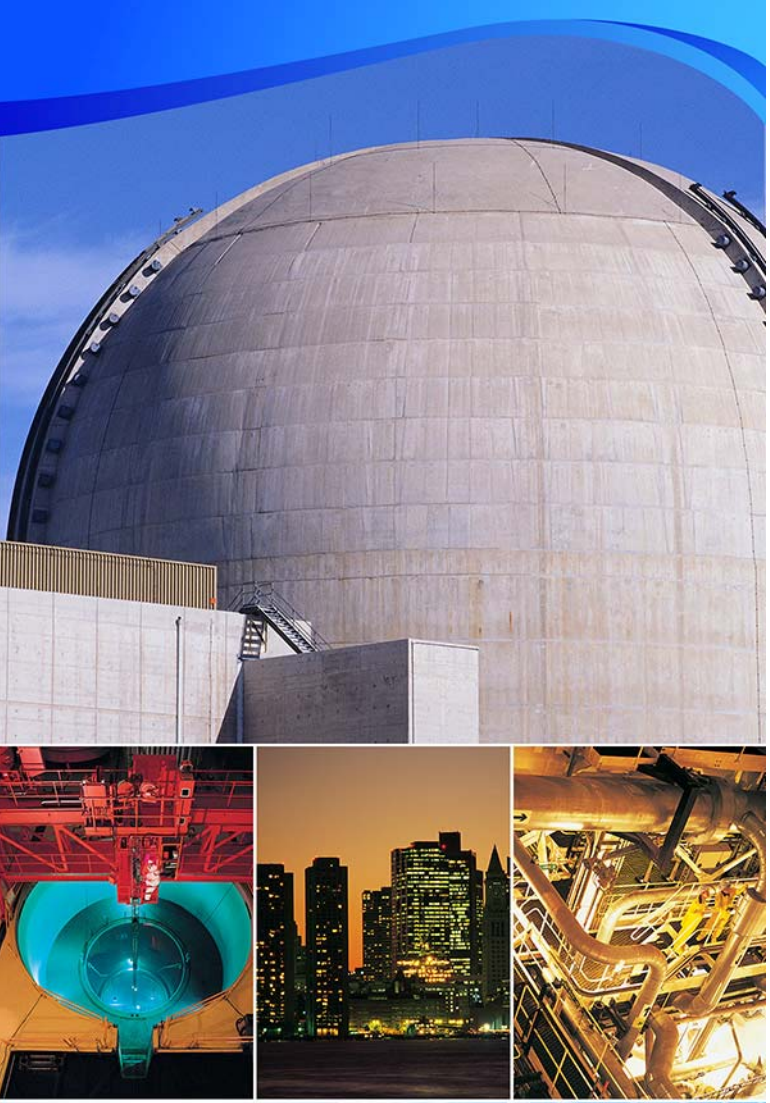

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Prospects for Nuclear Power

EPRI Global Climate Change Research Seminar
May 18-19, 2010

Westin Grand Hotel, Washington, DC

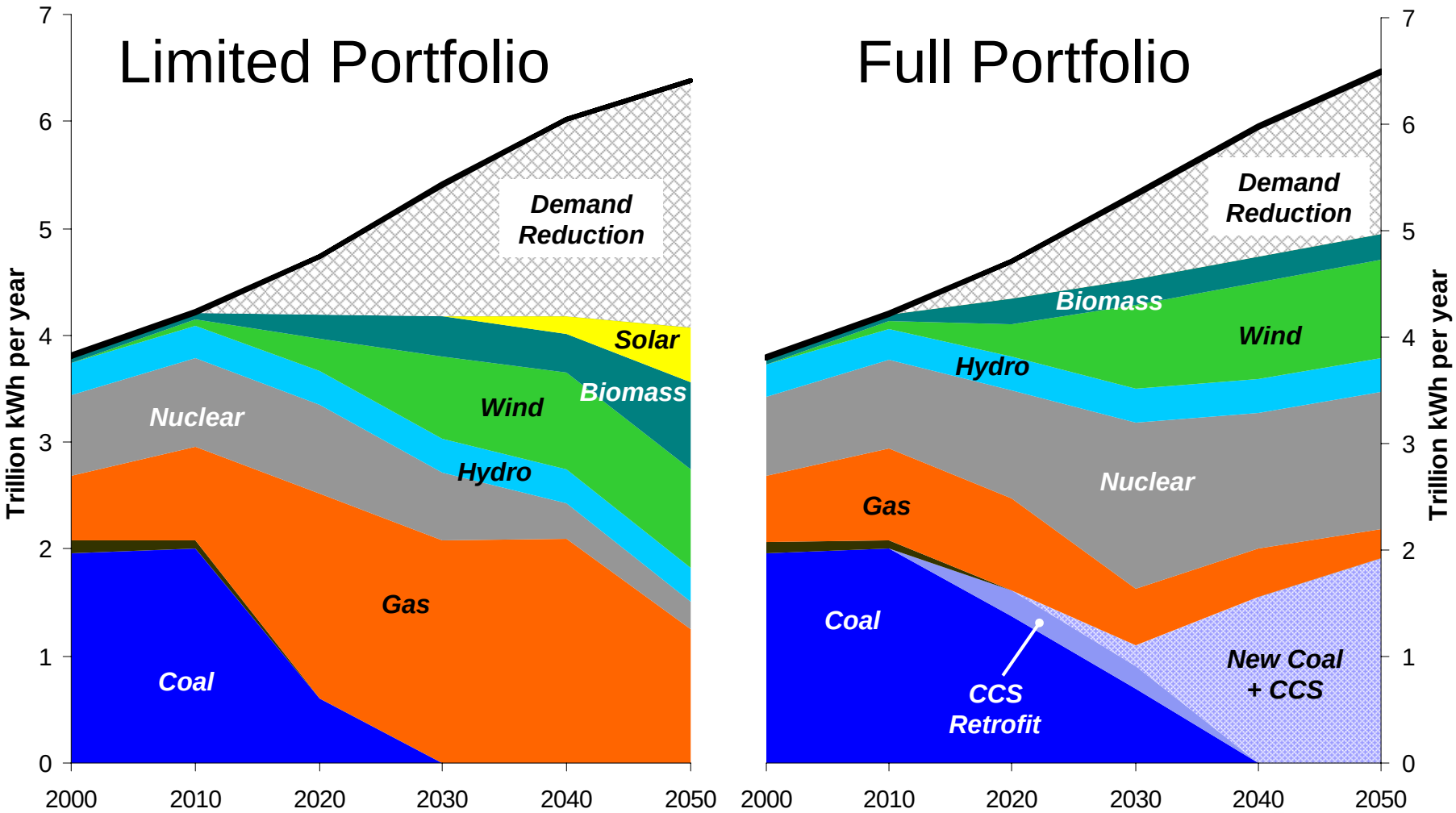
Revis James
Director, Energy Technology Assessment Center

Presentation Overview

- Role of nuclear power in the context of climate analyses
- Nuclear technology options
- Long-term operations of existing nuclear units
- New nuclear units
- Issues

Role of Nuclear under CO_2 Emissions Constraints

MERGE U.S. Electric Generation Mix



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Key Technology Insights from Economic Analyses

- Aggressive energy efficiency will be needed under most scenarios.
- Substantial renewables generation (e.g. >20%) will occur.
- Combined generation from nuclear and coal will exceed 50% for several decades.

