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The Future of Nuclear Power in the United States & in a Carbon Constrained World

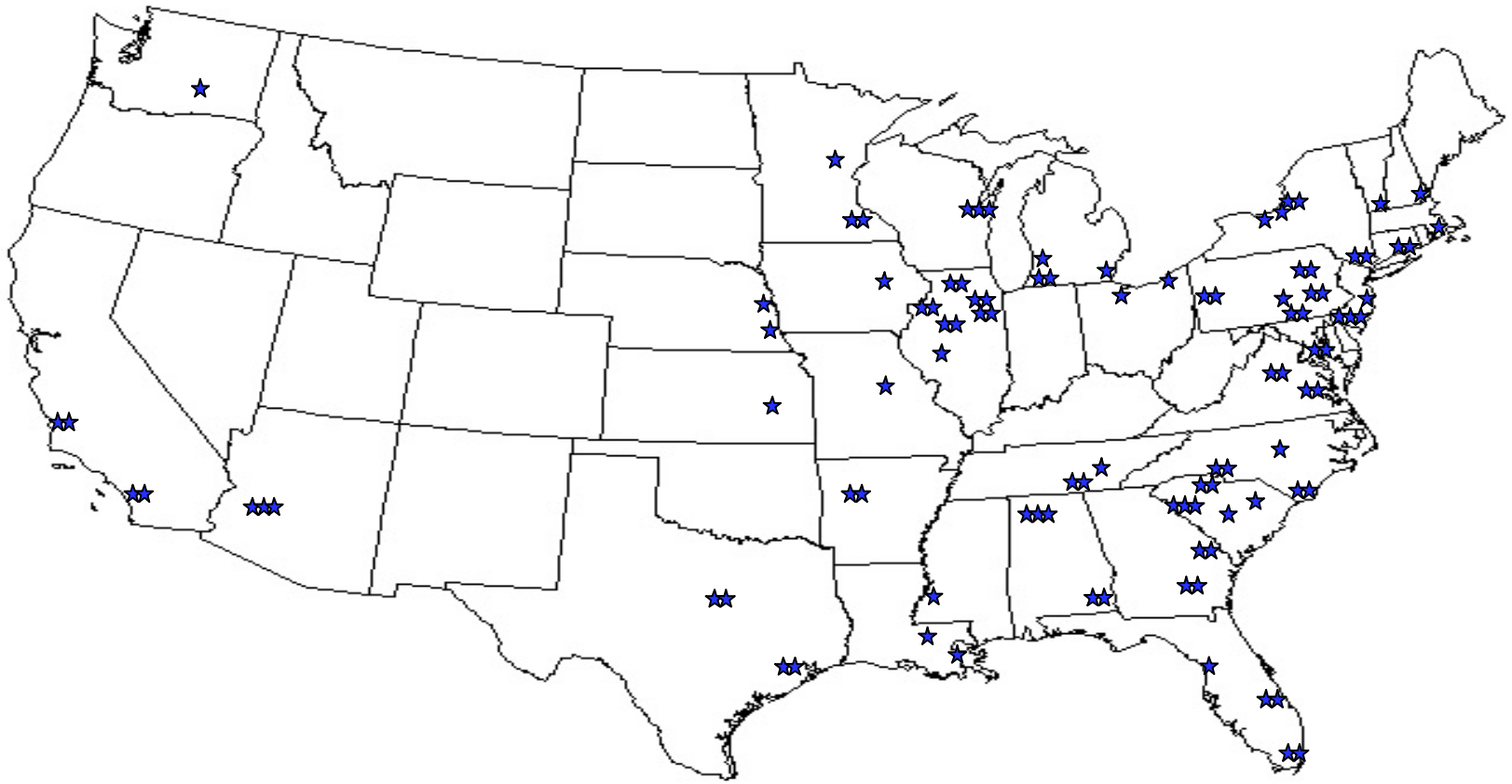
SIR Branch 35

April 16, 2008

Bob Woehl
Nuclear Regional Manager
Electric Power Research Institute

Current U.S. Nuclear Plants

104 Plants in 31 States



Source: Nuclear Energy Institute

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Topics for Today

Diablo Canyon NRC File Photo

- **Why Nuclear Power**
- **Some Nuclear Energy Perspectives**
  - **How is the nuclear fleet doing, Climate Change issues, others……**
- **Industry progress toward new plants**
- **Nuclear Challenges & Barriers to Success**
- **Conclusions**
- **Questions and Your Perspectives**

Why Nuclear….Why New Nuclear?

Factors driving the resurgence

1. **Two Carbons**
   - Natural gas and Coal cost (baseload)
   - CO2 buildup (future carbon tax or Cap)
2. Growth in electric power consumption
3. Nuclear sustained output and low cost
4. Greenhouse gas emission social considerations
5. Government Incentives

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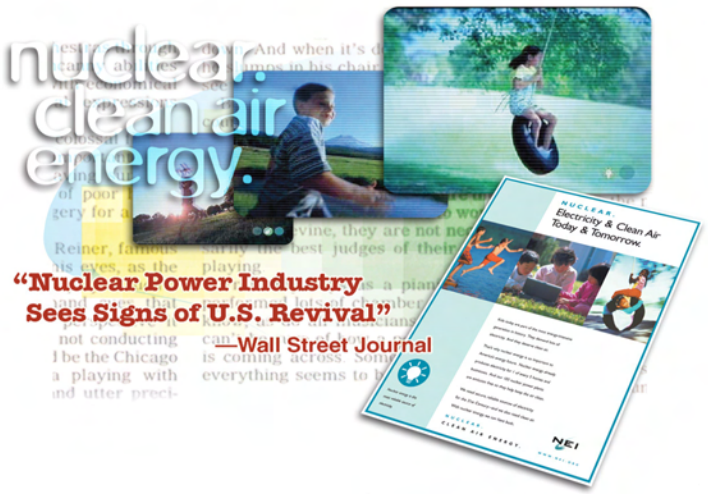
Why Nuclear Power?

- Nuclear is ***clean*** air energy **(now 70% of emission free power)**
- Nuclear energy is safe ***& reliable***
- Nuclear energy is ***affordable***
- Provides **"energy security"**
- Fuel is abundant and relatively cheap **(~0.5cents/KWh)**



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EPRI (Electric Power Research Institute)

- Founded in 1973 in Palo Alto
- Objective, non-profit electricity **collaborative research** organization
- Technology development, integration, demonstration and application
- Broad technology portfolio ranging from near-term solutions to long-term strategic research

Together…shaping the future of electricity

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Extensive Energy Research Program

Power Generation

Distributed Resources

Fossil Steam Plants

Combustion Turbine

Market Analysis

Renewables

Hydroelectric

Carbon Capture & Sequestration

Nuclear Power

Equipment Reliability

Nuclear Operations & Asset Management

High Performance Fuel

Nondestructive Evaluation

High Performance Workforce

Risk/Safety Mgt

Environment

Air Quality

Global Climate Change

Land & Groundwater

Water & Ecosystems

Electromagnetic Fields (EMF)

