UT-BATTELLE

Re-Emergence of Nuclear Power in the United States

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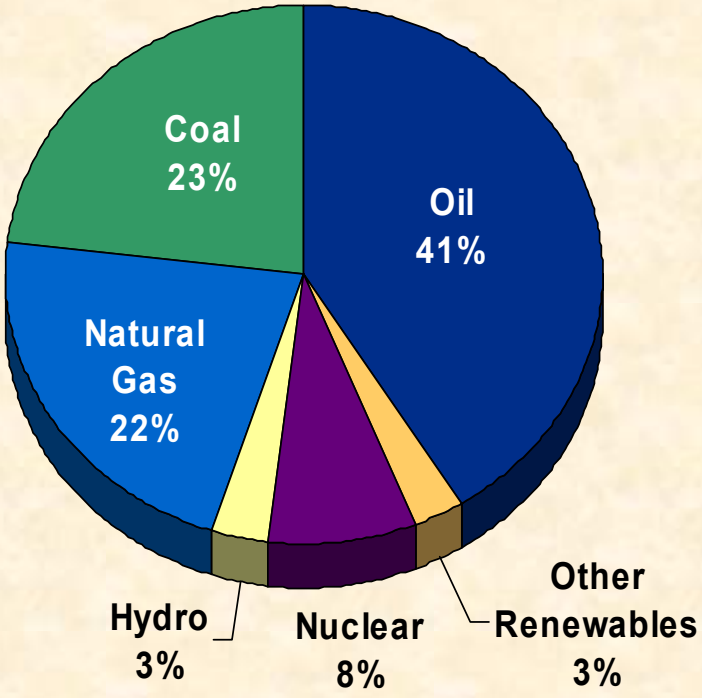
Presentation for the Friends of ORNL
November 17, 2004

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

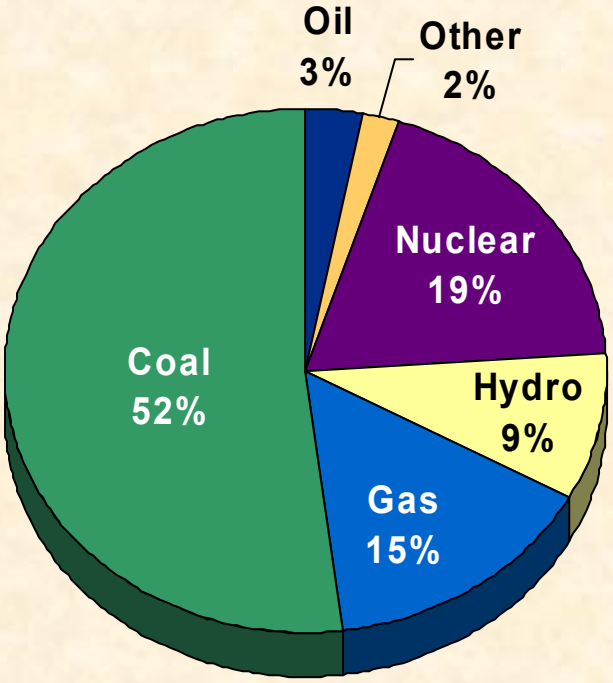
Re-Emergence of Nuclear Power
Drivers for building new nuclear plants

- Need for nuclear power plants
  - Meet electricity demand
  - Limit GHG emissions
- Nuclear is cost competitive
  - Industry performance
  - Life extension/License renewals
  - Industry restructuring
  - Gas price increase
- New plant construction/planning
- DOE/industry path forward
- ORNL roles in nuclear energy development

Why Nuclear Energy?...
We Depend on it Today



Energy Production



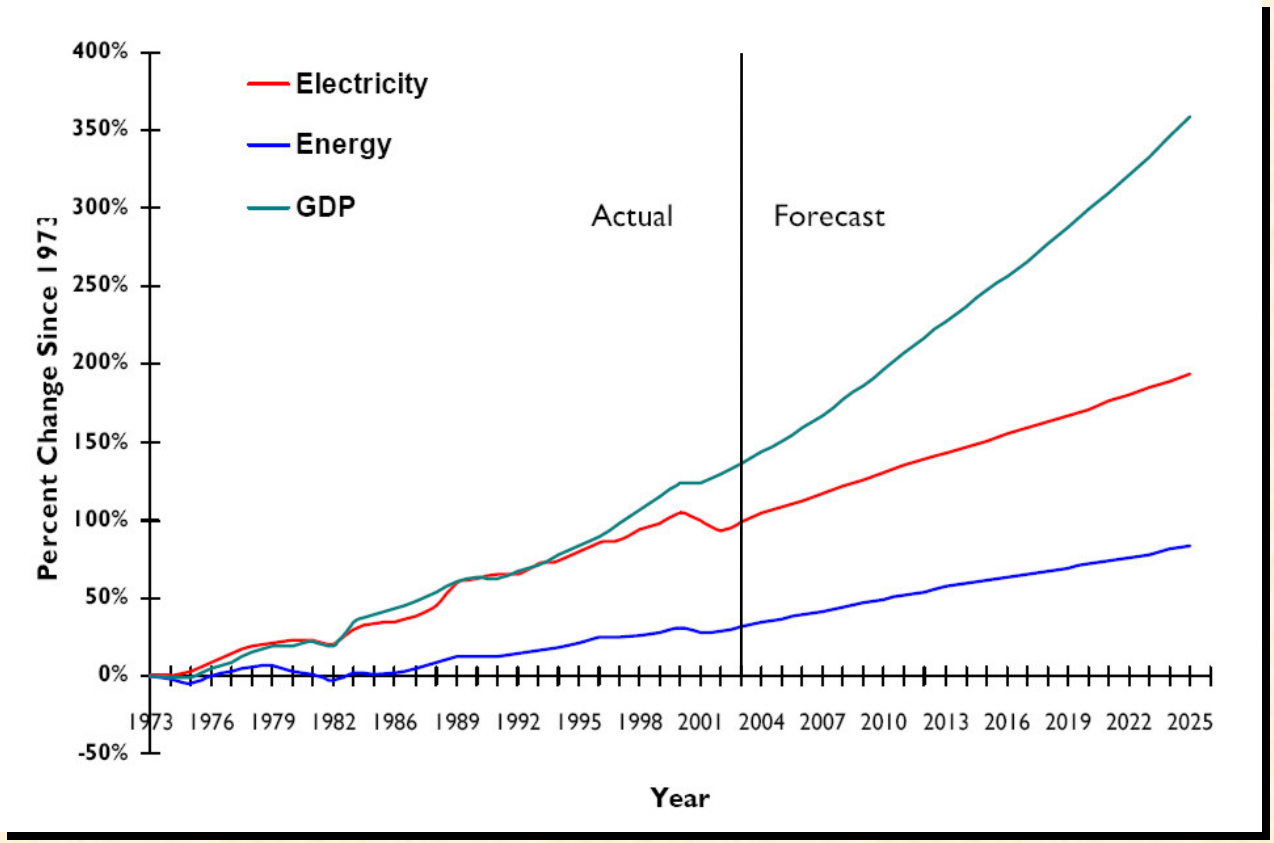
U.S. Electricity Production

Source: EIA

Economic, Energy, and Electricity Growth (1973-2025)

