


Future of Nuclear Industry

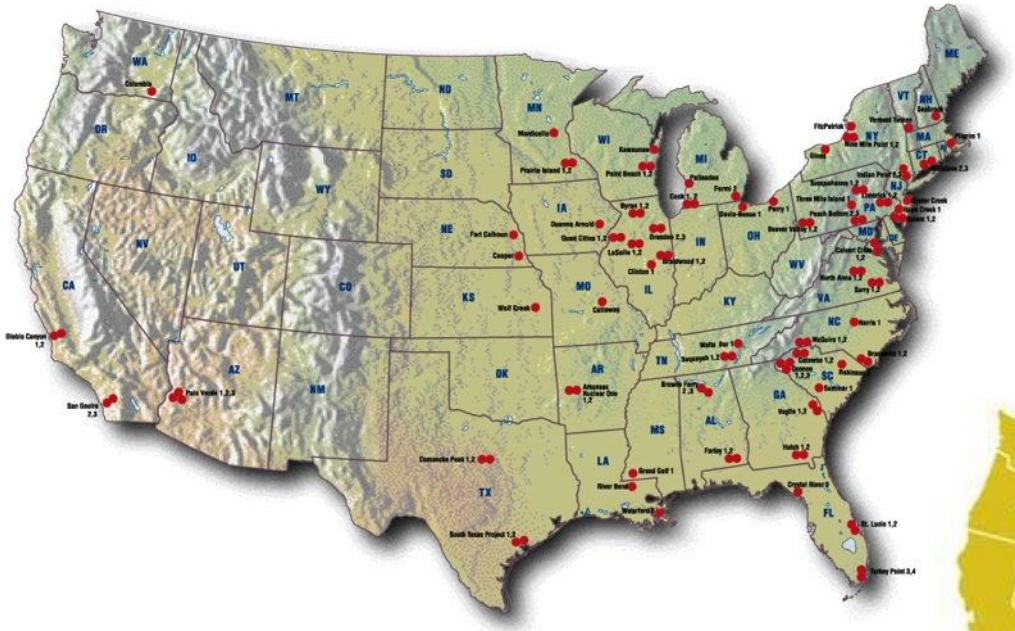
John Grossenbacher
Laboratory Director, Idaho National Laboratory

April 7, 2012

www.inl.gov

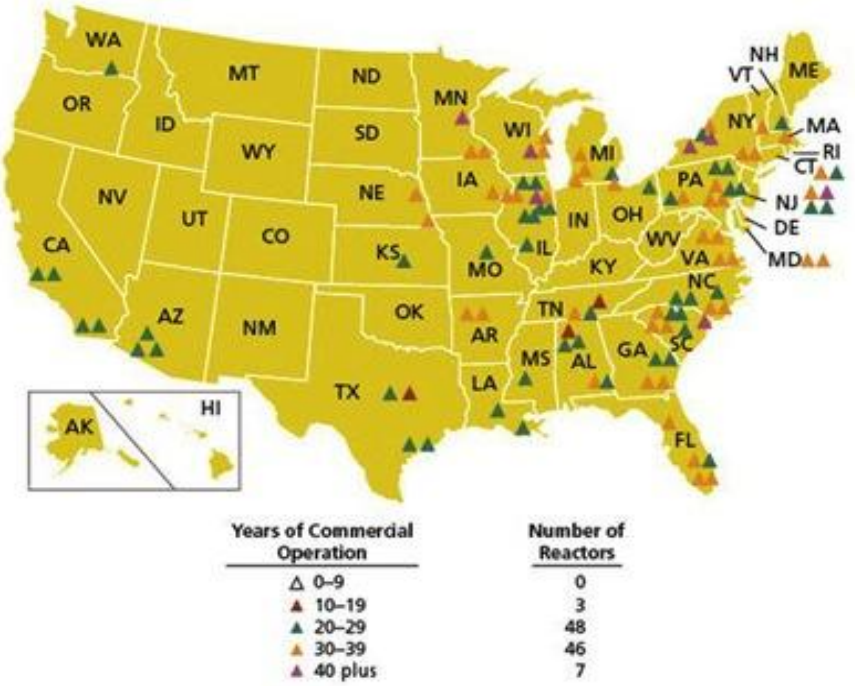
Idaho National Laboratory

Nuclear Energy in the U.S.