Occupational Health & Safety

Power Delivery

Transmission

Substations

Grid Reliability

Power Markets

Distribution

Power Quality

Energy Utilization

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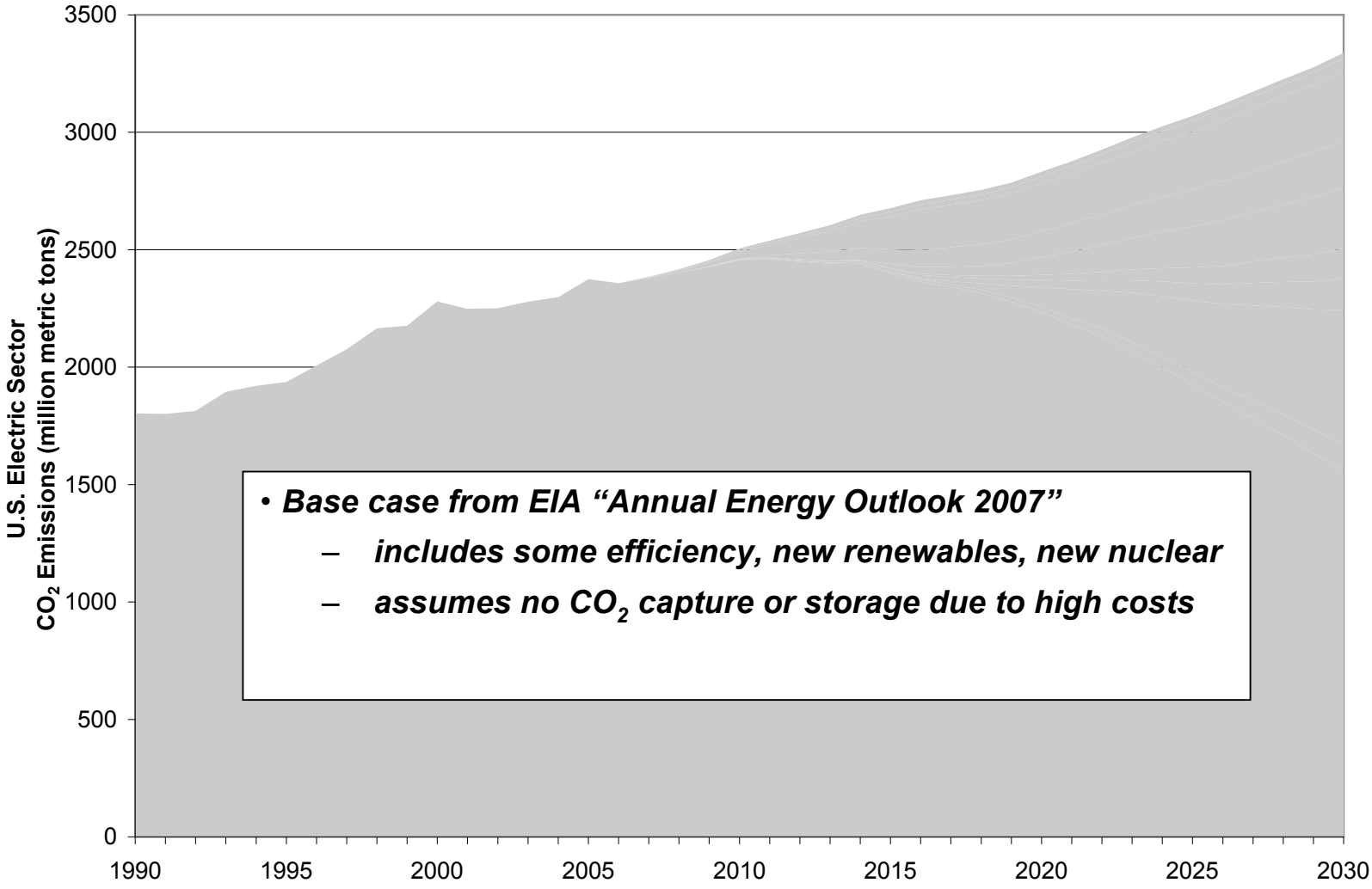
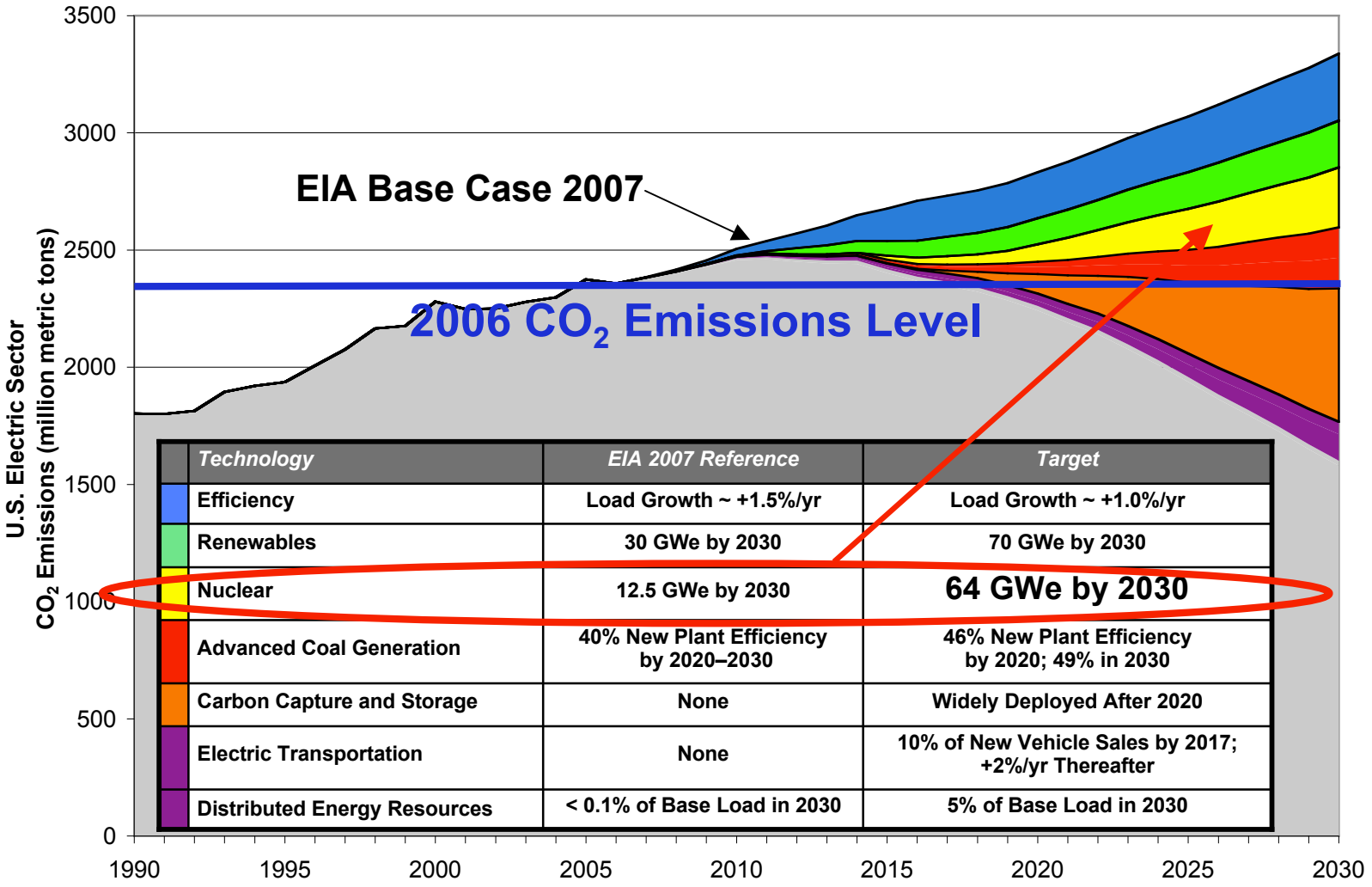
Forecasted U.S. Electricity Sector CO_2 Emissions