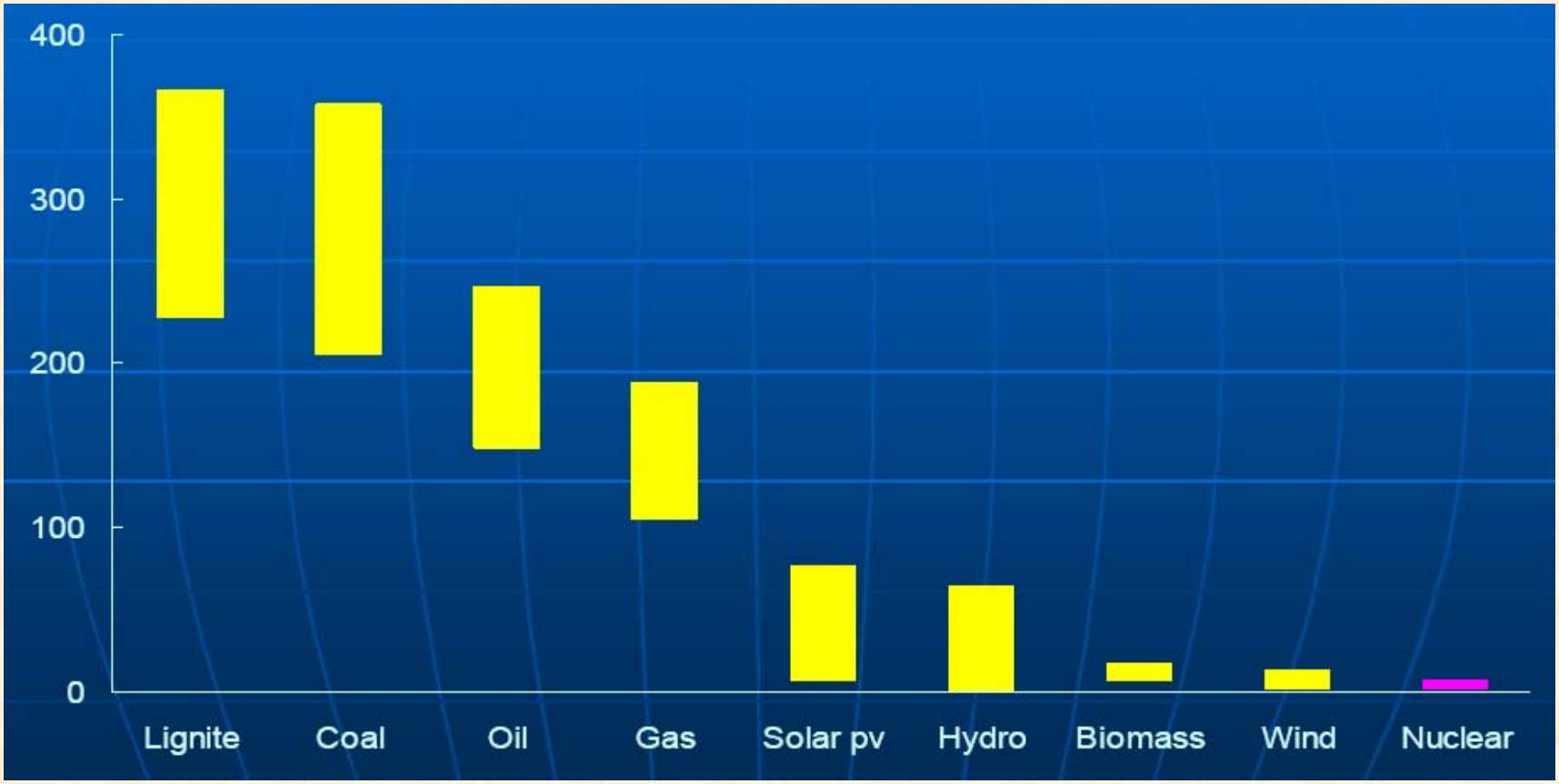
DOE/Industry Goal for 2020 to maintain ~30% clean generation

- **10,000 MWe upgrade to existing plants**
- **50,000 MWe new nuclear plants**



Greenhouse Gas Emissions from Electricity Production Chains

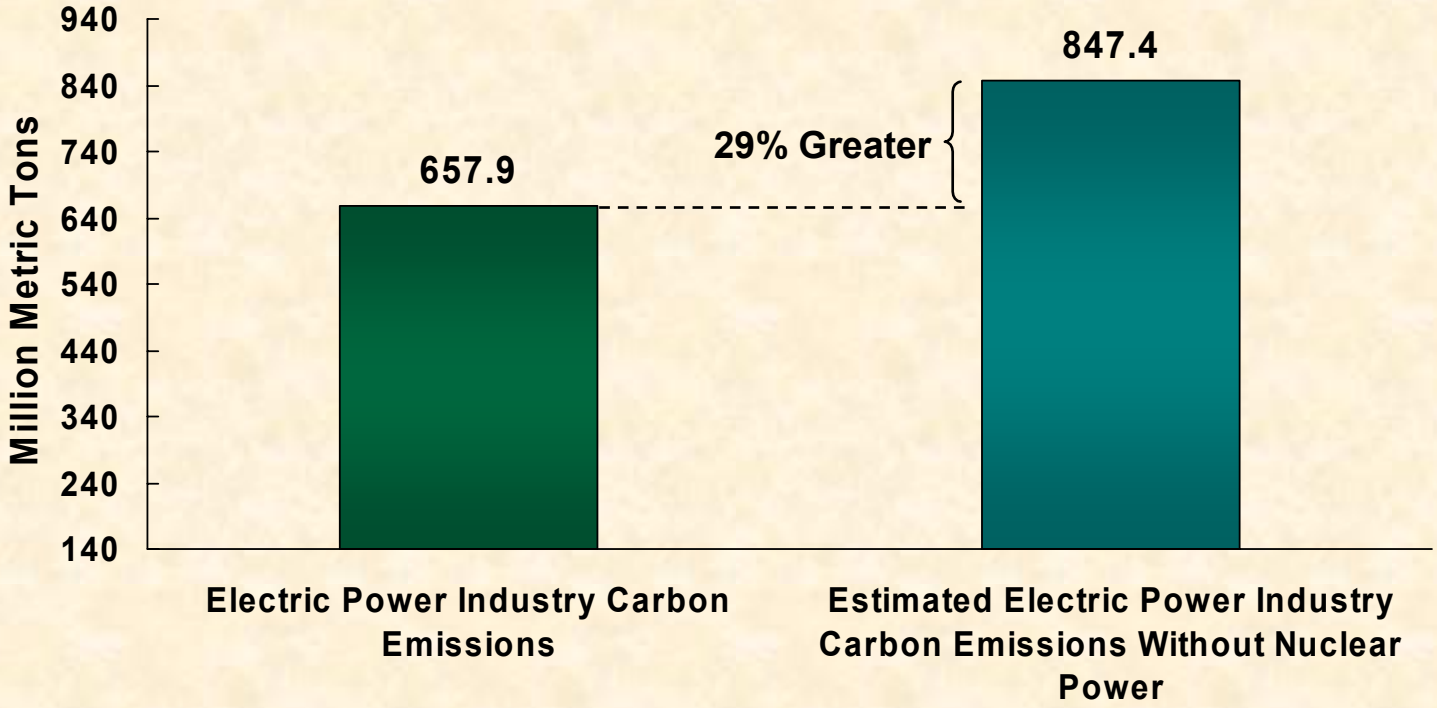
(gCO_2 equiv./kWh)



