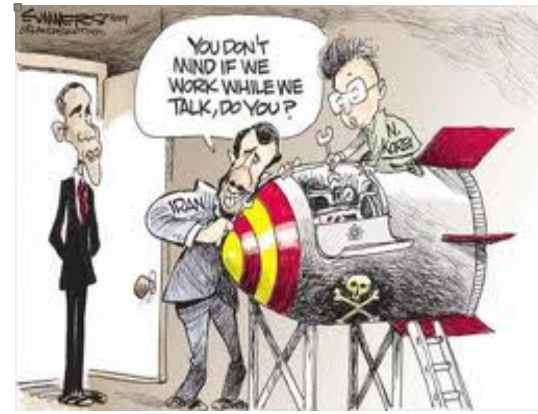
R&D Drivers are Numerous

Costs of New Construction



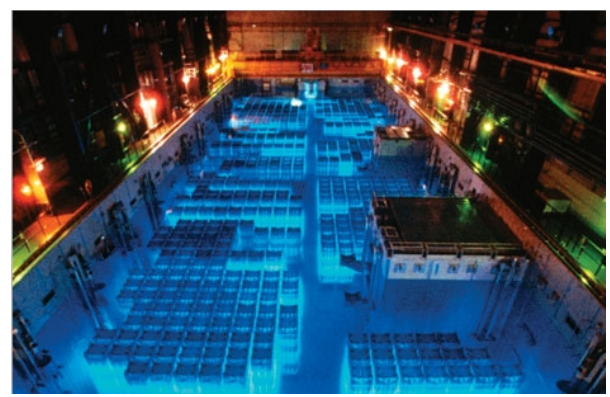
The NRC's new licensing process offers multiple opportunities for public input.

Licensing



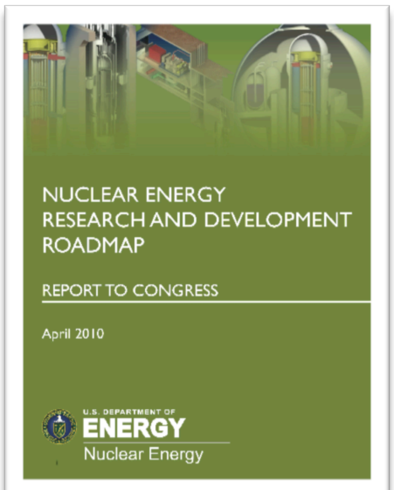
Nonproliferation & Security

Severe Accidents



Used Fuel Disposition

Current DOE Foci



Mission

- Advanced Nuclear Energy Technologies

R&D Objectives

- Sustain Current Fleet
- Improvements in Affordability
- Sustainable Fuel Cycles
- Reduced Proliferation Risk

Enabling Technologies

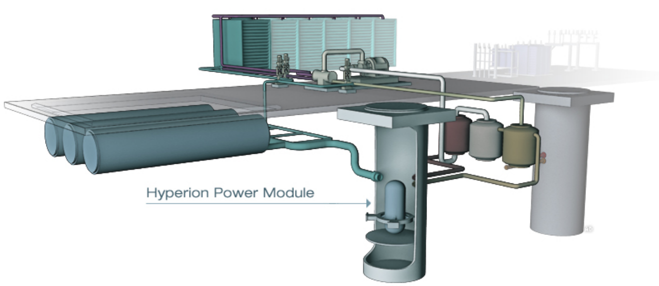
- Structural Materials
- Nuclear Fuels
- Reactor and Fuel Cycle Systems
- Instrumentation and Controls
- Power Conversion Systems
- Process Heat Transport Systems
- Dry Heat Rejection
- Separation Processes
- Waste Forms
- Risk Assessment Methods
- Nuclear Fuel Resources
- Computational Modeling & Simulation

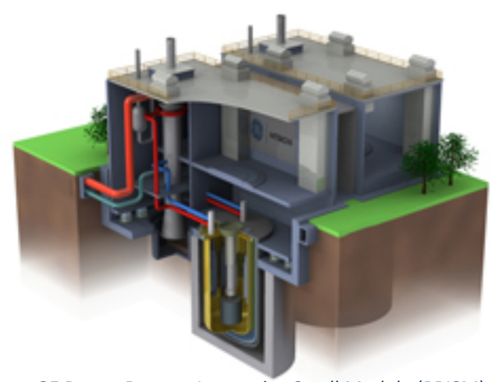
Current DOE Foci

- Small Modular Reactors (SMRs; driven by cost of construction)
- Accident Tolerant Fuels (driven by Fukushima experience)
- Used Fuel Disposition (driven by Blue Ribbon Commission Report)