PRISM Analysis Targets

Technology	*EIA 2007 Base Case*	*PRISM Analysis Target**
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	**12.5 GWe by 2030**	**64 GWe by 2030**
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
Carbon Capture and Storage (CCS)	None	Widely Available and Deployed After 2020
Plug-in Hybrid Electric Vehicles (PHEV)	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
Distributed Energy Resources (DER) *(including distributed solar)*	< 0.1% of Base Load in 2030	5% of Base Load in 2030

CO_2 Reductions…Nuclear's Role in Reaching U.S. Goals



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Electric Transportation	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
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Current U.S. Nuclear Plants

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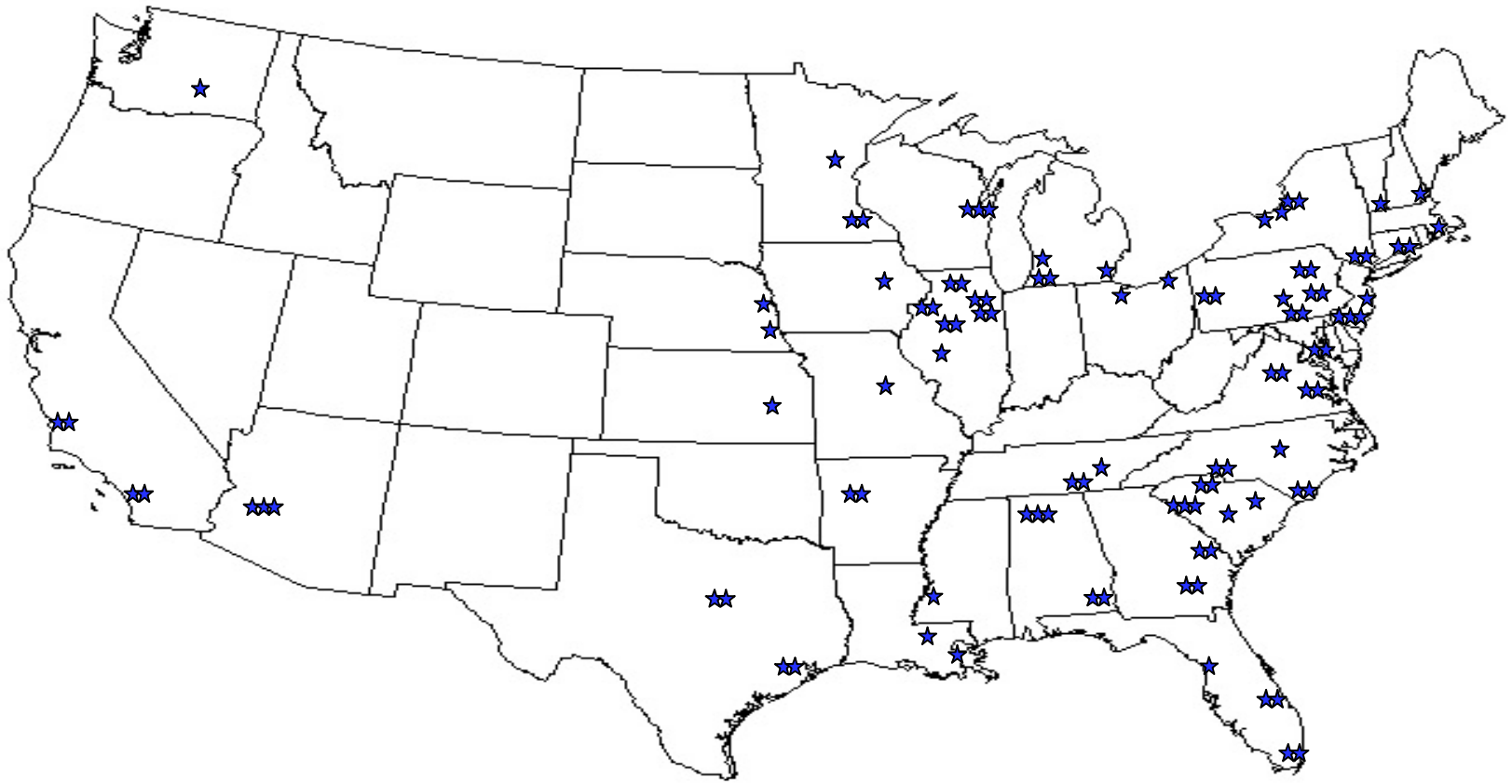
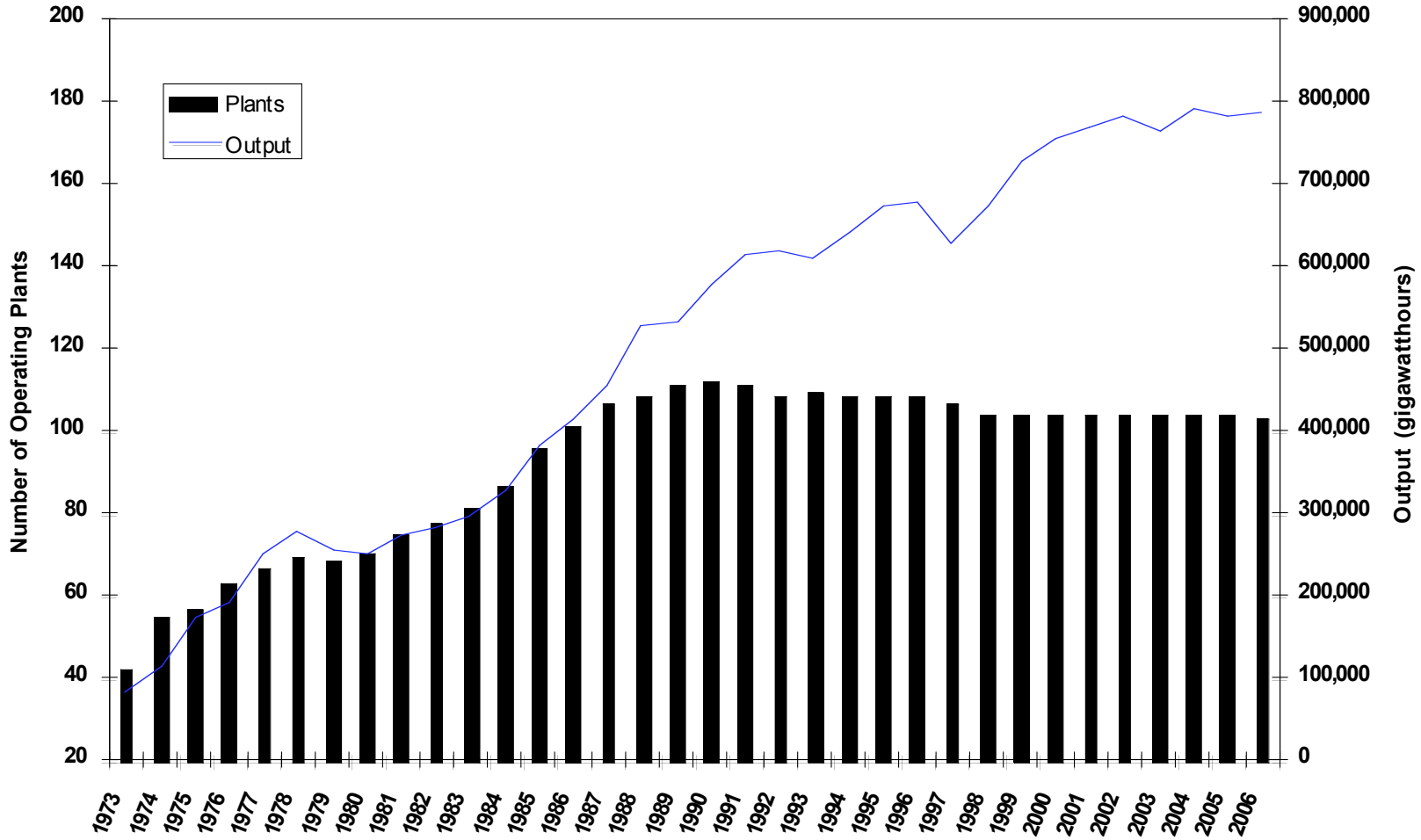