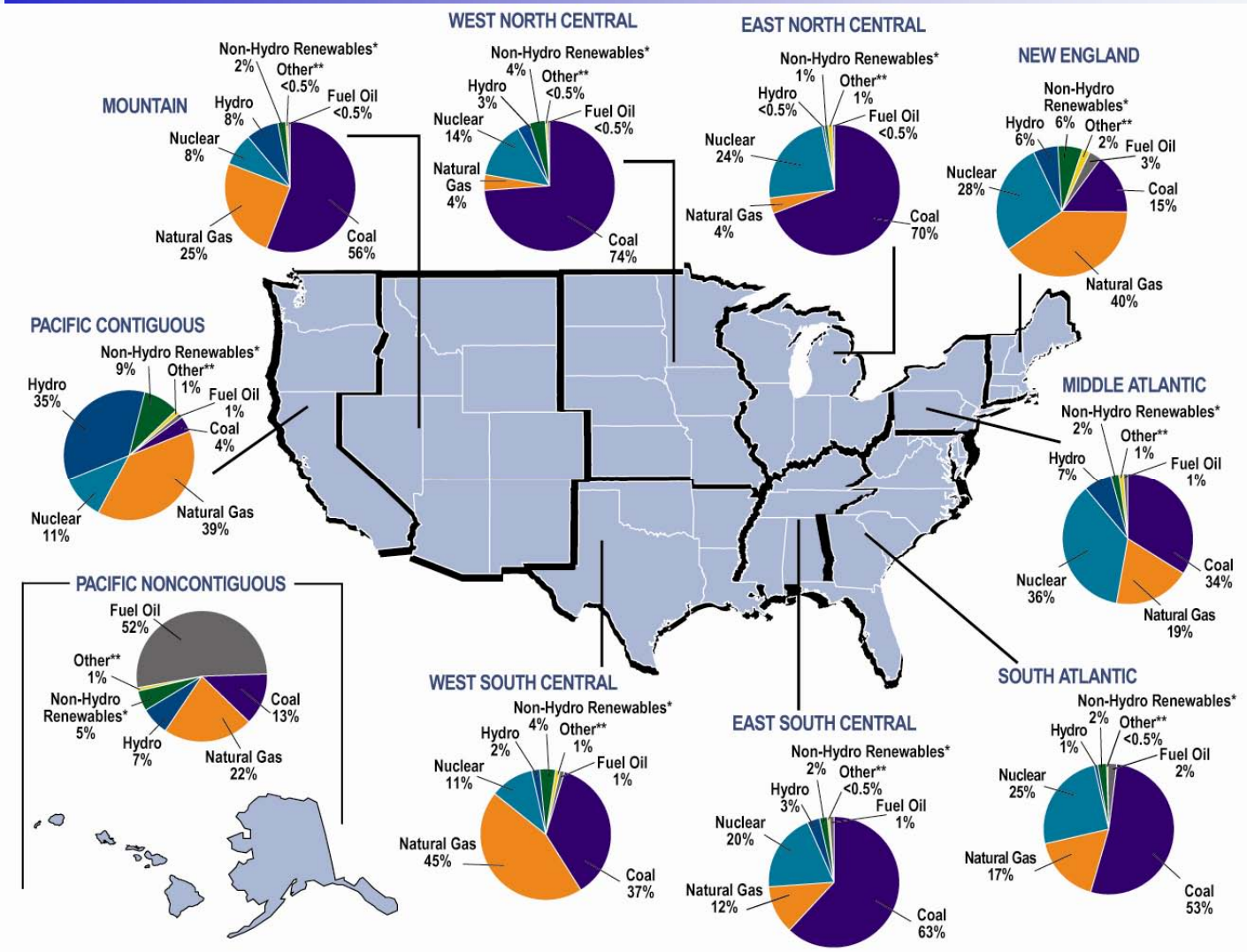
Snapshot of Existing Nuclear Fleet

Worldwide Nuclear Power

Operating NPPs	438
Installed Capacity	372 GWe
Nuclear Energy Produced in 2008	2,597 TWh
Share of Nuclear Power Worldwide Production	15%
Number of countries with operating NPPs	31
NPPs Under Construction Since 2004	43 GWe

Source: IAEA – May 2010

U.S. Regional Electricity Generation Fuel Mixes



Source: U.S. Department of Energy, Energy Information Administration, Power Plant Operations Report (EIA-923); 2008 preliminary generation data.

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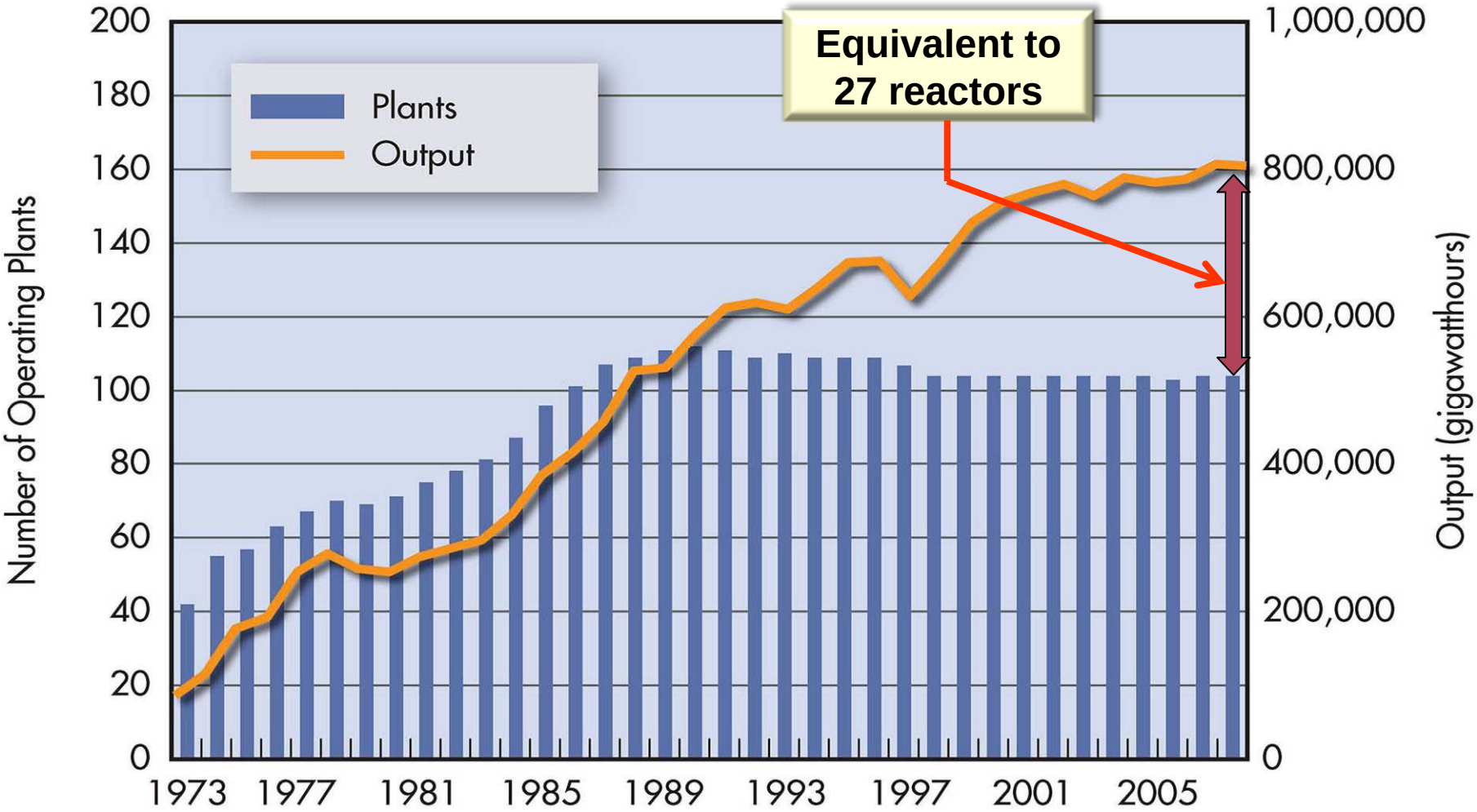
U.S. Nuclear Industry Efficiency Gains



Sources: Nuclear Energy Institute & Energy Information Administration

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U.S. Plants Sustaining ~90% Capacity Factor

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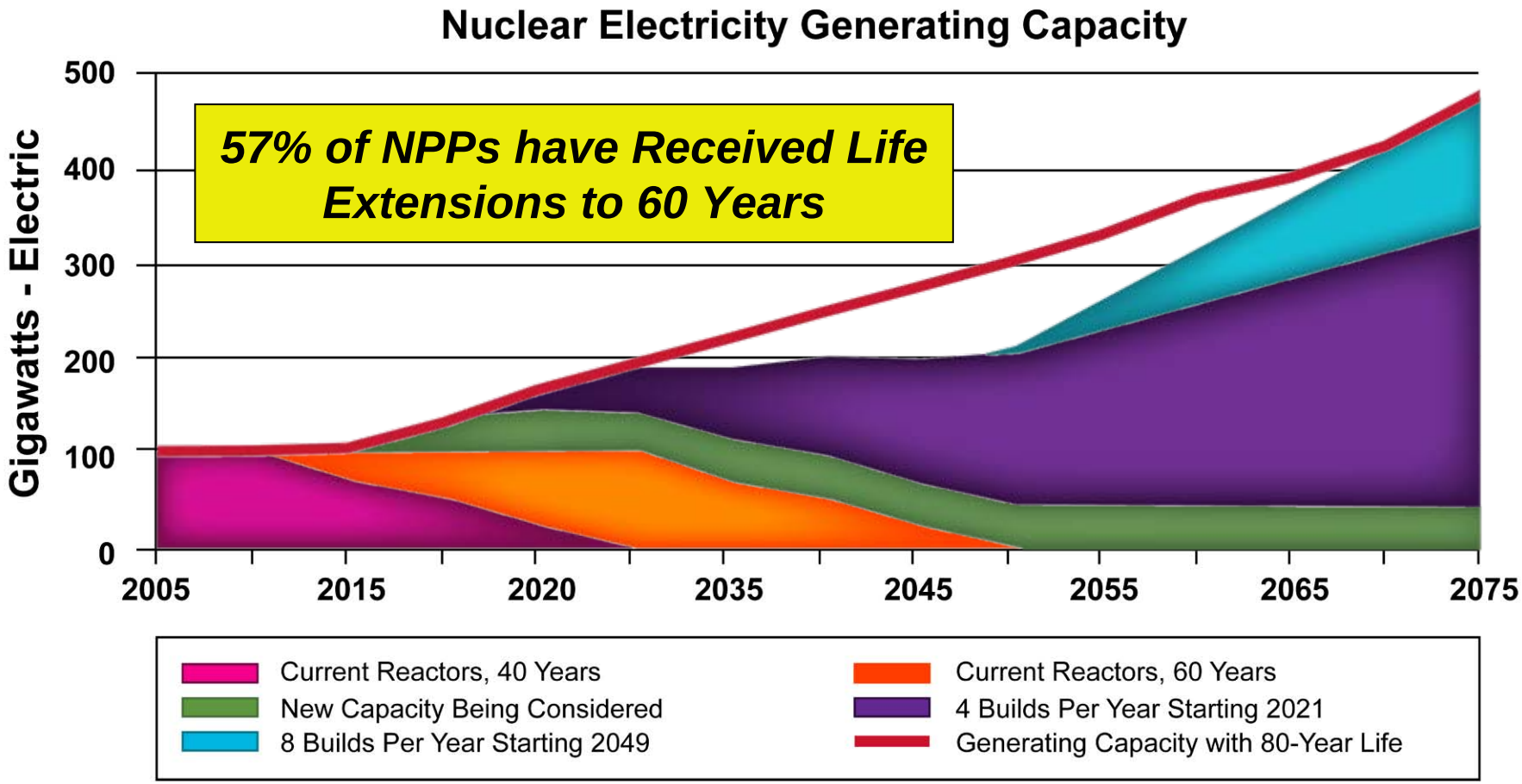
Extending Operations of Existing Nuclear Units

Nuclear Long Term Operations

- Original fleet of plants licensed for 40 years of operation
- License renewal process established to extend operations from 40-60 years.
  - EPRI led technical basis for first plants (e.g. Calvert Cliffs)
- R&D underway to extend beyond 60 years
  - EPRI/ DOE collaborating on the technical basis effort
- Preliminary surveys of the utility community indicate that roughly 60% of the fleet are likely (> 75%) to seriously consider extending licenses for 80 years.