Source: OECD/IEA Statistics

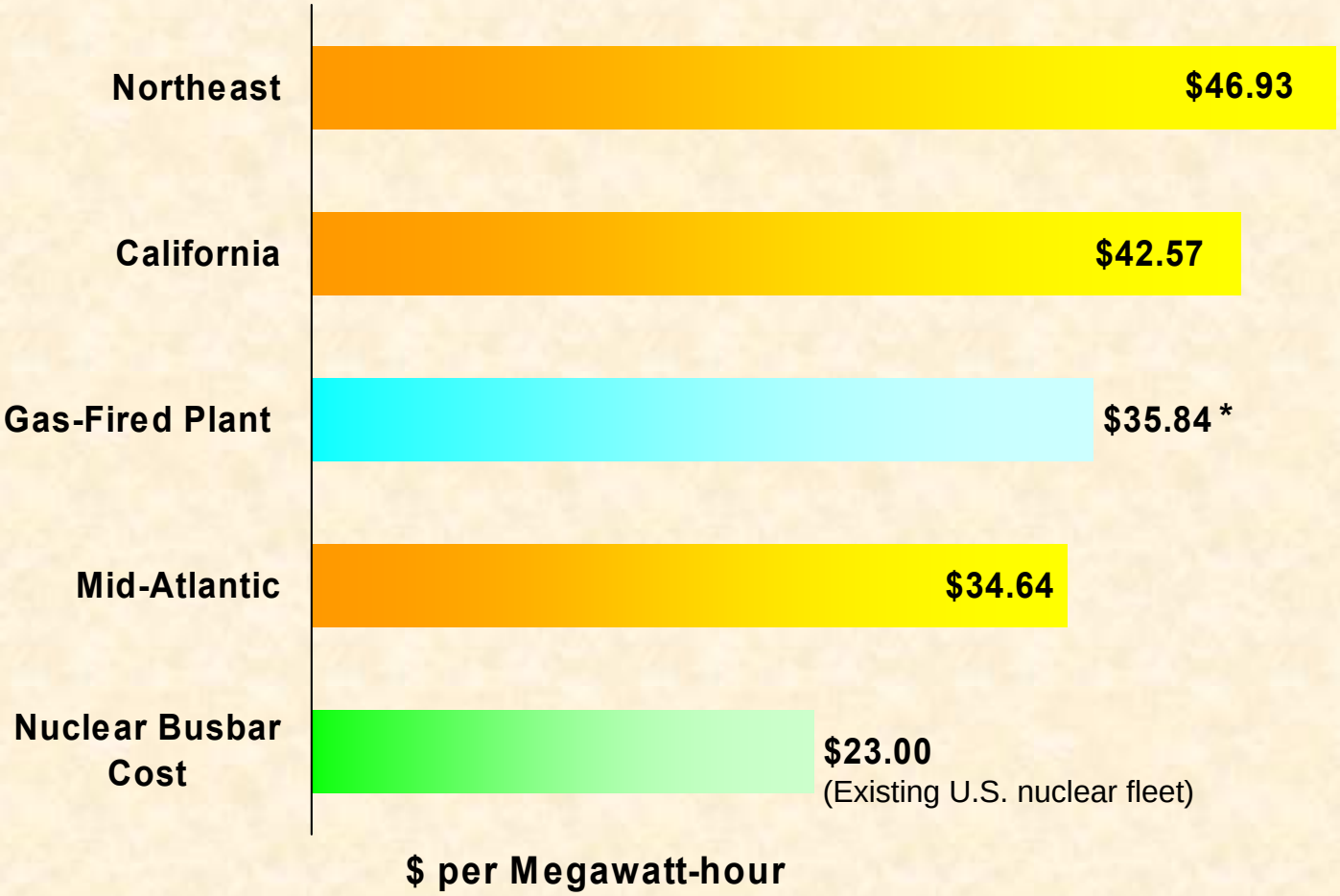
Perspective on USA Nuclear Power and Carbon Emissions (2002)

Electric sector carbon emissions would be 29% larger without nuclear power



Emissions avoided by nuclear power are calculated using regional fossil fuel emissions rates from EPA CEMS data and individual plant generation data from EIA. Total Emissions are calculated from EPA CEMS data. Last updated 9/15/03

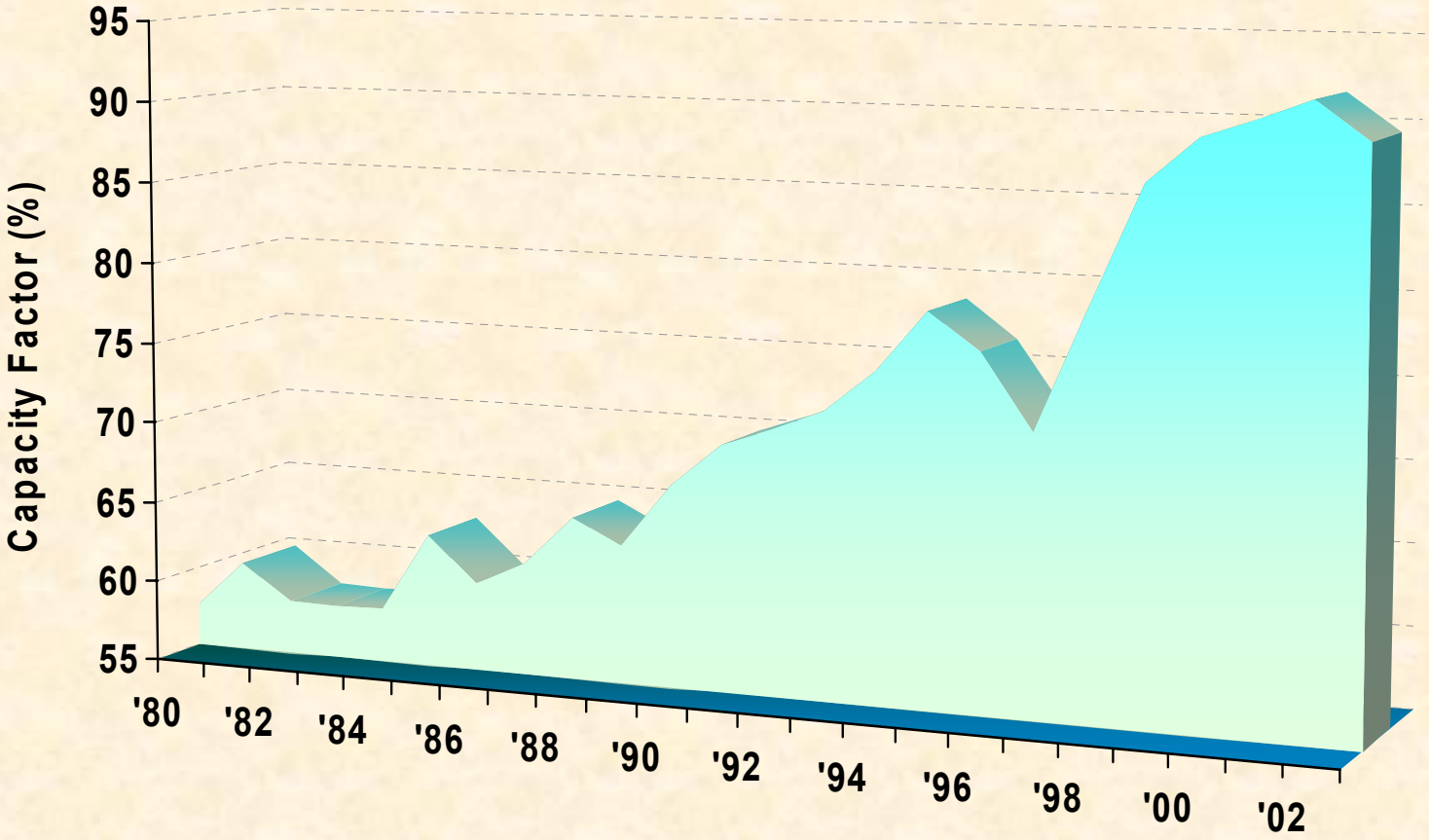
Existing Nuclear Power is Clearly Cost Competitive