Source: Nuclear Energy Institute

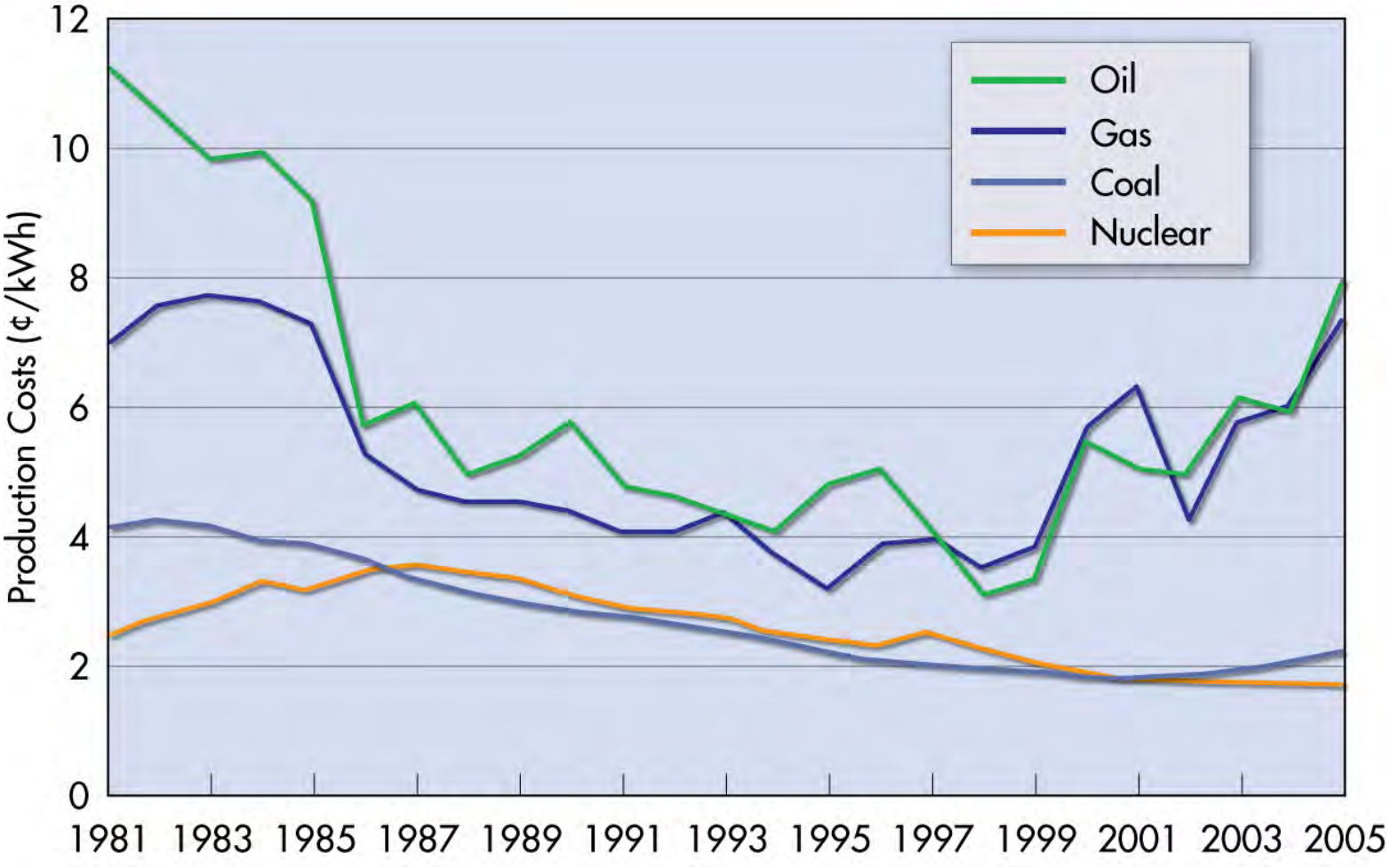
20 Years of U.S. Nuclear Industry Efficiency Gains