Potential for Significant Nuclear Generation



Source: DOE Life Beyond 60 Workshop

Nuclear Long-Term Operations: EPRI R&D Scope

Provide the technical basis for license renewal and life extension decisions beyond 60 or 80 years

- Aging of passive structures and components
- On-line diagnostics to prevent equipment failures
- Managing crack growth in primary system metals
- Realistic and efficient safety analysis tools

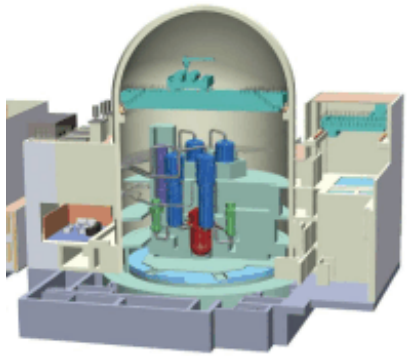
Demo Plant Activities: Ginna and Nine Mile Point 1

- **EPRI, U.S. DOE, and Constellation Energy have a 3-year collaboration to demonstrate the assessment of aging concerns at Ginna and NMP-1**
  - **Long-term operations actions**
    - examine data, inspect and test for aging degradation
    - pilot technical approaches for long-term operations
  - **Key areas**
    - Comprehensive containment examination
    - Incremental reactor internals inspection for > 60 years
    - Others include confirmation of reactor pressure vessel life and assessment of cable condition in severe environments

Building New Nuclear Units

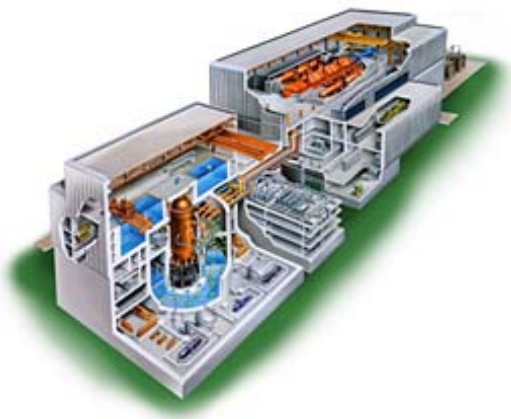
The Technology…
Gen III/III+ LWR Designs Under Consideration

Westinghouse
* AP1000 (1117 MWe)



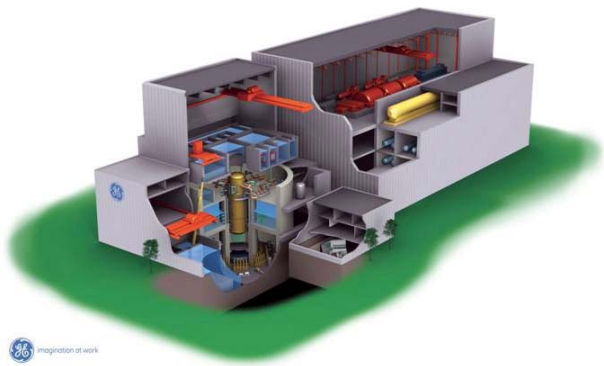
MHI APWR (1700 MWe)

AREVA US EPR (1600 MWe)



GE-Hitachi & Toshiba
* ABWR (1,371 MWe)

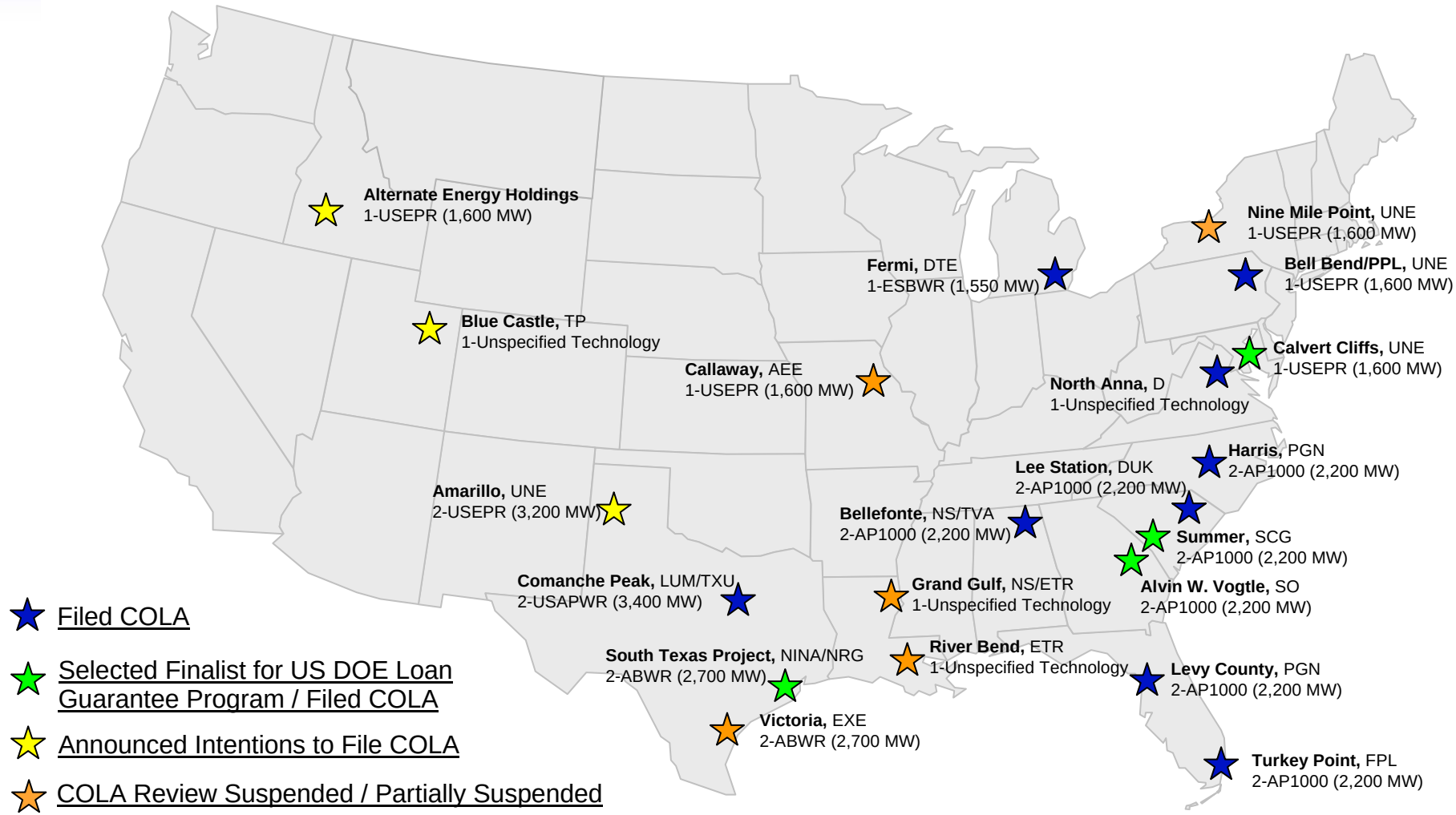
Current Status of Announced U.S. Intentions	
Technology	**Units**
AP1000	14
EPR	7
TBD	4
ABWR	4
APWR	2
ESBWR	1



GE-H ESBWR (1535 MWe)

**** Design Certified***

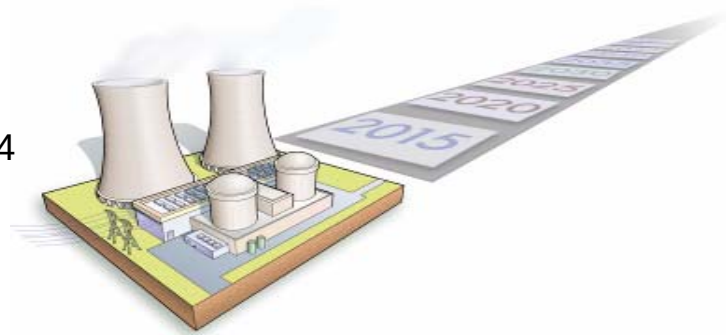
New Nuclear Plants Under Consideration in US



Source: NRC Expected New Nuclear Power Plant Applications (July 2009) / U.S DOE Nuclear Power Deployment Scorecard

The Numbers…

- 32 nuclear units under consideration at 21 nuclear sites, representing 20 nuclear operators
- 18 Combined Operating License Applications (COLAs) filed to date for 28 new units
  - Five COLAs suspended/partially suspended (6 new units) pending technology decision or for financial reasons
- Four early site permits issued by NRC (Clinton, Grand Gulf, North Anna and Vogtle)
- Projecting 10 GW by 2020; 64 GW by 2030
- Four sites down selected for US DOE's Loan Guarantee Program; seven units equivalent to 8700 MW
  - SCANA's VC Summer Units 3&4
  - Southern Nuclear Operating Companies Vogtle Units 3&4
  - Unistar Nuclear Energy's Calvert Cliffs Unit 3
  - NINA/NRG's South Texas Project Units 3&4