*Gas @ $4.00/MBTU
Source: NEI

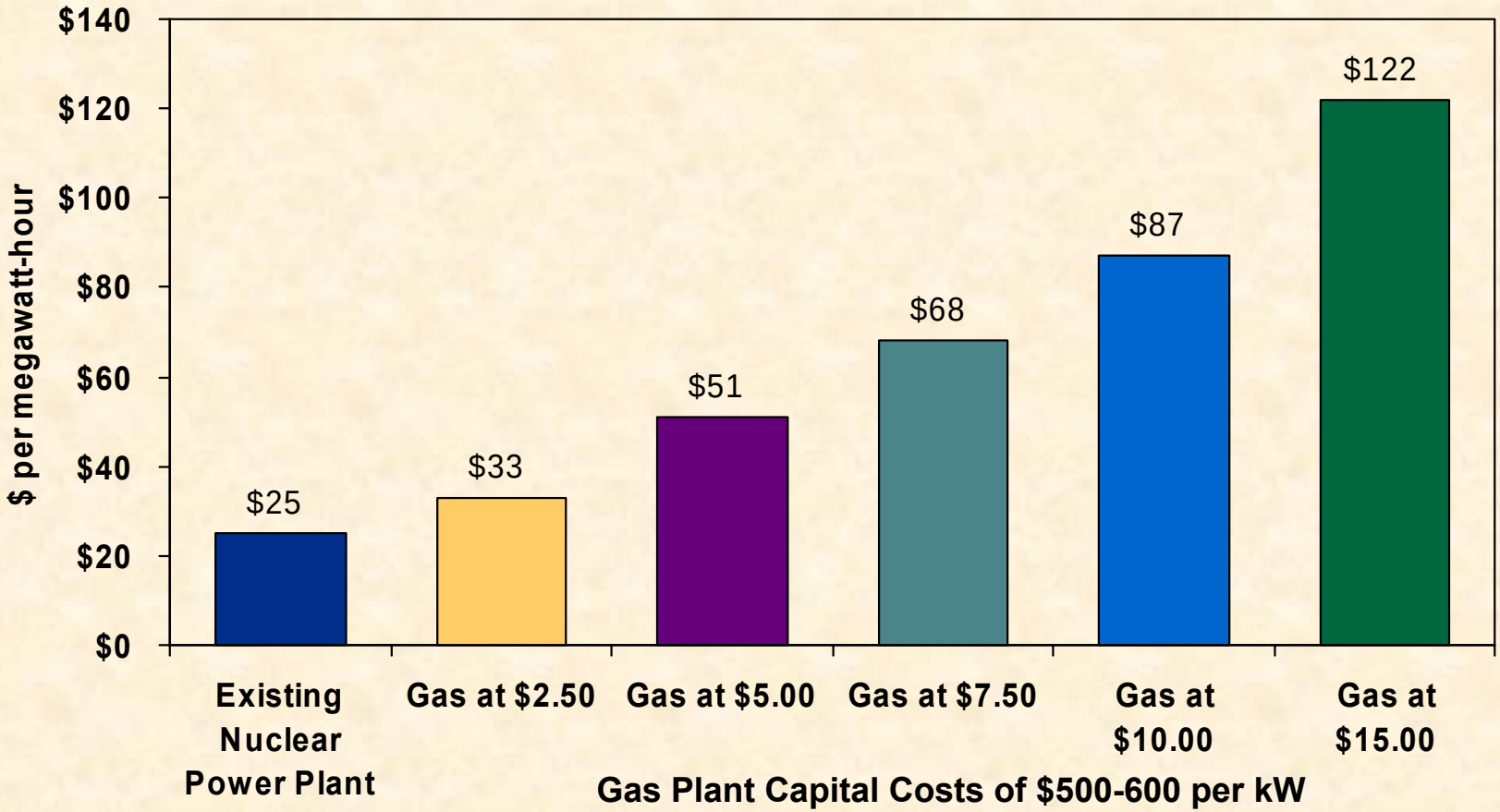
Nuclear Capacity Factors Have Improved Dramatically

(Equivalent to 23−1000 MWe Plants)