Equivalent to Adding 27 New Nuclear Plants

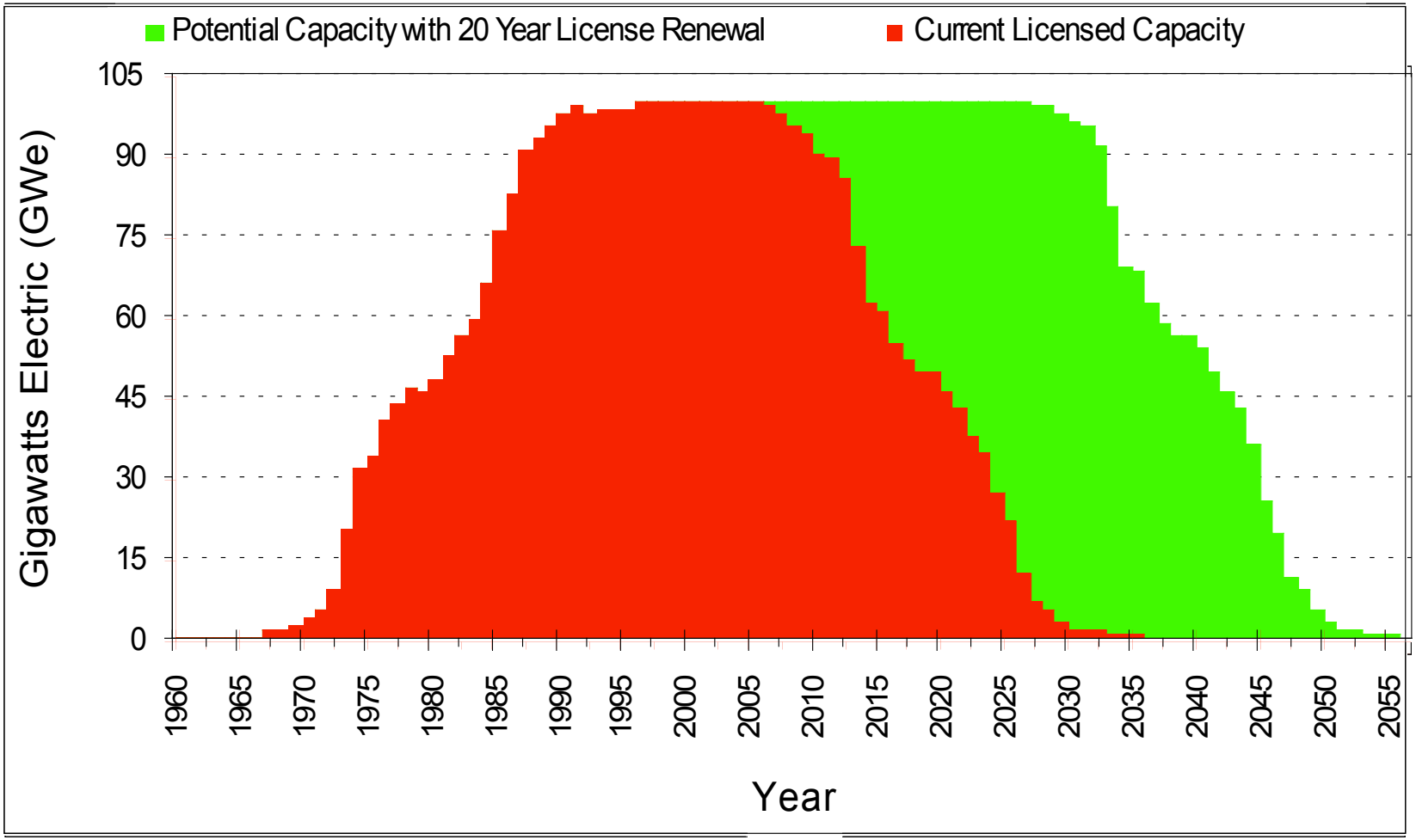


Sources: Nuclear Energy Institute & Energy Information Administration

Economic Performance Continues to Improve

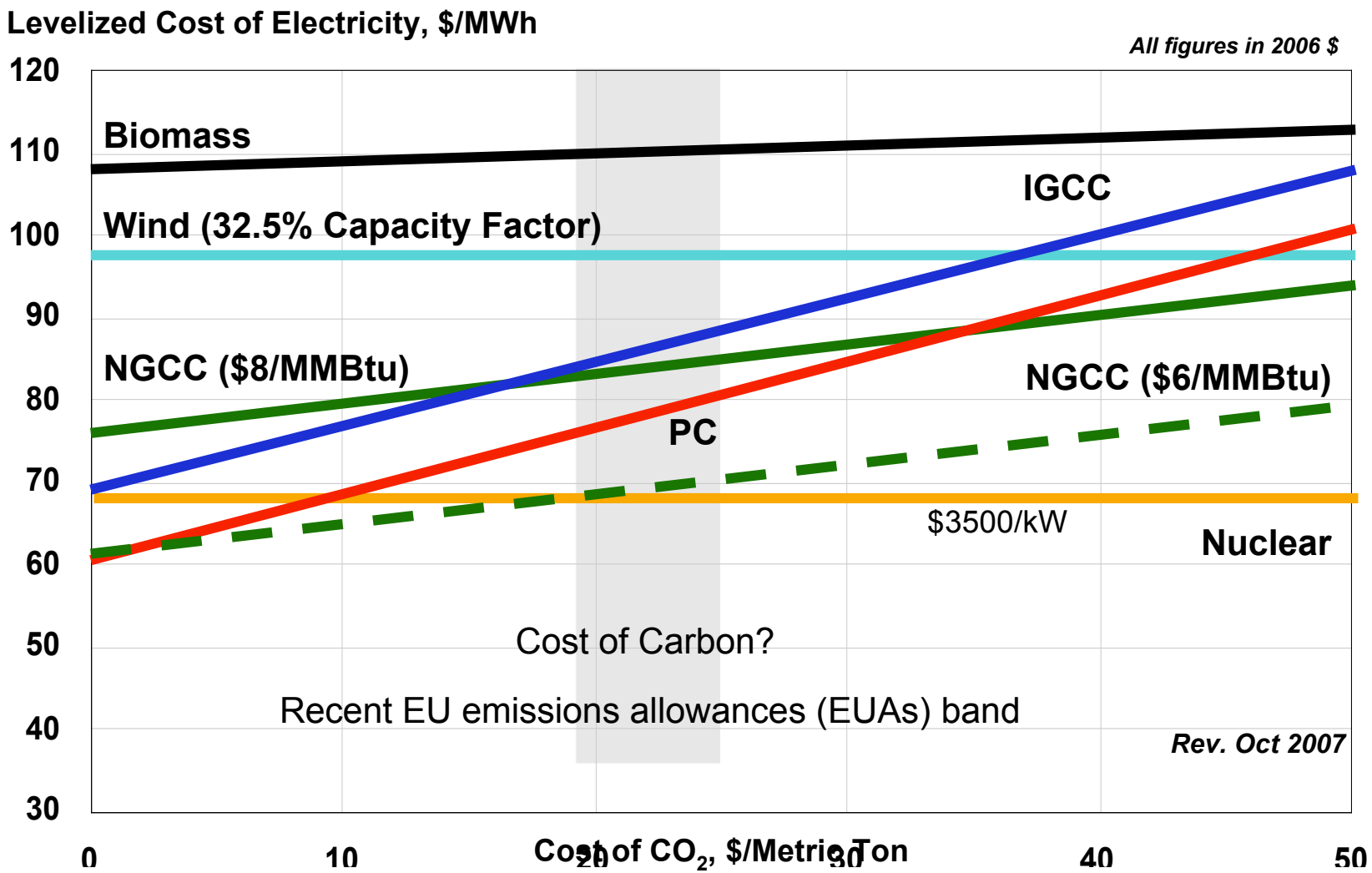


U.S. License Renewal Opportunity



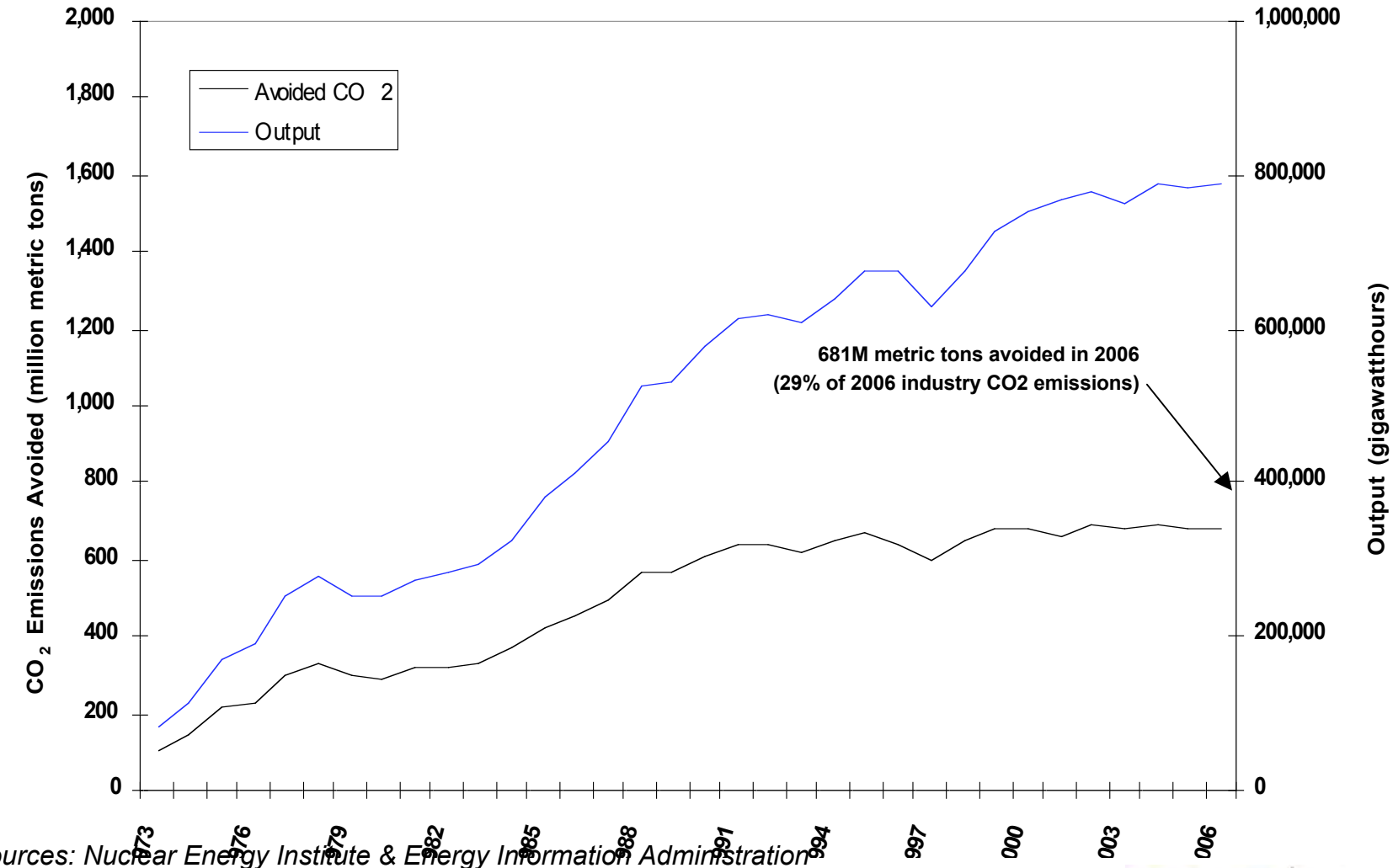
Electricity Generation Options 2010–2015

Baseload of Choice…?



U.S. Nuclear Plant Impact on CO2 Emissions

Largest Domestic Source of Emissions-Free Energy



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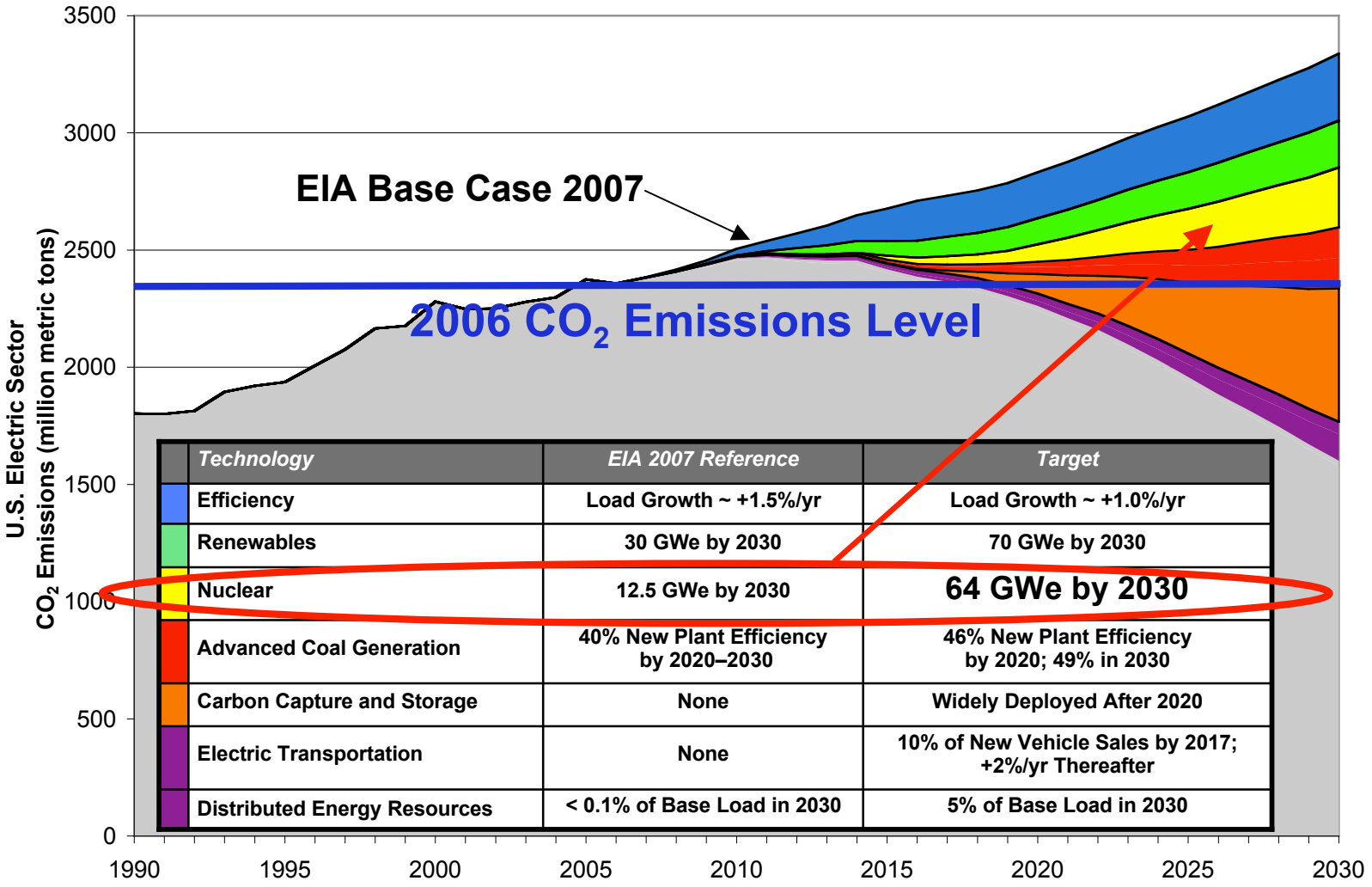

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U.S Energy Policy Act of 2005 Nuclear Incentives

- ***Production Tax Credits***
  - 1.8 cents per kilowatt-hour for 6,000 megawatts (MW) of capacity from new nuclear power plants for the **first eight years of operation**.
- ***Government Guaranteed Debt Financing***
  - Loan guarantees up to 80 percent of the project cost. Full payment must be made within 30 years or 90 percent of the project's life.
- ***Standby Support: Risk Insurance***
  - 100% of cost of plant start up delays up to $500M/plant for **first 3 reactors**, 50% of cost of delays up to $250M/plant for **next 3 reactors**
- ***Nuclear R&D, Hydrogen Projects Funding***
  - The bill authorizes $2.95 billion for nuclear research and development and hydrogen projects.
- ***Price-Anderson Act Extension***
  - Provides no-fault insurance coverage and liability limitations