Source: NRC Expected New Nuclear Power Plant Applications (July 2009) / U.S DOE Nuclear Power Deployment Scorecard

Modular Nuclear Plants - Strategy

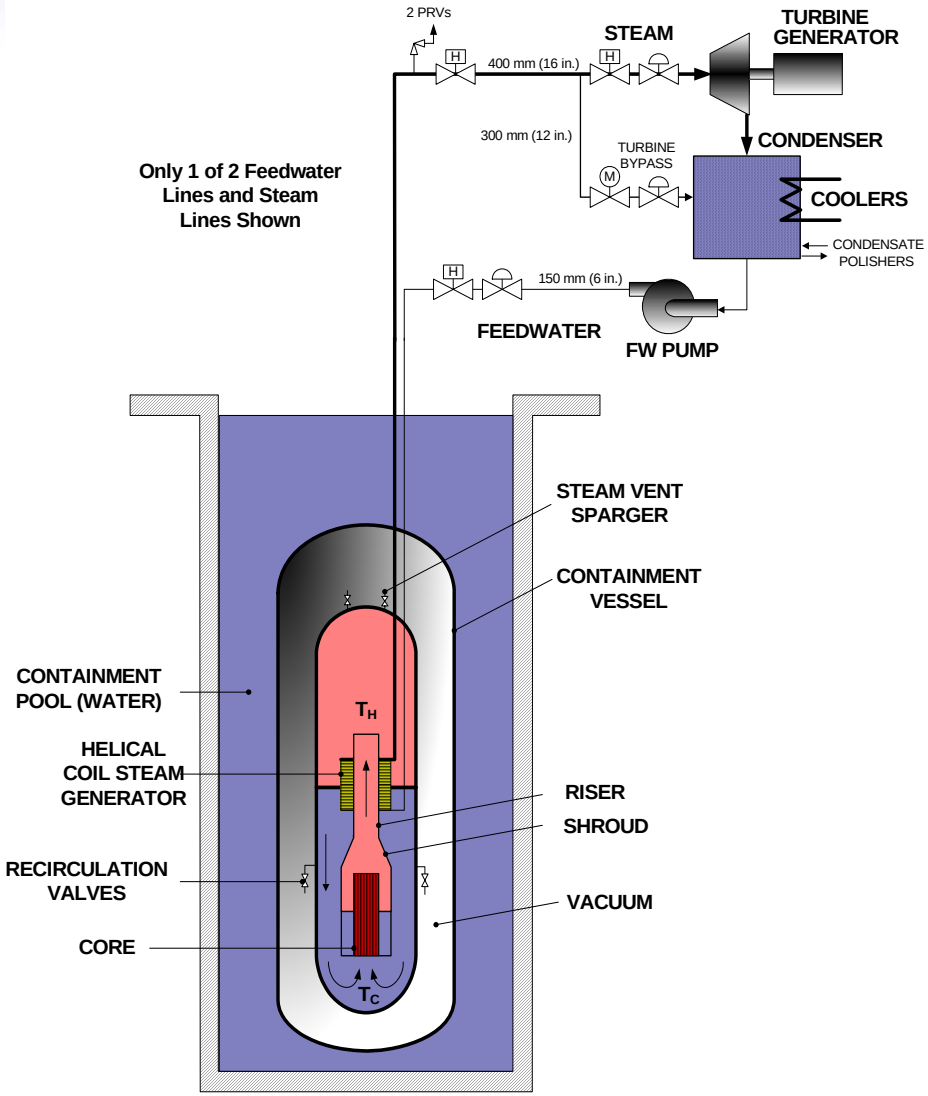
- Construction
  - Pre-fabricated components/systems
  - Smaller scale increases number of potential suppliers
  - Shipping to site simplified
  - Onsite engineering/construction reduced

- Operational/safety
  - Passive safety systems/safety design simplified
  - On-line refueling

- Financial
  - Can sequentially add modules to match load growth
  - Smaller plant size minimize financial risks, complexity and uncertainty
  - Off-site manufacturing improves productivity and mitigates construction risks