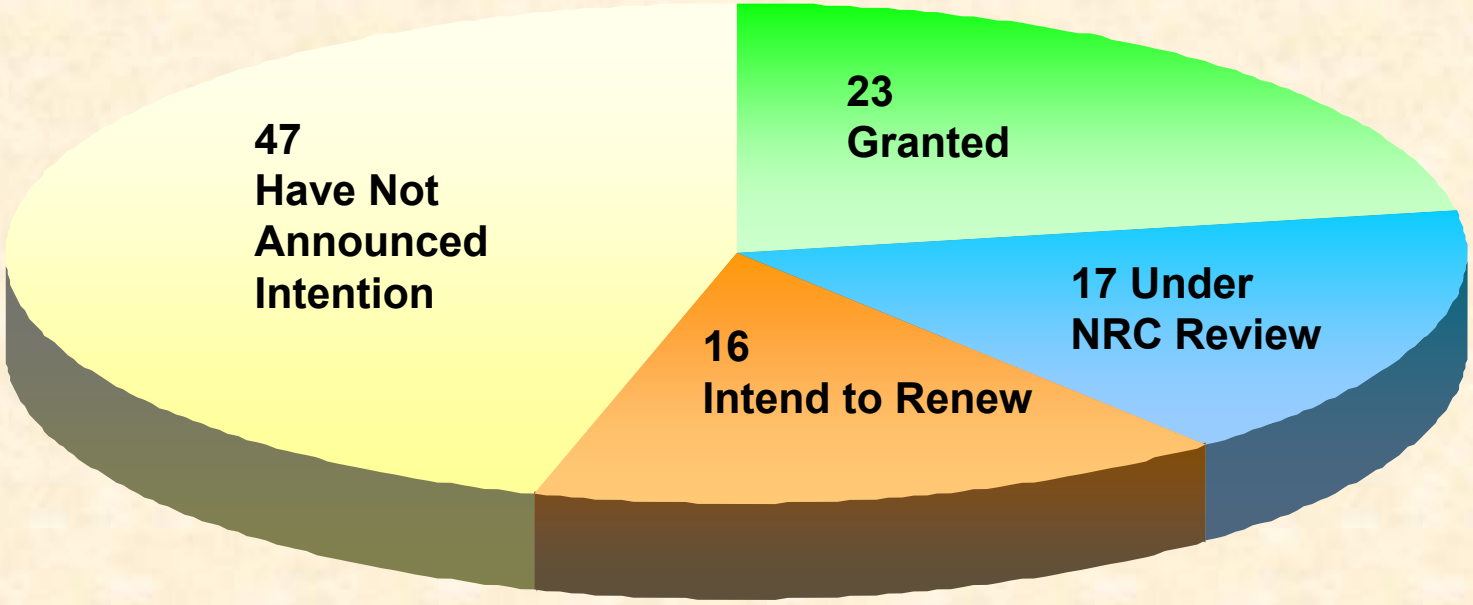
Source: NEI

Rising Natural Gas Prices Emphasize Price Stability of Nuclear Electricity



Source: NEI

Most Operating U.S. Nuclear Plants Will Renew Their Licenses – Adds 20 years



License Renewal Status

Source: NEI

Restructuring of U.S. Nuclear Industry

Consolidation of Owners/Operators

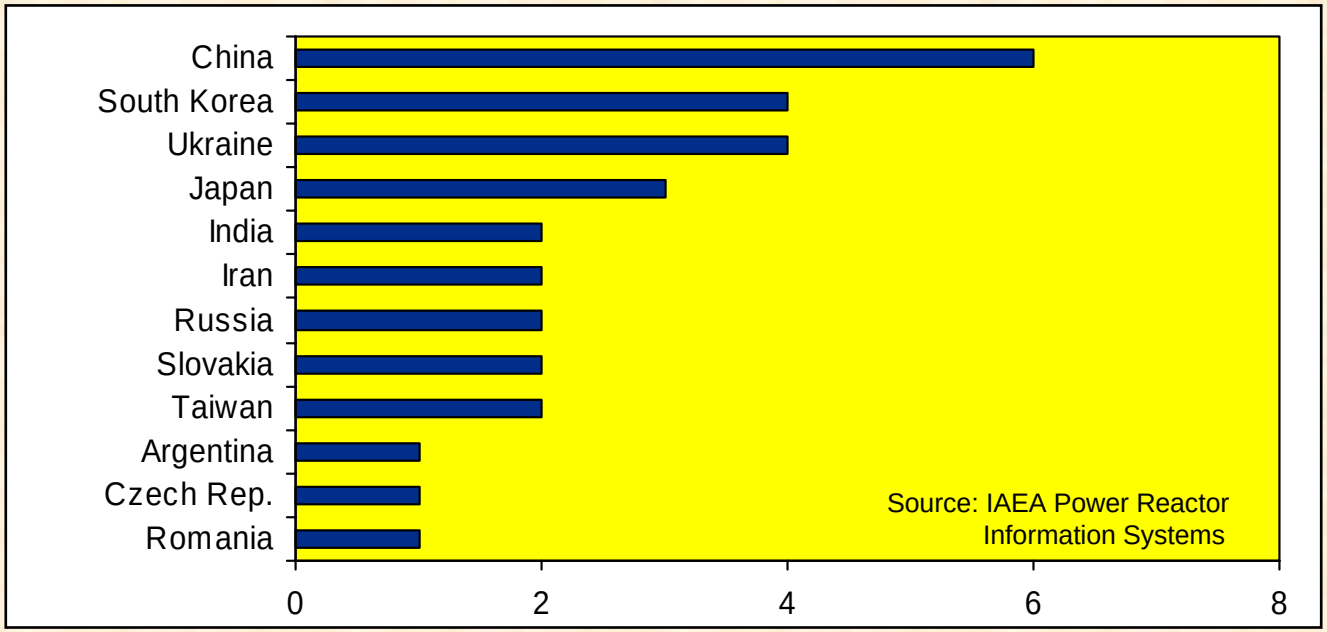
- 12 owners operate 74% of U.S. Nuclear plants
- 4 utilities formed a nuclear management company to operate 8 plants at 6 sites

Vendors

- 3 nuclear plant vendors [Westinghouse (BNFL), Framatome, GE]
- 3 nuclear fuel vendors [Westinghouse (BNFL), Framatome, Global Fuels (GE)]
- Canadian vendor (AECL) has advanced CANDU (ACR-700)

New Nuclear Plants Under Construction or Planned

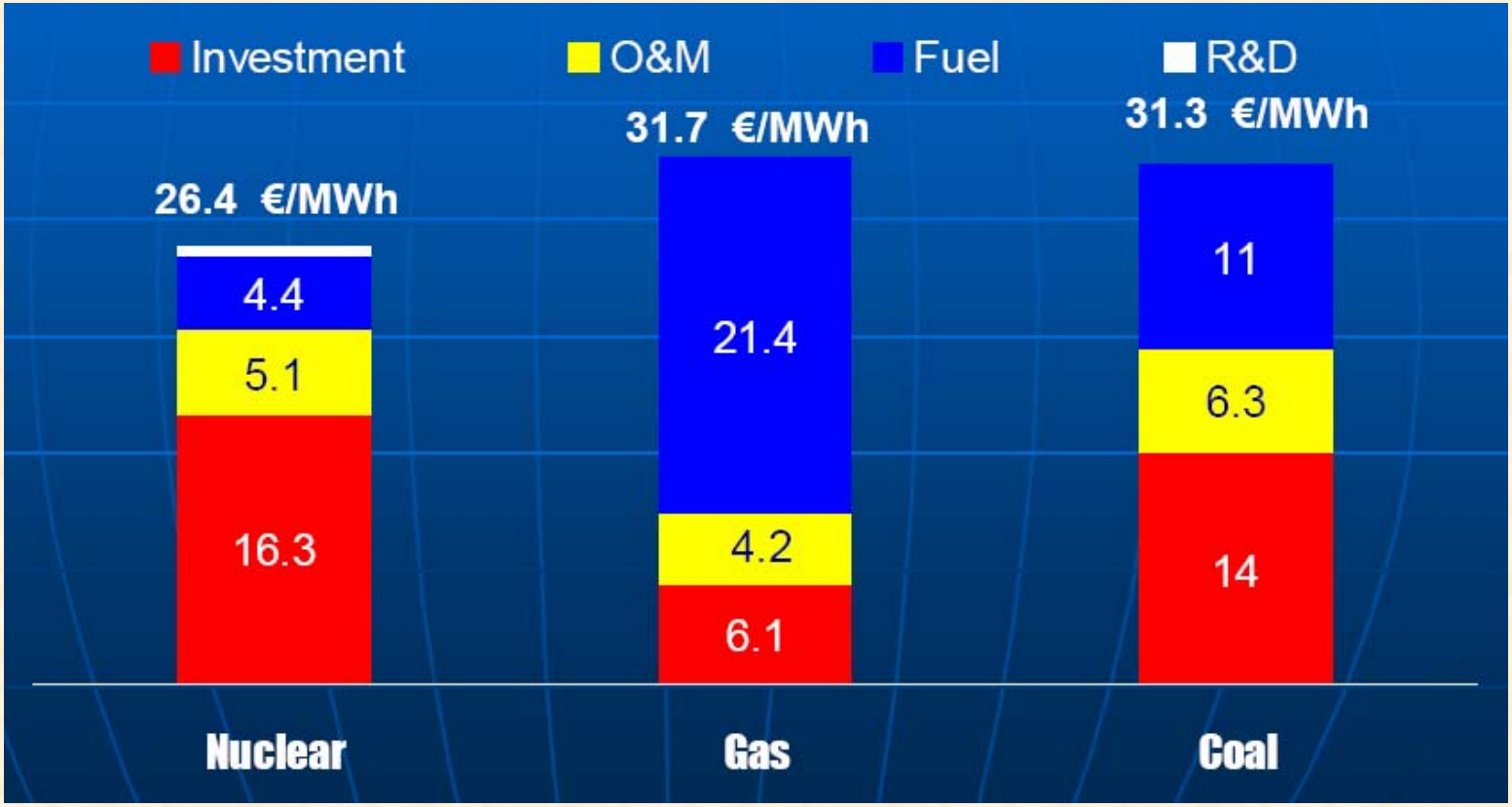
- 30 new nuclear plants under construction in 12 countries



- Finland ordered 2 x 1600 MWe advanced EPR plants
- France (EDF) ordered 2 x 1600 MWe advanced EPR plants
- U.S. (TVA) upgrade/restart 1200 MWe Browns Ferry – 1
- U.S. utilities actively evaluating economic/regulatory risks

International Perspective: Competitiveness of Alternatives in France

(8% Discount Rate - €2001)



Source: French Ministry of Industry 2003

International Perspective: Competitiveness of Alternatives in Finland

(5% Discount Rate - €2001)

€/MWh	Nuclear	Coal	Gas	Peat	Wood	Wind
Investment	13.8	7.6	5.3	10.2	13.0	40.1
O&M	7.3	7.4	1.5	6.5	8.2	10.0
Fuel	3.0	17.1	23.7	15.8	18.4	-
TOTAL	24.1	32.1	30.5	32.5	39.6	50.1

Source: Lappeenrenta University 2001

U.S. Generation Cost Comparison

University of Chicago Study – August 2004
"The Economic Future of Nuclear Power"

	LCOE* - $/MWh (2003)	
	No GHG Control	GHG Control
Coal	33-41	83-91
Gas	35-45	58-68
Nuclear	41-47	41-47
Nuclear (with Incentives)	26-35	26-35

*LCOE – Levelized Cost of Electricity

**Financing Incentives

- 20% Investment Tax Credit
- 8 year Production Tax Credit, $18/MWh

Assumptions	Coal	Gas	Nuclear
Capital ($/MWe)	1200	590	1200 (NOAK)
Fuel ($/MWh)	11.26	23.60**	4.35
O&M ($/MWh)	7.73	2.60	13.50
Construction (years)	4	3	5
Efficiency (%)	30-35	55-60	~30