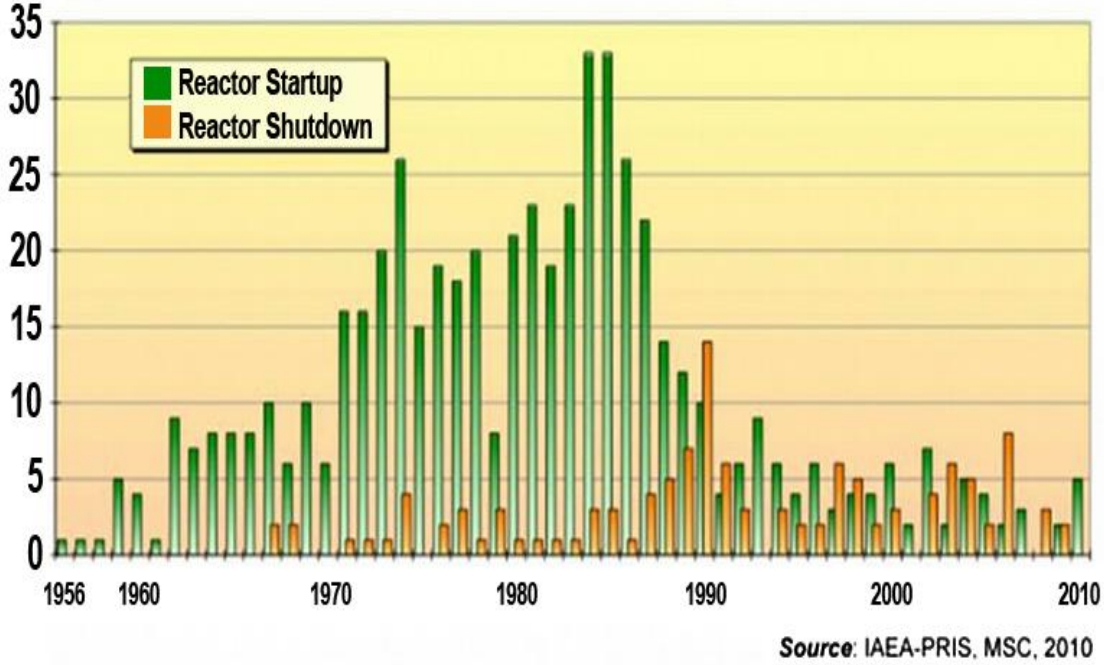


- 104 reactors in 31 states
- 4 new nuclear plants under construction
- 22 early site permits
- Providing 20% of our electricity
- 69% carbon free generation

- 71 reactors with 20 year license extensions, 32 with pending extensions
- 140 power uprates, 20 more under review. *Equivalent to about six new reactors*
- 23 commercial reactors have shut down



Nuclear Energy in the Rest of the World



Reactor Startups and Shutdowns in the World (1956-2010)

There are 66 commercial plants being built world-wide and only four of those are in the U.S.

440 Reactors Worldwide (104 of those are in the U.S.)

Factors for Change

- **Increase demand for electricity — 22% increase in the U.S. by 2035**
- **Concern about carbon emissions**
- **Cost of energy and its impact on economic competitiveness**
- **Costs, risks and environmental impacts of nuclear energy and its alternatives**
  - Baseload power
  - Fukushima

Factors for Change in the U.S.

- **Helpful to Nuclear Energy**
  - 4 new plants under construction in 2 states
  - 9 license extensions approved (post Fukushima)
  - Blue Ribbon Commission may resolve the Yucca Mountain impasse
  - U.S. reactors evaluated as safe (post Fukushima)
  - *Demonizing Technology*
- **Not Helpful to Nuclear Energy**
  - Low natural gas prices, anticipated very large supply
  - Financial turmoil and recession
  - Fukushima's impacts on public opinion and cost of related regulations
  - NRC uncertainty
  - No effort to put a price on CO_2 emissions
  - Lack of a long-term view
  - *Romanticizing Technology*

Important Issues Relative to Building a New Nuclear Power Plant Anywhere in the U.S.

- **Public acceptance**
  - Water use (cooling technology)
  - Spent nuclear fuel (long term storage and permanent disposal)
  - Safety Post-Fukushima (including seismic)

- **Owner costs, financing and schedule**
  - Financing/costs of new plants in regulated and unregulated markets
  - Political and regulatory risk
  - 10 years from site selection to commercial operation
  - Supply chain (e.g., infrastructure to produce large components and nuclear grade equipment, transportation of large components)
  - Construction and operations workforce (experience)

Impact of Fukushima

- Japan
- Germany
- Switzerland
- China
- India
- Korea

Reactor Technologies — Past, Present and Future

Generation I

Big Rock Point, GE BWR

Early Prototypes

- **Calder Hall** (GCR)
- **Douglas Point** (PHWR/CANDU)
- **Dresden-1** (BWR)
- **Fermi-1** (SFR)
- **Kola 1-2** (PWR/VVER)
- **Peach Bottom 1** (HTGR)
- **Shippingport** (PWR)