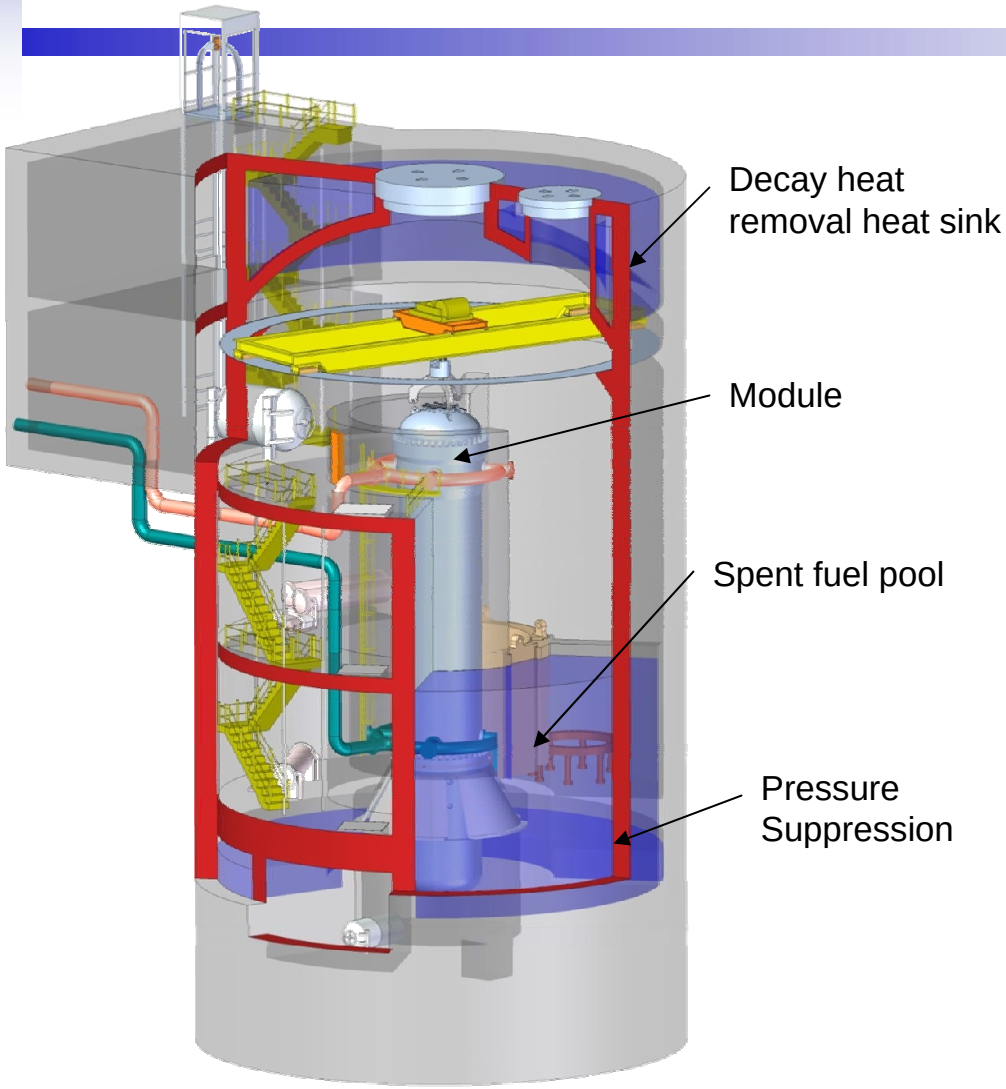
20

Modular Nuclear Reactor - NuScale



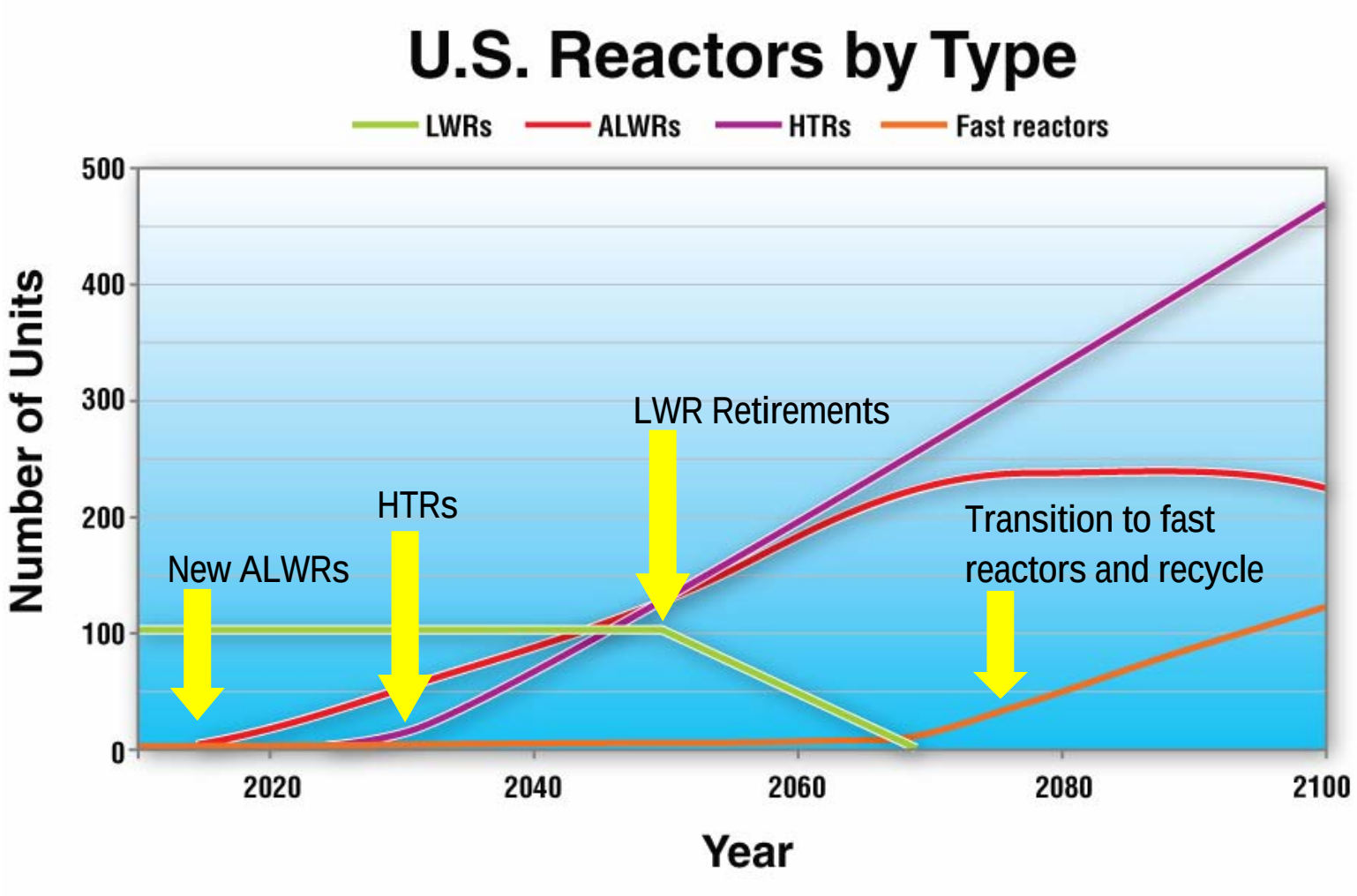
- ~40 MWe
- Construction:
  - Major components prefabricated and shipped by rail, truck or barge - Entire nuclear system is 60’ x 15’ / 300 tons.
- Natural Circulation Cooling:
  - Inherently safe – Eliminates major accident scenarios
  - Reduced cost - Eliminates pumps, pipes, auxiliary equipment
- Below Ground:
  - Enhanced security and safety – Critical components - reactor, control room, fuel pool - located below ground

Modular Nuclear Reactor - B&W



- **mPower Reactor: ~ 125 MWe**
- **Underground containment**
- **Used fuel stored in spent fuel pool for life**
- **Natural circulation decay heat removal system for emergency/refueling cooling**
- **Primary coolant treatment system within containment**
- **Steam generator inspection within containment**

Potential Long-Term Nuclear Technology Deployment



Key Challenges for Nuclear Power

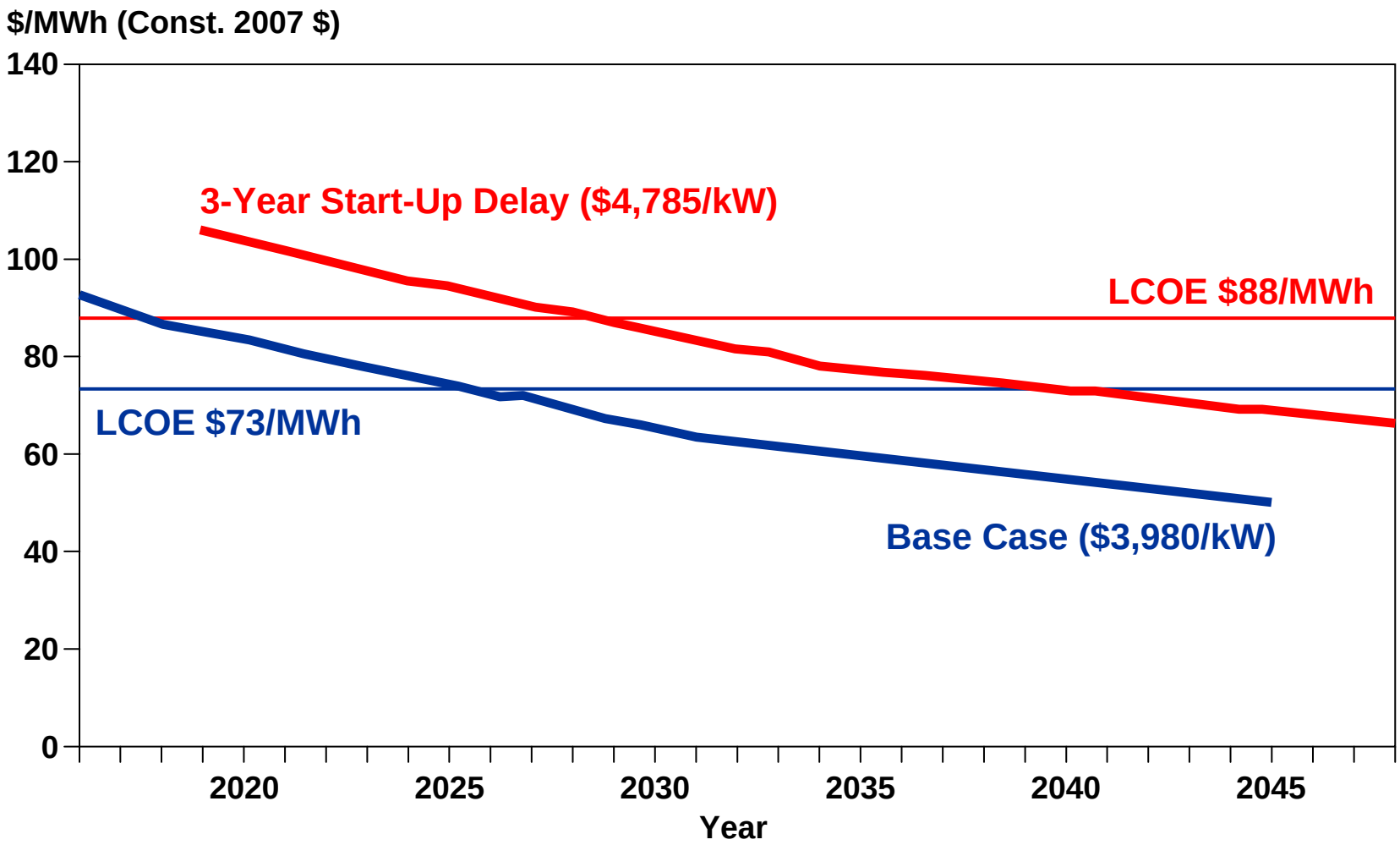
- Cost
- Siting
- Water
- Waste management

Capital Investment Hurdle

(Market values as of 3.26.09)

Exelon	$30.2 billion
Southern	$23.9 billion
Dominion	$18.5billion
FPL	$21.2 billion
Duke	$18.6 billion
Entergy	$13 billion
Two-unit nuclear power station	**$12-16 billion**
PPL Corp.	$11.3 billion
Progress	$10.04 billion
AmerenUE	$4.95 billion
DTE Energy	$4.62 billion
NRG	$4.16 billion
SCANA	$3.75 billion

Impact of Construction Delays



Conclusion

- Nuclear power will very likely be a key element of a least-cost portfolio of electricity generation technology options under CO_2 emissions constraints.
- Continued safe and reliable operation of the existing nuclear fleet is critical.
- Ultimately, a substantial number of new nuclear units will be needed.
- It is technically feasible to expand nuclear electricity generation over the long-term.