**Gas @ ~$4.50/1000 CF

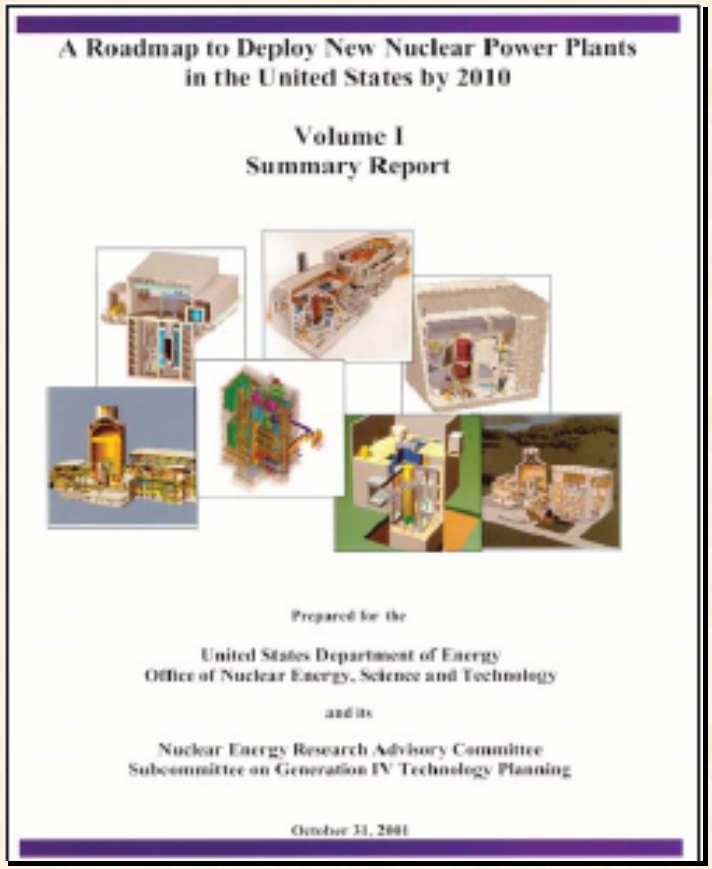
U.S. DOE Nuclear Power 2010 and Generation IV Programs are Addressing Near-Term Regulatory and Long-Term Viability Issues

NP-2010 Program

- **Eliminate regulatory uncertainties/demonstrate 10CFR52 Process (early site permitting and a combined operating license)**
- **Complete design and engineering of Generation III+ Reactor**

Generation IV Nuclear Energy Systems Program

- **Generation IV International Forum**
- **Concept screening and Technology Roadmap**
- **Broad spectrum of advanced system concepts**


A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010

Volume I
Summary Report

Prepared for the

United States Department of Energy
Office of Nuclear Energy, Science and Technology

and its

Nuclear Energy Research Advisory Committee
Subcommittee on Generation IV Technology Planning

October 31, 2001

U.S. Program Is Focused on Generation III and IV Systems

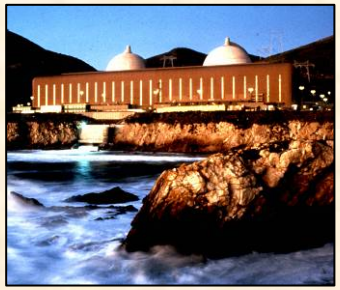
Generation I

Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors



- LWR-PWR, BWR
- CANDU

Generation III

Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

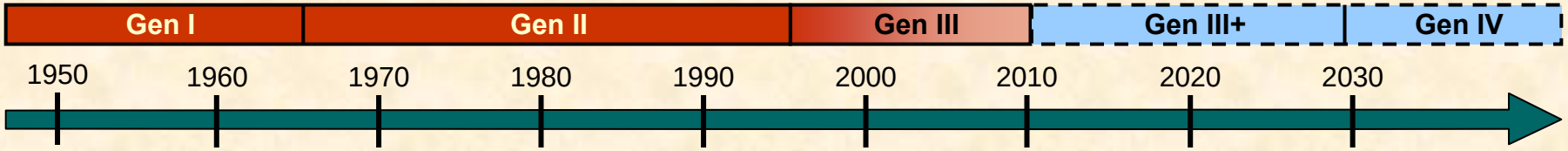
Generation III+

Evolutionary Designs Offering Improved Economics

- AP1000
- ESBWR
- ACR-700

Generation IV

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

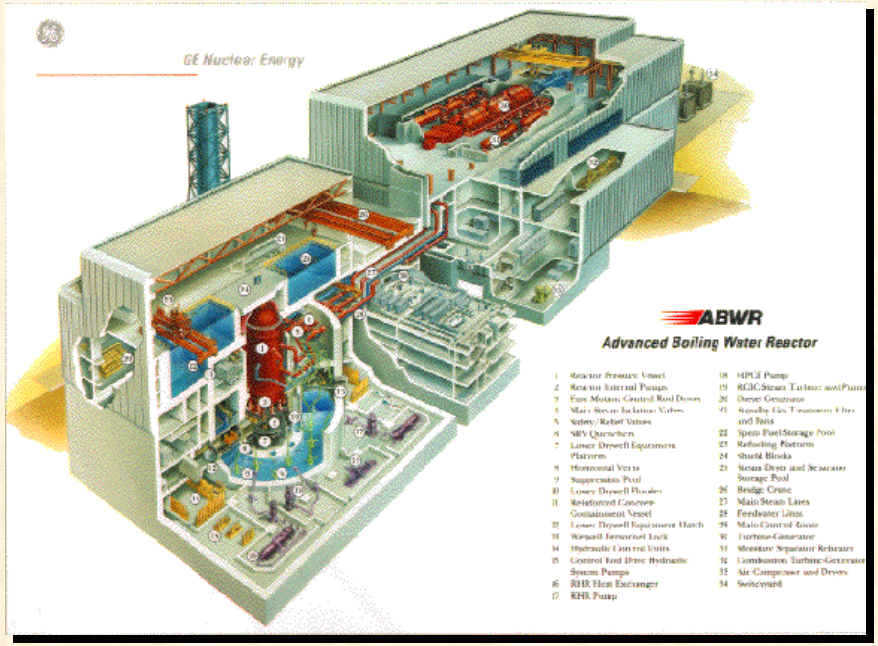


Improved Designs Validating New Licensing Process

- New process created in 1992 Energy Policy Act
- Regulatory approvals up front, before major investment
  - Design certification
    - Three reactors (AP600, ABWR, System 80+) already certified
    - AP1000 completed U.S. Nuclear Regulatory Commission review, others in pre-review
  - Early site approval
    - Dominion, Exelon, Entergy have filed applications with the U.S. NRC for early site permits
  - Combined construction/operating license
    - DOE selected two industry teams to demonstrate process
    - TVA evaluating process for advanced reactor/Bellefonte site
    - First combined license expected approximately 2008 - 2010
    - First new plant in service approximately 2012 - 2014