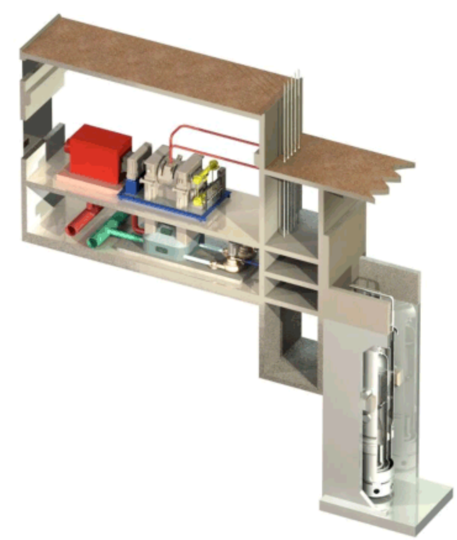
Small Modular Reactors Offer Unique Attributes and Pose Unique Challenges

- Desired Attributes
  - Economies of prefabrication
  - Economies of scale
  - Grid insensitive
  - Transportable
  - “Securable”
- Challenges of some proposed designs
  - Heat management
  - Natural circulation
  - Advanced coolants
  - In-vessel components
  - Controlling clusters
  - Licensing





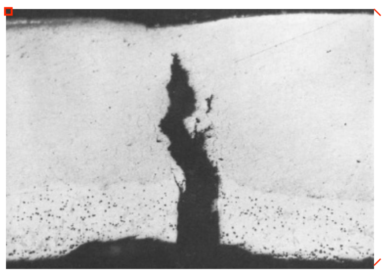
GE Power Reactor Innovative Small Module (PRISM)

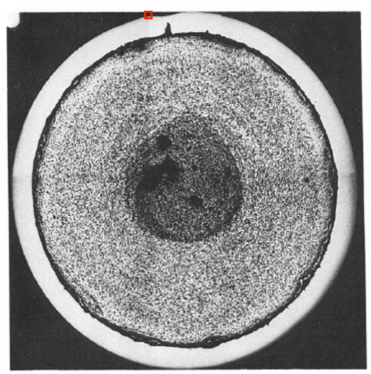


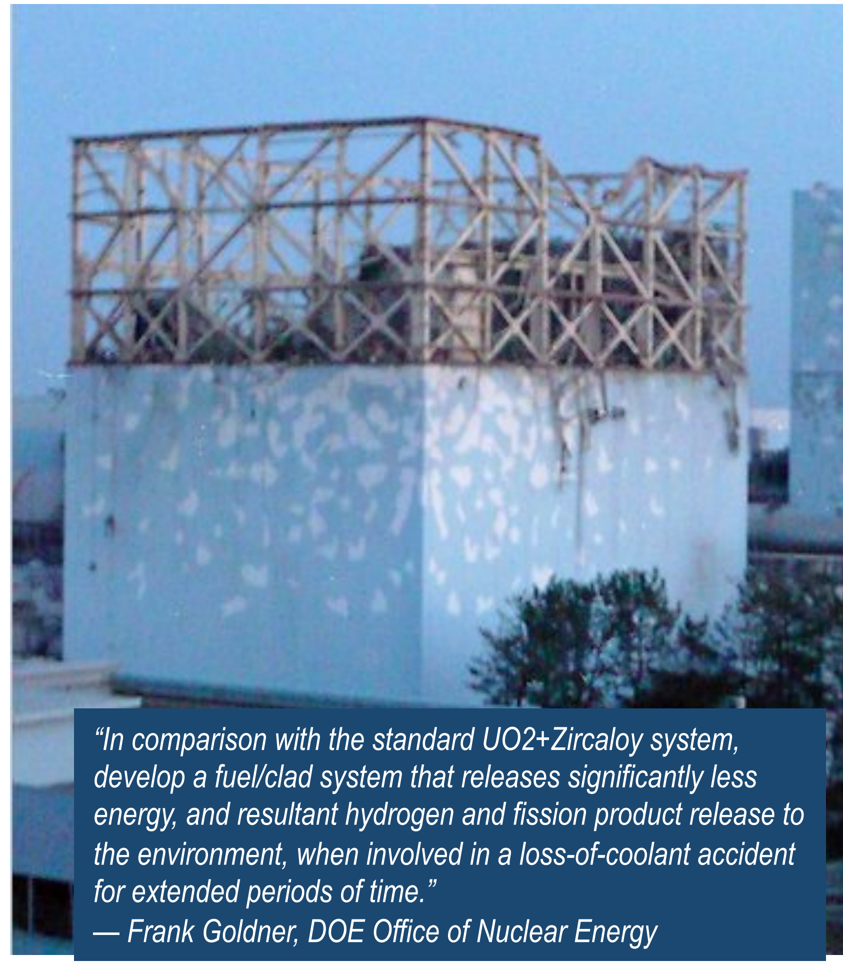
Single-unit side view of the NuScale system design