Together...Shaping the Future of Electricity

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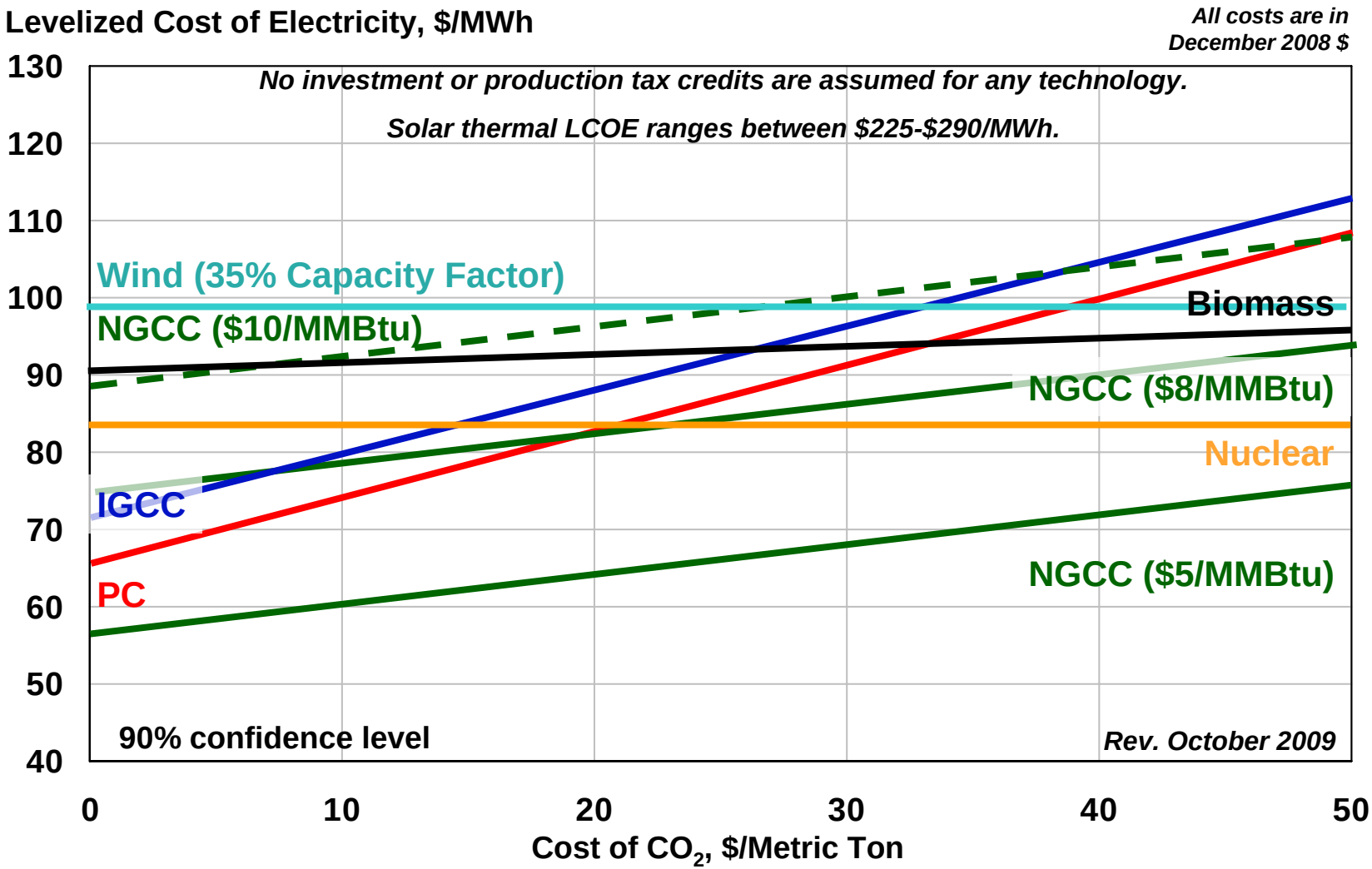
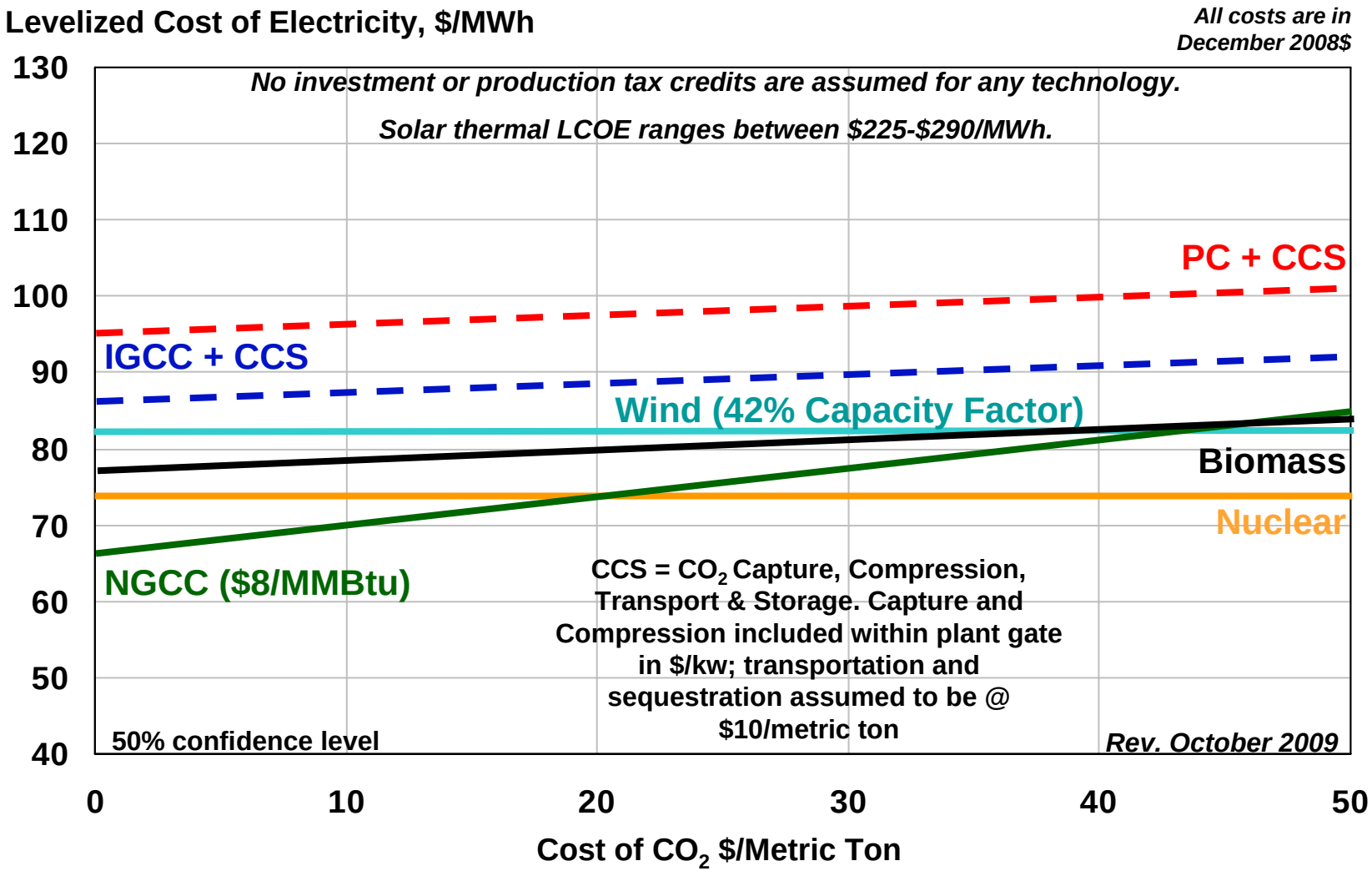
Image from *NASA Visible Earth*

Backup Slides

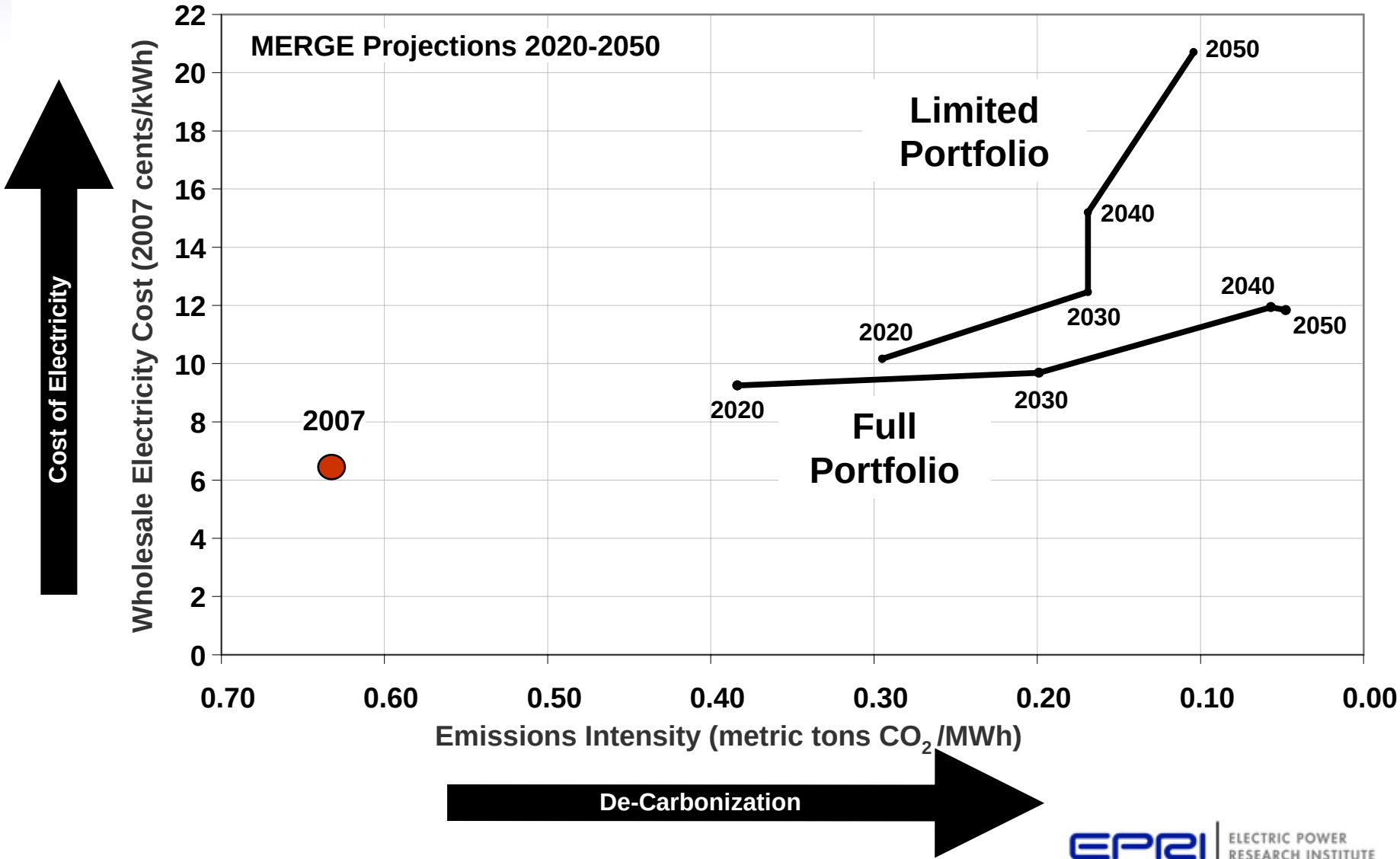
Comparative Levelized Costs of Electricity – 2015



Comparative Levelized Costs of Electricity – 2025



MERGE De-carbonization Results



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Key Nuclear Points for the Prism Analysis

- The Prism analysis is based on an assumed level of nuclear deployment.
- Assumption is based on domain expert assessment of what would be technically feasible, based on current technology and anticipated new technology.
- Prism assumption is 64 GW of new nuclear by 2030, or about 45 new units assuming 1400 MW/unit.
- Under this assumption –
  - historical peak build rates would not be exceeded
  - Nearly all new plants could be located on existing sites
- Prism assumes that all existing and new units operate to 60 years.