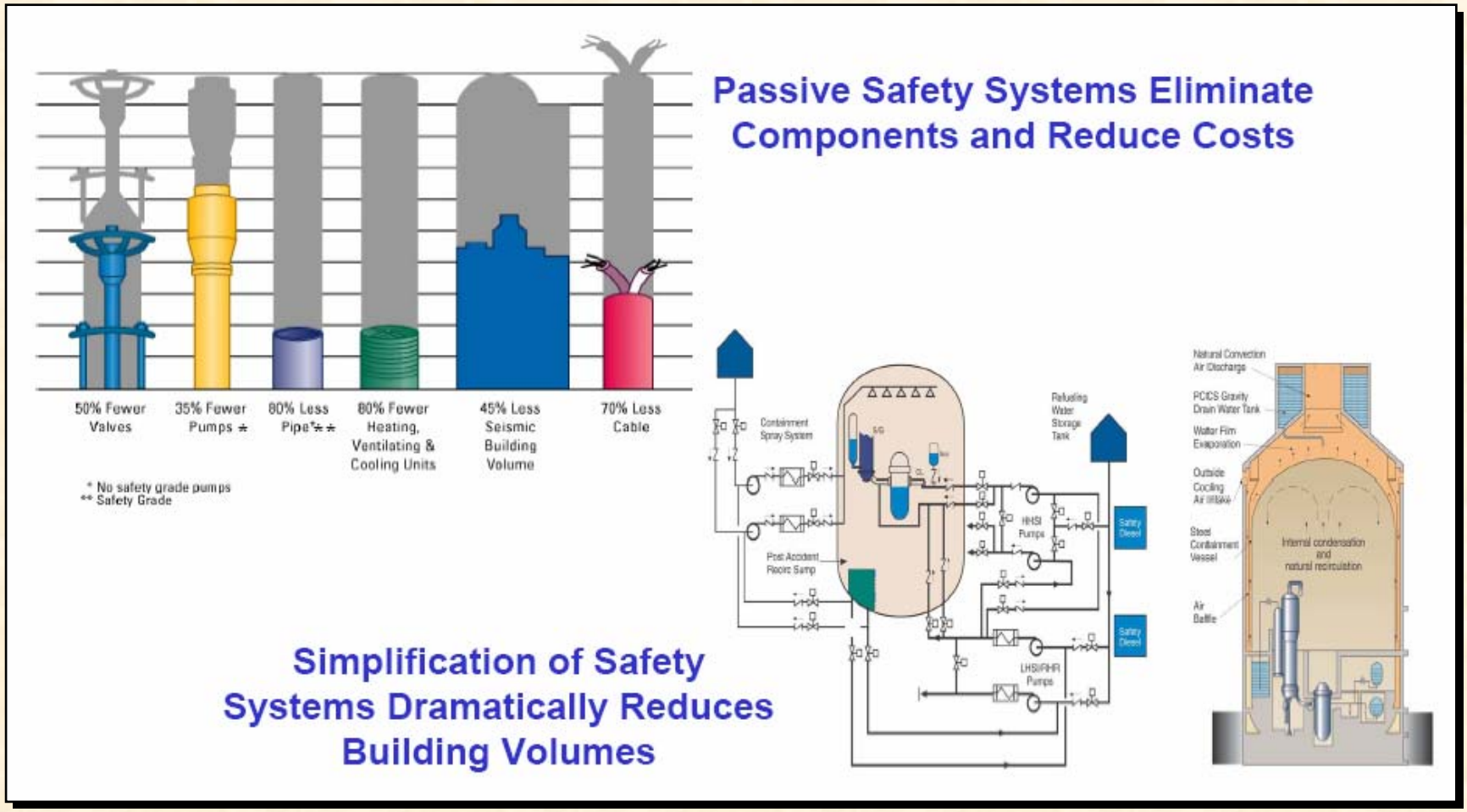
Advanced Boiling Water Reactor

- Single cycle, forced circulation, boiling water reactor
- 1300 MWe
- Safety enhancements
  - Containment overpressure protection
  - Core debris flooding capability
  - Independent water makeup system
  - Redundant emergency diesels
  - Combustion turbine as alternate power source