California Specific Issues

Positive Forcing Factors

Need for more power

Increasing cost of natural gas and alternative baseload options

Sustained nuclear plant high output and low cost

CA's Coal Prohibition

Greenhouse gas emission

Social considerations

Government Incentives

Diablo Canyon Power Plant

NRC File Photo

California Specific Issues

Prohibiting Issues

- Legal Moratorium on new nuclear
- No Waste Repository operating
- Transportation Issues
- On-Site High Level Waste buildup
- Political worry (Legislature, CEC)
- Water

San Onofre Nuclear Generating Station *NRC File Photo*

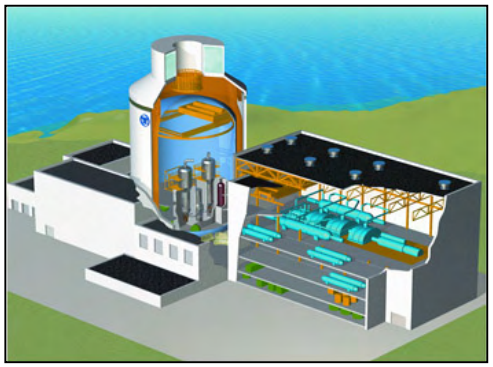
California Specific Issues

Big Questions - after State hurdles

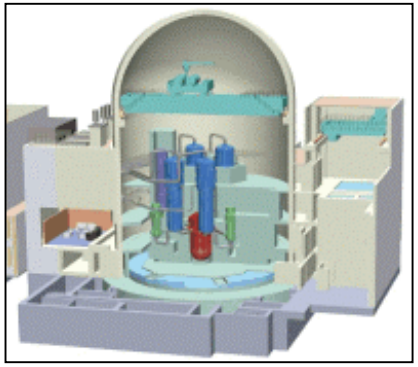
- Skyrocketing of commodity prices
- Increased global competition for resources
- Grid constraints to wield power

Palo Verde Nuclear Generating Station NRC File Photo

Near-Term Deployment Technologies
(Next Generation Light Water Reactor Technology)

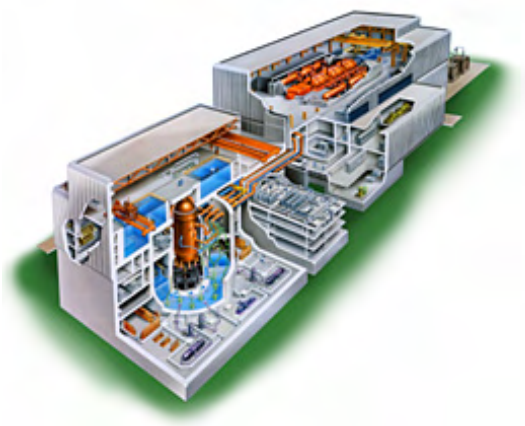


*Westinghouse
AP1000 (1115 MWe)



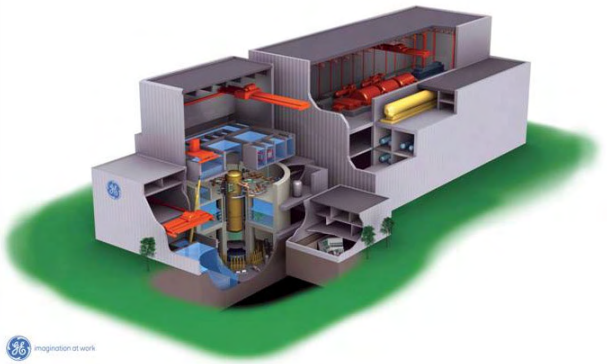
MHI APWR (1700 MWe)

AREVA US EPR (1600 MWe)



*GE ABWR (1371 MWe)

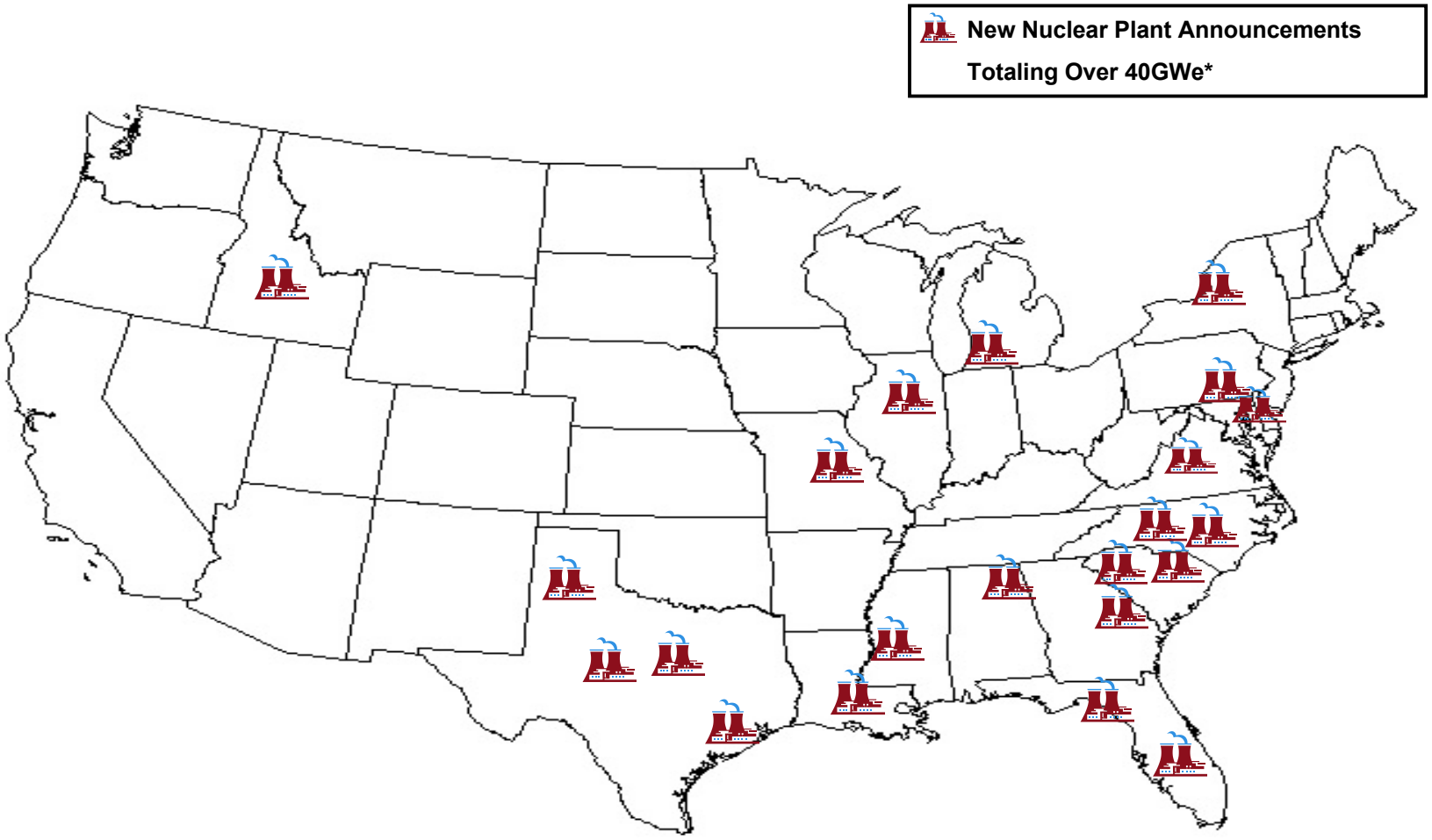
Current Status of Announced U.S. Intentions	
Technology	**Units**
AP1000	12
EPR	7
TBD	***6***
ESBWR	4
ABWR	2
APWR	2