Accident Tolerant Fuels are a Relatively New Desire

- Desired attributes
  - Withstand higher temperatures
  - Eliminate hydrogen production under accident conditions
  - Research will likely focus on replacing or modifying Zircaloy cladding



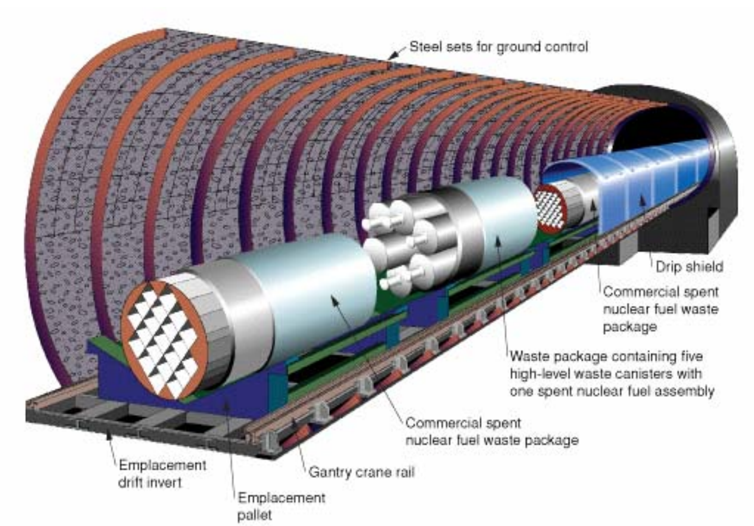


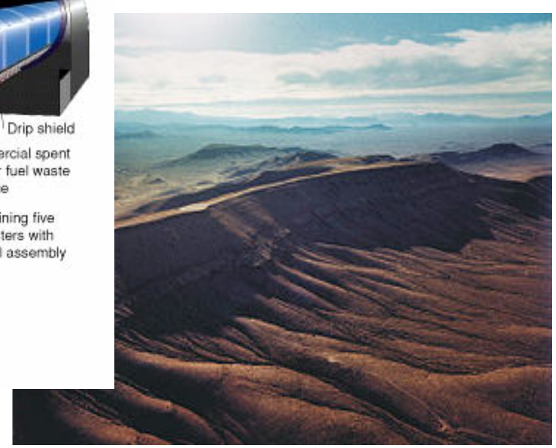


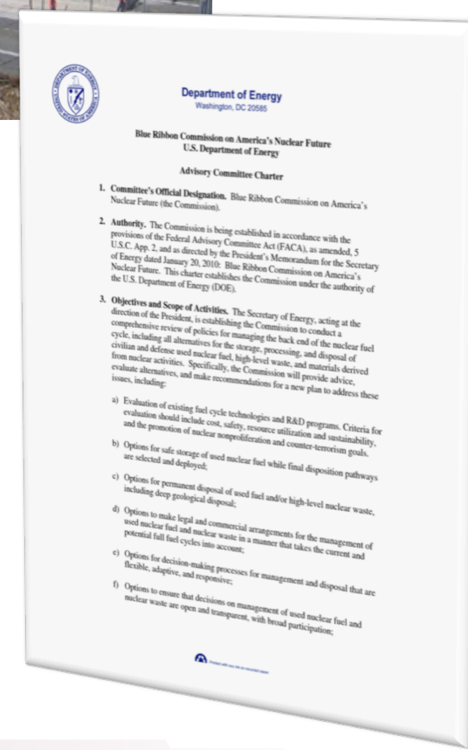
"In comparison with the standard UO2+Zircaloy system, develop a fuel/clad system that releases significantly less energy, and resultant hydrogen and fission product release to the environment, when involved in a loss-of-coolant accident for extended periods of time."
— Frank Goldner, DOE Office of Nuclear Energy