Generation II

Diablo Canyon, Westinghouse PWR

Large-scale Power Stations

- **Bruce** (PHWR/CANDU)
- **Calvert Cliffs** (PWR)
- **Flamanville 1-2** (PWR)
- **Fukushima II 1-4** (BWR)
- **Grand Gulf** (BWR)
- **Kalinin** (PWR/VVER)
- **Kursk 1-4** (LWGR/RBMK)
- **Palo Verde** (PWR)

Generation III / III+

Kashiwazaki, GE ABWR

AP1000, Westinghouse PWR

Evolutionary Designs

(Economics, Safety, Scalability, Process Heat)

- **ABWR** (GE-Hitachi; Toshiba BWR)
- **ACR 1000** (AECL CANDU PHWR)
- **AP1000** (Westinghouse-Toshiba PWR)
- **APR-1400** (KHNP PWR)
- APWR (Mitsubishi PWR)
- **Atmea-1** (Areva NP -Mitsubishi PWR)
- **CANDU 6** (AECL PHWR)
- **EPR** (AREVA NP PWR)
- **ESBWR** (GE-Hitachi BWR)
- **Small Modular Reactors**
  - Atomenergoproekt PWR
  - B&W mPower PWR
  - India DAE AHWR
  - KAERI SMART PWR
  - NuScale PWR
  - Westinghouse IRIS PWR
- **VVER-1200** (Gidropress PWR)
- **NGNP** (Next Generation Nuclear Plant)

Generation IV

Japan Sodium Fast Reactor

Revolutionary Designs

(Economics, Safety, Fuel Utilization, Waste Management)

- **GCR** Gas-Cooled fast Reactor
- **LFR** Lead-cooled Fast Reactor
- **MSR** Molten Salt Reactor
- **SFR** Sodium-cooled Fast Reactor
- **SCWR** Super-Critical Water-cooled Reactor
- **VHTR** Very High Temperature Reactor

1950 1970 1990 2010 2030 2050 2070 2090

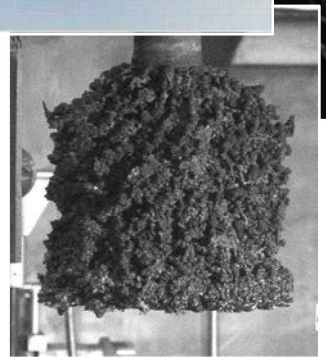
Fuel Cycle Technologies

Past and Present

- **Open or Once-through**
- **Partial Reprocessing/ Recycling***
  - Aqueous
  - Electrometallurgical (Pyro)

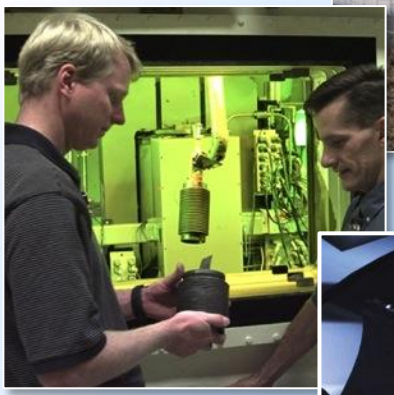
Future

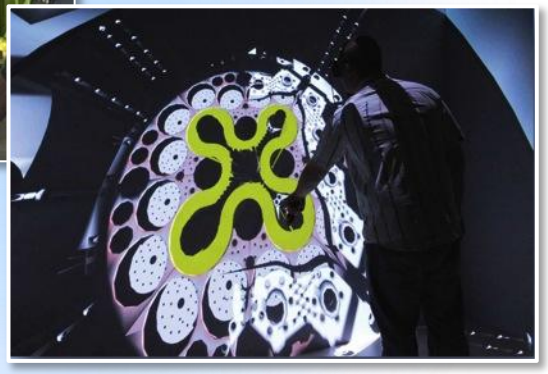
- **Modified open**
- **Full Recycle**



** France, UK, China, Russia, Japan, India, (U.S.)*

"Emerging" Technologies





- **Fuel cycle, waste, repositories**
  - Laser enrichment
  - Electrometallurgical processing (Pyro)
  - Advanced aqueous separations
  - Centrifugal Contactors
  - Deep boreholes
  - Dry storage R&D
  - Hot Isostatic Press
- **Reactors**
  - Small Modular Reactors (SMRs)
  - High Temperature Gas-cooled Reactors (HTGRs)
  - Sodium Fast Reactors (SFR)
- **Fukushima Related**
  - Defense in depth (multiple, redundant, independent systems) for beyond design basis accidents (protect, mitigate emergency planning)
  - Accident tolerant fuels
- **Research and Development Tools**
  - Fuels and materials modeling/simulation and disciplined validation of fuels and materials behavior

Idaho National Laboratory

The National Nuclear Laboratory