Key Nuclear Points for the MERGE Analysis

- The MERGE analysis calculates level of deployment for nuclear and other technologies based on key assumptions:
  - Current and future electricity production costs
  - Available primary fuel reserves
  - CO_2 emissions constraint
- MERGE assumes that all existing and new units operate to 60 years – retirements are considered.
- Nuclear costs assumed to improve 3%/decade due to learning.
- Horizon of analysis is 2050.

MERGE ASSUMPTIONS – URANIUM

- Nuclear power is based on a once-through fuel cycle, in which spent fuel is not reprocessed and in which other nuclear fuels are not used (e.g. advanced fuel cycles).
- The 2009 MERGE analysis models a finite amount of energy equivalent to known global uranium reserves.
- The assumed global uranium reserve is 7,700 exajoules (EJ), based on a detailed assessment performed by Working Group III of the Intergovernmental Panel on Climate Change.
- Current annual global consumption is around 30 EJ.

MERGE Assumptions - Nuclear

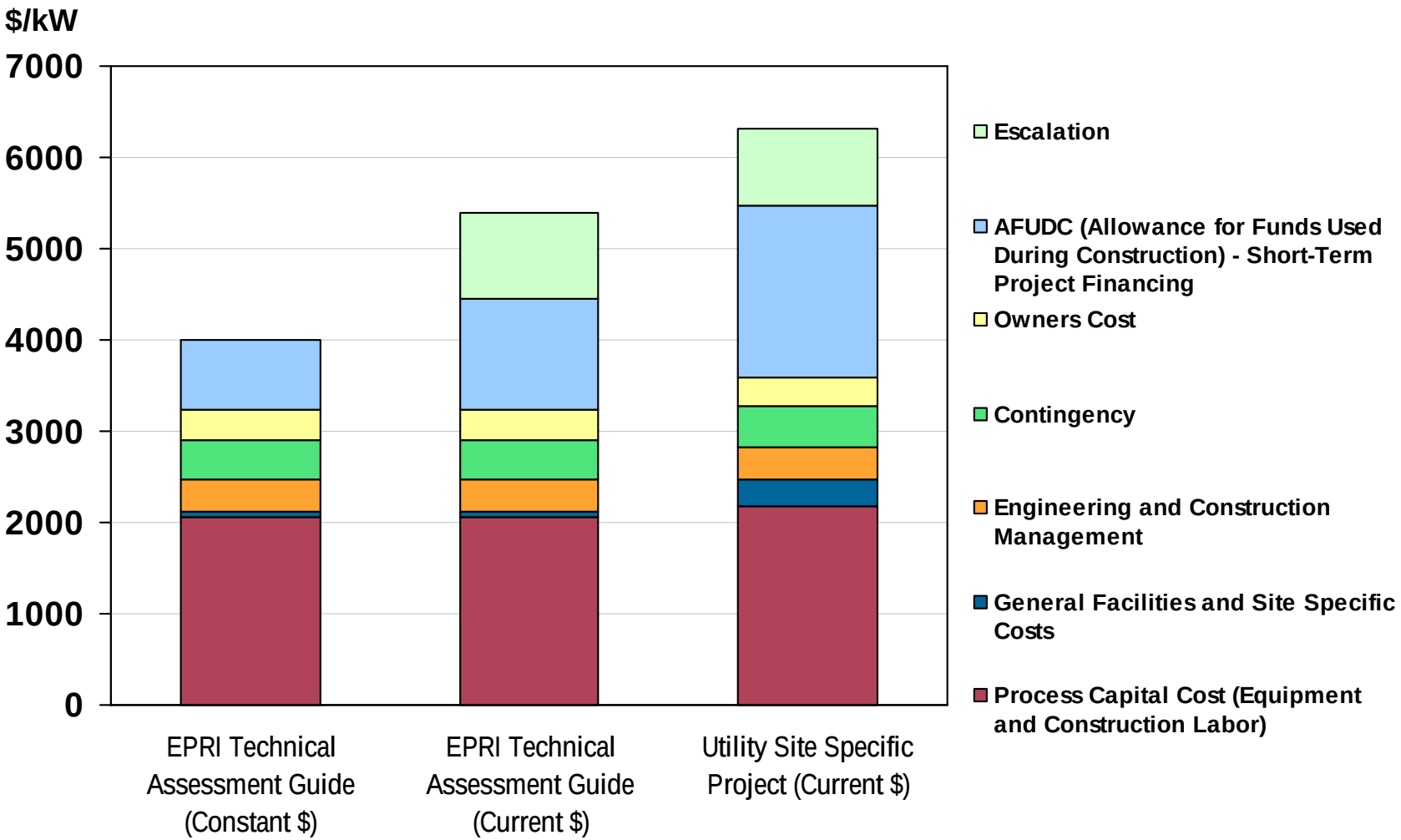
	2010	2020	2030-2050	
Nuclear				
Limited Portfolio	$84/MWh	$84/MWh	$84/MWh	○ Capacity factor = 90% ○ Efficiency = 33% ○ Plant life for new, existing units = 60 years ○ Added non-market cost = ~$10/MWh (at current generation share for nuclear); scales up with increasing nuclear generation share. ○ Inclusive of fuel cost ○ In limited portfolio, nuclear fleet does not expand from current levels, (including no new plants to replace retiring capacity.)
Full Portfolio	$84/MWh	$74/MWh	2030: $71/MWh 2040: $69/MWh 2050: $67/MWh	

Nuclear Capital Requirements – Reference Case

Project Duration:	-7	-6	-5	-4	-3	-2	-1	0
Year:	2009	2010	2011	2012	2013	2014	2015	2016
Project Expenditure	5%	5%	5%	14%	25%	23%	23%	
Total Plant Cost ($/kW, including site specific costs, engineering, & contingency)								2670
Allowance for Funds Used During Construction (AFUDC, $kW)								1010
Owner's Cost ($/kW)								300
Total Capital Requirement (TCR, $/kW, constant 2007 $)								3980

- *Site specific costs assume standard substation, raw water intake, transmission tie-in costs.*
- *No inflation and escalation to future operations date included.*

Capital Requirements – Different Methods of Quoting



Source: EPRI Report 1018329, Section 1.8.3

Levelized Cost of Electricity (MIT 2009)

Table 1: Summary of Results

	MIT (2003)				Update			
		LCOE				LCOE		
	Overnight Cost	Base Case	w/ Carbon Charge $25/tCO2	w/ same cost of capital	Overnight Cost	Base Case	w/ Carbon Charge $25/tCO2	w/ same cost of capital
	$2002/kW	2002¢/kWh	2002¢/kWh	2002¢/kWh	$2007/kW	2007¢/kWh	2007¢/kWh	2007¢/kWh
Nuclear	2,000	6.7		4.4	4,000	8.4		6.5
Coal	1,300	4.3	6.4		2,400	7.2	9.3	
Gas	500	4.1	5.1		900	6.5	7.4	

Historical worst case nuclear capital costs could bounded at ~ $5000/kW - $5500/kW