The U.S. continues to vacillate on disposition of used nuclear fuel

- Issues
  - Corrosion of containers
  - Retrievability
  - Soil transport
  - Volume







Department of Energy
Washington, DC 20585

Blue Ribbon Commission on America's Nuclear Future
U.S. Department of Energy

Advisory Committee Charter

1. **Committee's Official Designation.** Blue Ribbon Commission on America's Nuclear Future (the Commission).

2. **Authority.** The Commission is being established in accordance with the provisions of the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App. 2, and as directed by the President's Memorandum for the Secretary of Energy dated January 20, 2010: Blue Ribbon Commission on America's Nuclear Future. This charter establishes the Commission under the authority of the U.S. Department of Energy (DOE).

3. **Objectives and Scope of Activities.** The Secretary of Energy, acting at the direction of the President, is establishing the Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities. Specifically, the Commission will provide advice, evaluate alternatives, and make recommendations for a new plan to address these issues, including:

   a) Evaluation of existing fuel cycle technologies and R&D programs. Criteria for evaluation should include cost, safety, resource utilization and sustainability, and the promotion of nuclear nonproliferation and counter-terrorism goals.

   b) Options for safe storage of used nuclear fuel while final disposition pathways are selected and deployed;

   c) Options for permanent disposal of used fuel and/or high-level nuclear waste, including deep geological disposal;

   d) Options to make legal and commercial arrangements for the management of used nuclear fuel and nuclear waste in a manner that takes the current and potential full fuel cycles into account;

   e) Options for decision-making processes for management and disposal that are flexible, adaptive, and responsive;

   f) Options to ensure that decisions on management of used nuclear fuel and nuclear waste are open and transparent, with broad participation;

What about the private sector SMRs?

[mPower Reactor]

[Holtec Inherently Safe Modular Underground Reactor (HI-SMUR) 140]]

[Hyperion Power Module (HPG)]

[NuScale Reactor]

[Gas Turbine Modular Helium Reactor (GT-MHR)]
and
[Energy Multiplier Module (EM^2)]

[Super-Safe, Small and Simple (4S)]

[Power Reactor Innovative Small Module (PRISM)]

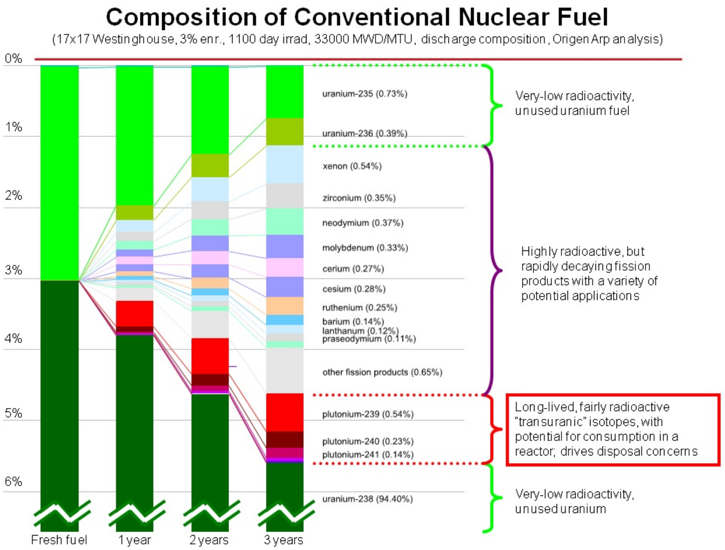
[The Westinghouse SMR]

[Antares]

[Pebble Bed Modular Reactor Ltd. (PBMR)]

Where can experimentation help?

- Development of new materials more robust to harsh environments (radiation, heat)
- Nondestructive stoichiometry of used fuel
- Used fuel disposition
- Instrumentation and Controls



Nuclear Energy University Programs (NEUP)

www.neup.gov

Thank you ….

ksbradley@anl.gov
(630) 252-4685