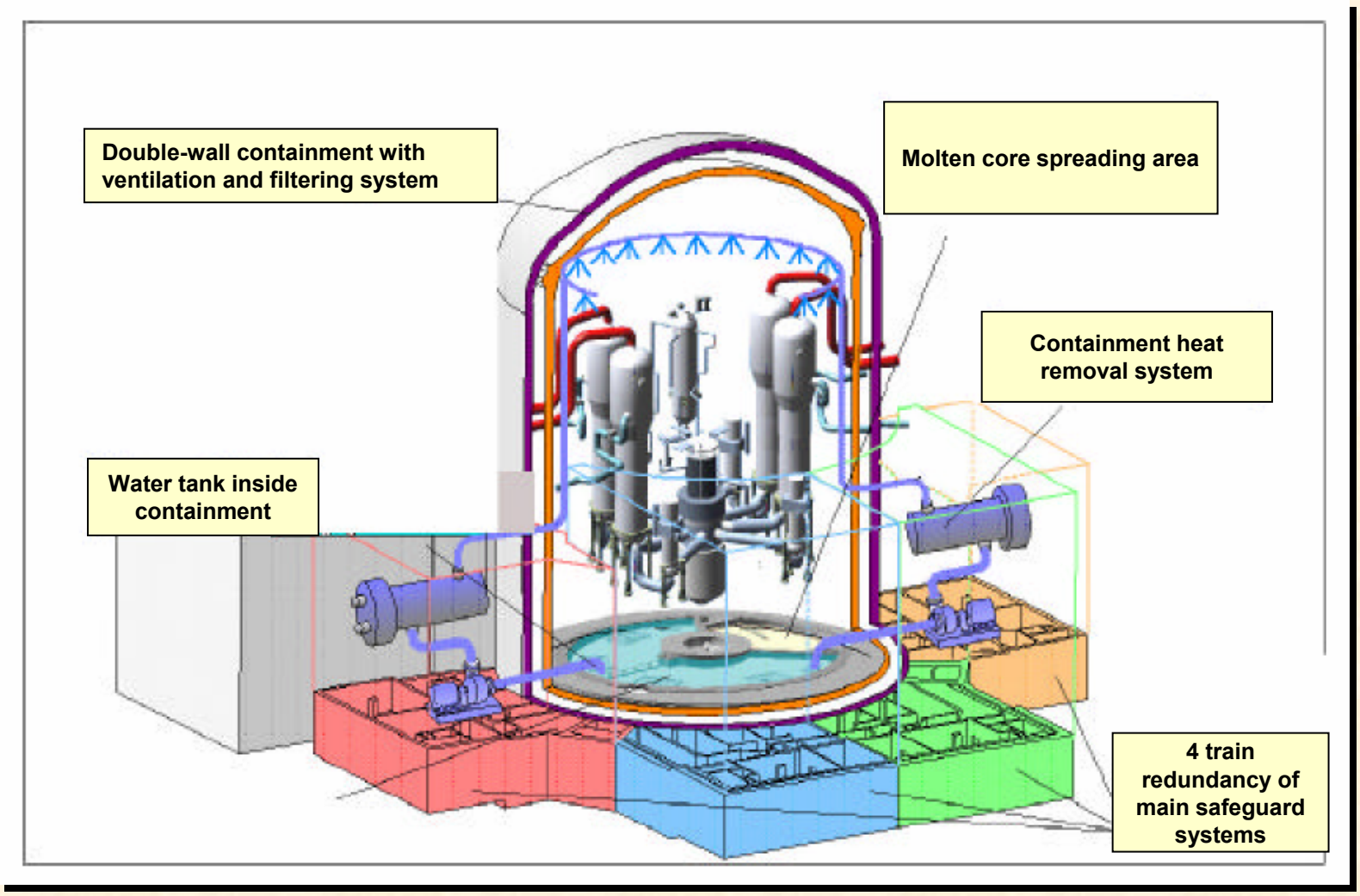
Source: General Electric

AP1000 Design – A Cost Competitive Design



Source: Westinghouse

EPR Safety Features



Source: Framatome ANP

Generation IV Systems

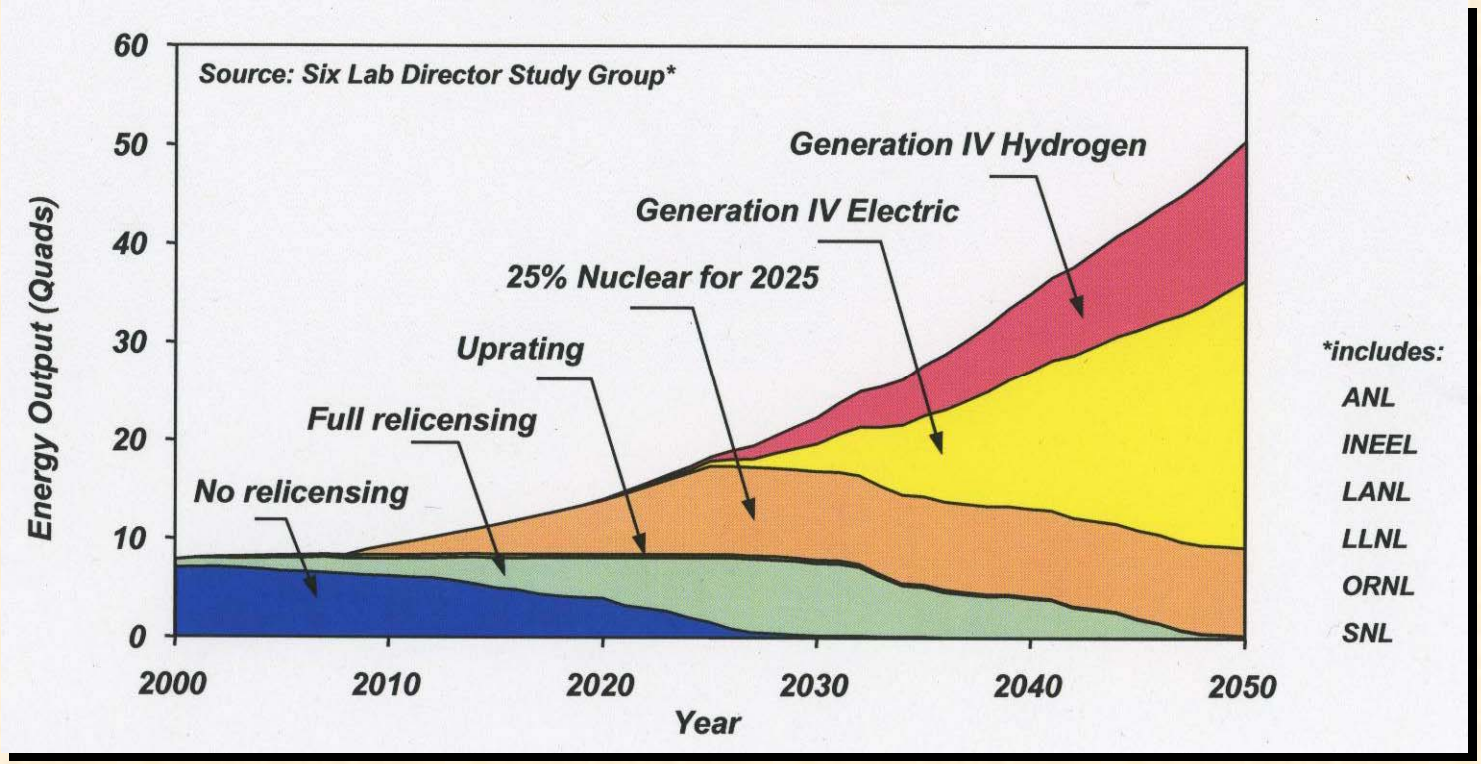
- Very-High-Temperature Reactor System
- Lead-Cooled Fast Reactor System
- Gas-Cooled Fast Reactor System
- Supercritical-Water-Cooled Reactor System
- Molten Salt Reactor System
- Sodium-Cooled Fast Reactor System

Each system has R&D challenges ahead – none are certain of success

Expansion of the Nuclear Energy Supply

By 2050, with robust technology development:

- **50% of U.S. electricity production could be nuclear**
- **25% of U.S. transportation could use hydrogen from nuclear energy**



Source: Nuclear Lab Study

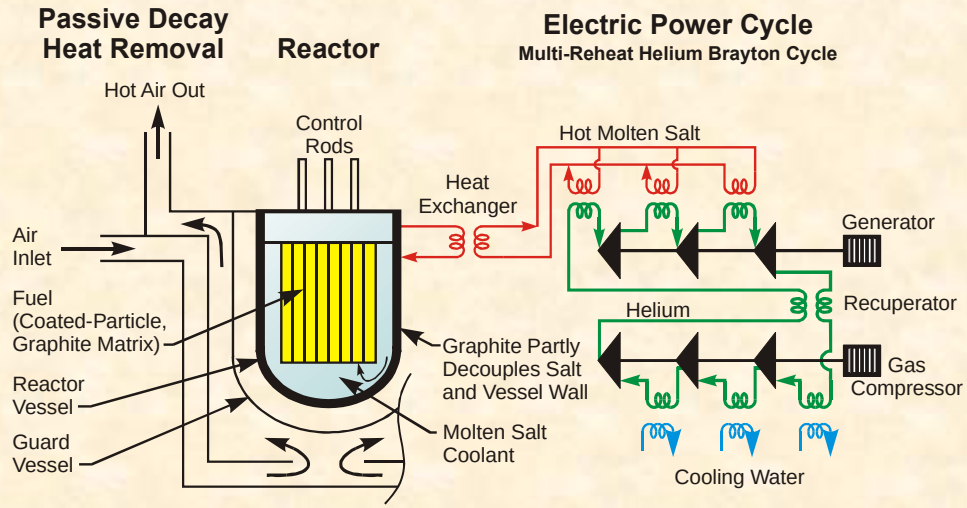
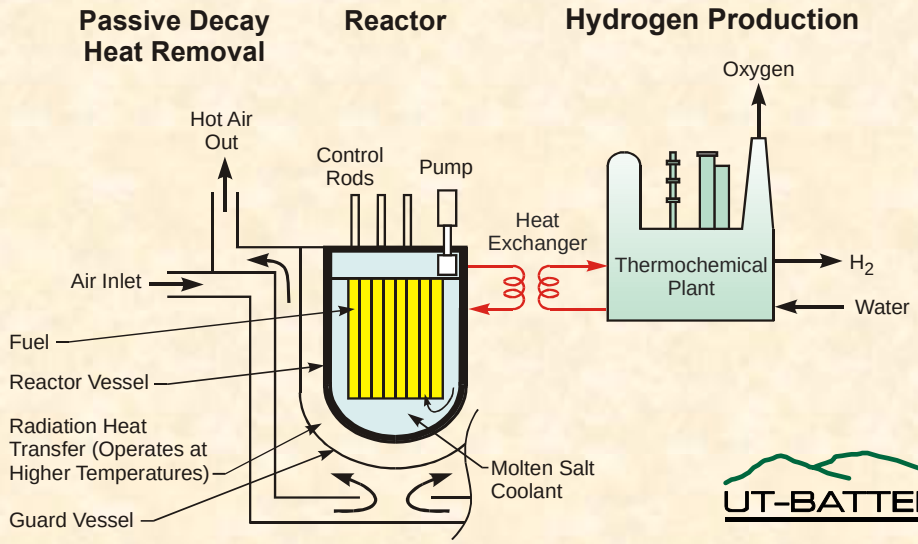
ORNL Contributions to Nuclear Renaissance

- Leadership in developing National Energy Strategy incorporating Nuclear Energy
- Participation in developing and evaluating GEN IV reactor concepts
- Center of excellence and lead for structural and fuel materials
  - Life extension of current plants
  - Advanced fuel materials
  - Plutonium fuels evaluation
  - Advanced reactor materials and fuels
  - Irradiated materials examination and analysis
- Nuclear data and analysis codes for criticality and shielding
- Advanced nuclear systems concept designs and evaluations

The Advanced High Temperature Reactor (AHTR)

- Concept by ORNL, UC-B, SNL
- Molten salt coolant
- Coated particle fuel
- Graphite moderator
- Low pressure system
- Power >2000 MWt
- 750–1000ºC outlet temperature
- Favorable projected economics

Electricity production



Hydrogen production