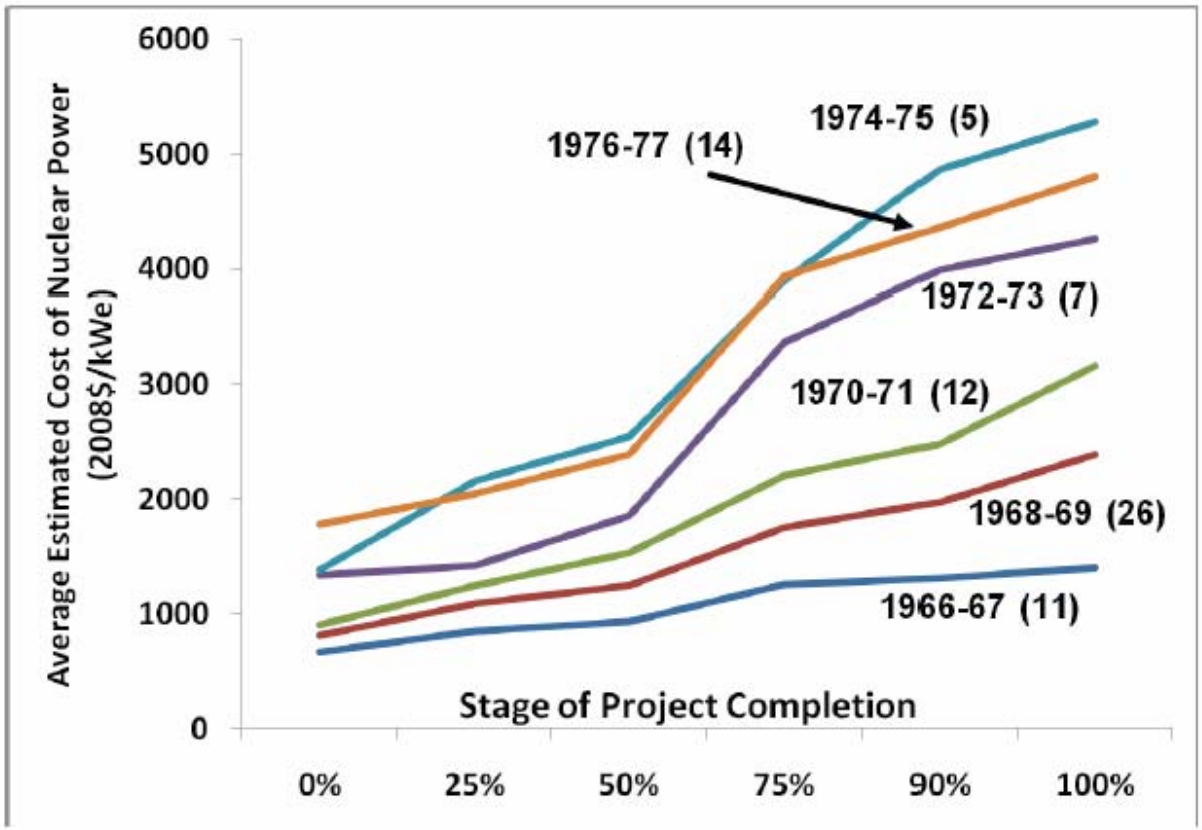


Figure 5: Average estimated capital cost of US nuclear plants at different stages of project completion. The number in parentheses is the number of projects that began construction in the indicated years. Cost estimate at 0% completion is the initial estimate, at 50% completion is the estimate at mid-stage, and at 100% completion is the final realized cost. Source: Gielecki and Hewlett (EIA Monthly Energy Review, August 1994).

Impact of Financing Options

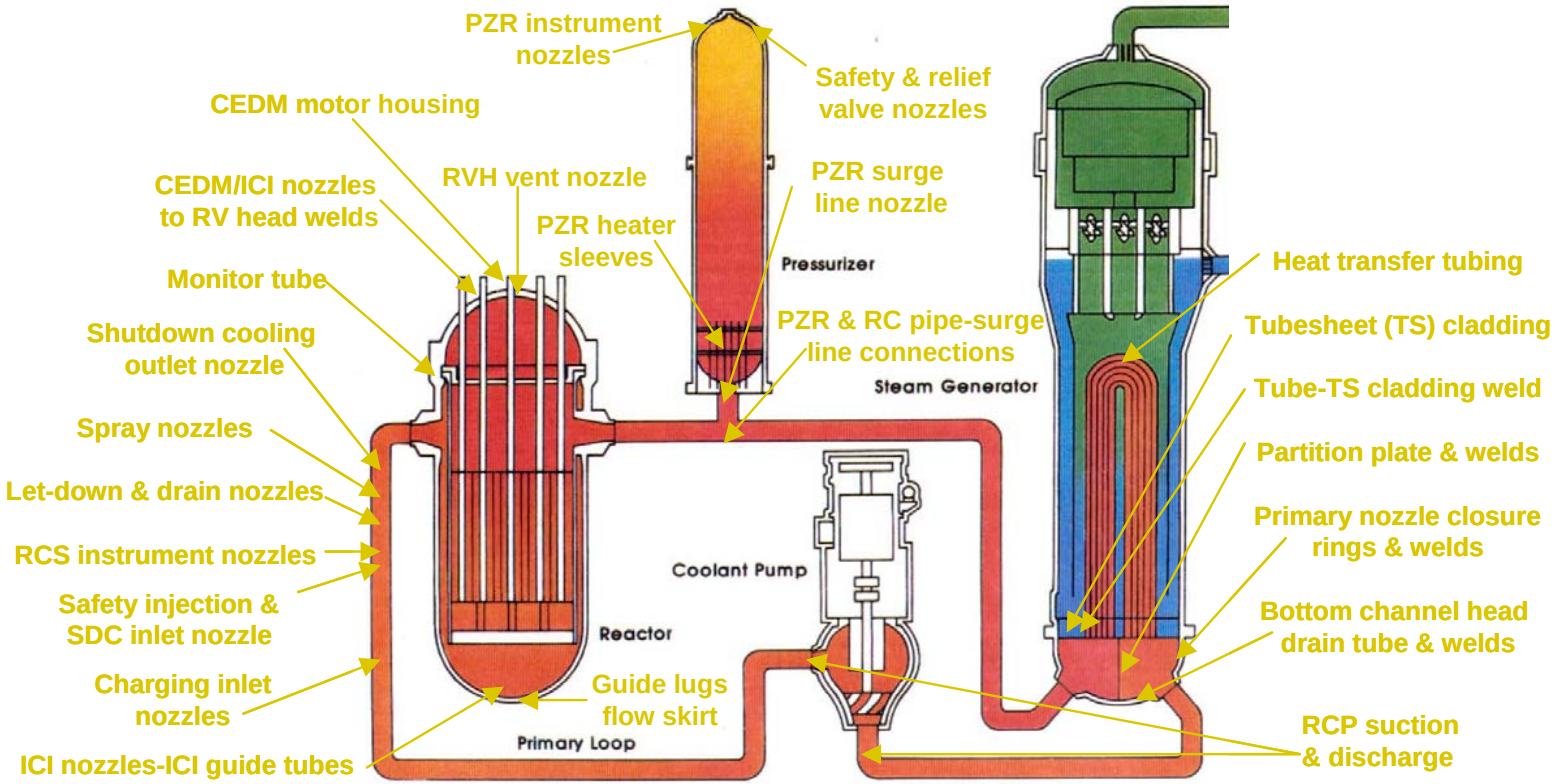
TCR ($/kW)	*Debt/Equity Ratio*	*Return On Equity (Nominal)*	*Debt Interest (Nominal)*	*AFUDC ($/kW) (Calculated)*	*LCOE ($/MWhr)*	
3980	50/50	11.5%	7.5%	1010	73	Reference case (LCOE DR 5.5%)
3607	80/20	11.5%	6%	652	58	Lower interest rate, ROE (LCOE DR 2.7%)
3882	80/20	20%	6%	917	70	Lower interest rate, higher ROE (LCOE DR 4.4%)
4812	80/20	20%	12%	1811	98	Higher interest rate, ROE (LCOE DR 7.3%)

- Base Case varied with D/E ratio, ROE, and debt interest.
- All cases use same Total Plant Cost ($2670/kw)and Owner's Cost ($300/kw).
- All costs in constant December 2007 $.
- Debt Interest deduction from revenue included in LCOE calculation.

- TCR- Total Capital requirement (all inclusive installed costs). TCR is impacted by D/E,ROE, and DI.
- AFUDC – Allowance for funds used during construction. AFUDC calculated with weighted cost of capital in real terms (no inflation).
- LCOE- Levelized Cost of Electricity over the life of the plant.

R&D Focus: Materials Aging

Extension of ***Materials Degradation Matrix*** for primary metals for failure mechanisms to 80 years



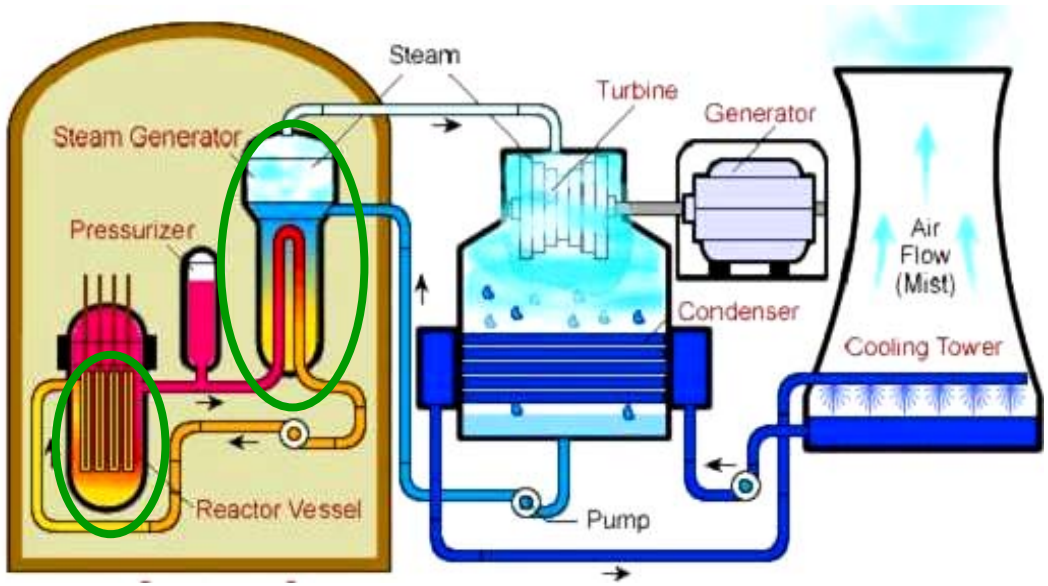
EPRI Nuclear R&D Activities

Inspection

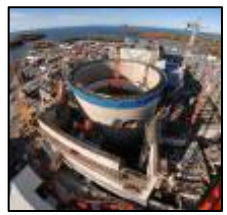
Risk & Safety

Equipment Reliability

Material Degradation



Adv. Nuclear Technology



Fuel Reliability

Radiation Exposure and Waste Management

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