GE ESBWR (1535 MWe)

**** Design Certified***

U.S. New Nuclear Plant Announcements
Concentrated at Existing Plant Sites



Source: NEI and various press releases – Aug 2007

** Assume Average 1,250 MWe per Unit*

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U.S. New Plant Announcements – April 2008

14 new unit Combined Operating License Applications submitted to date

Company	Site(s)	Design, # of Units	Combines License Submittal
Alternate Energy Holdings	Bruneau, ID	EPR	FY 2009
Amarillo Power	Vicinity of Amarillo, TX	EPR	FY 2009
AmerenUE	Callaway, MO	EPR	FY 2008
Constellation (UniStar)	Calvert Cliffs, MD plus two other sites	EPR (3)	First submittal - FY 2008
Detroit Edison	Fermi, MI	Not yet determined	FY 2008
Dominion	***North Anna, VA***	***ESBWR (1)***	***November 2007***
Duke	***Cherokee County, SC***	***AP1000 (2)***	***December 2007***
Duke	Davie County, NC	Not yet determined	Not yet determined
Duke	Oconee County, SC	Not yet determined	Not yet determined
Entergy	River Bend, LA	ESBWR (1)	FY 2008
Entergy (NuStart)	***Grand Gulf, MS***	***ESBWR (1)***	***February 2008***
Exelon	Clinton, IL	Not yet determined	Not yet determined
Exelon	Victoria County, TX	ESBWR (2)	FY 2008
Florida Power & Light	Turkey Point, FL	Not yet determined (2)	FY 2009
NRG Energy / STPNOC	***Bay City, TX***	***ABWR (2)***	***September 2007***
PPL Corp.	Susquehanna, PA	EPR	FY 2009
Progress Energy	***Harris, NC***	***AP1000 (2)***	***February 2008***
Progress Energy	Levy County, FL	AP1000 (2)	FY 2008
South Carolina Electric & Gas	***Summer, SC***	***AP1000 (2)***	***March 2008***
Southern Company	***Vogtle, GA***	***AP1000 (2)***	***March 2008***
Texas Utilities	Comanche Peak, TX	APWR (2)	FY 2008
TVA (NuStart)	***Bellefonte, AL***	***AP1000 (2)***	***October 2007***

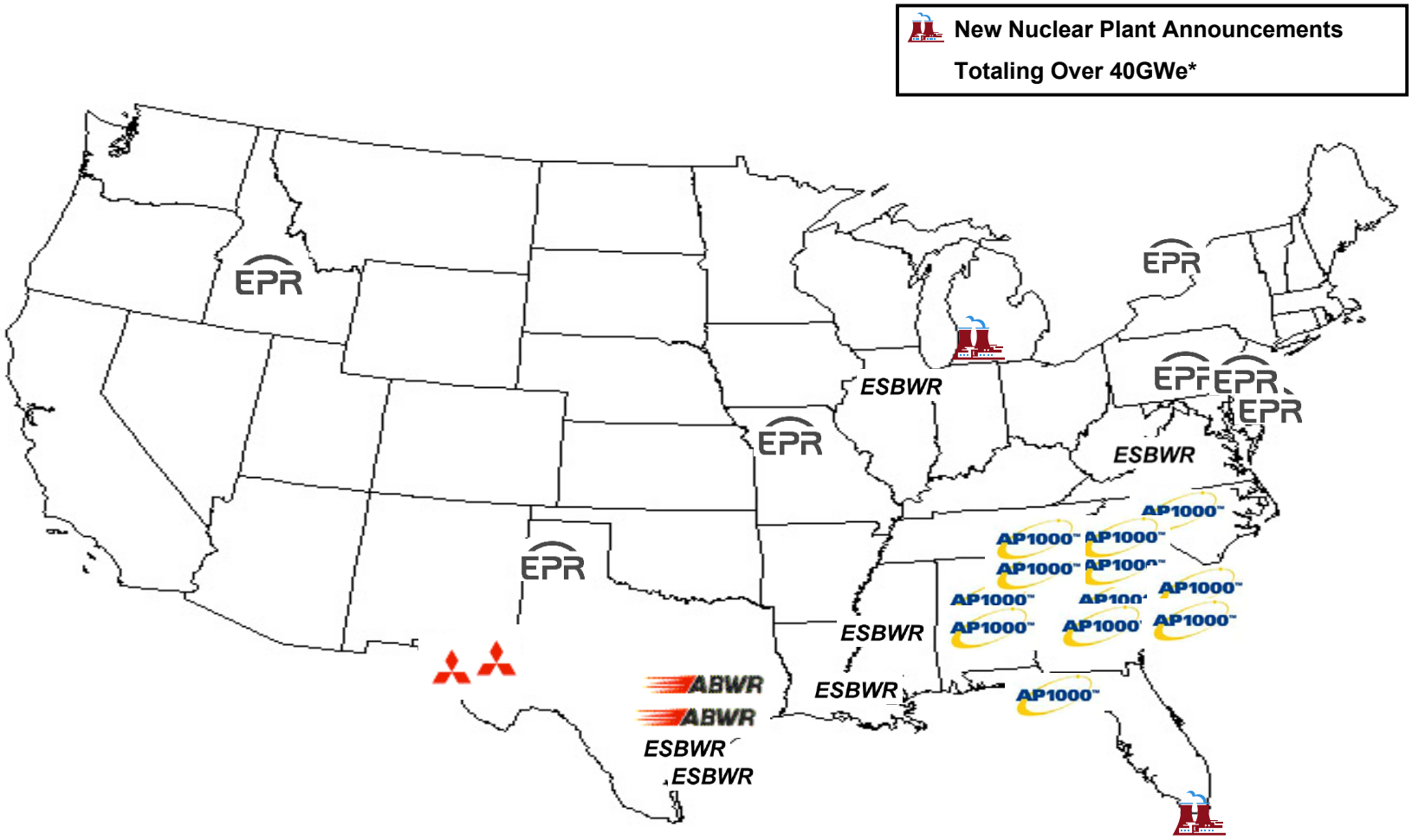
FY - Federal Fiscal Year, CY - Calendar Year

Updated: 4/08

COLA Submitted

U.S. New Nuclear Plant Announcements

Concentrated at Existing Plant Sites



Source: NEI and various press releases – Aug 2007

** Assume Average 1,250 MWe per Unit*

Status of Nuclear Power Worldwide

Status	Number of Countries	Number of Reactors	GWe
Current fleet	31	439	372
Construction Underway	13	34	28
Planned (or ordered) Plants	18	93	100
Proposed Plants	29	222	193

Construction =

First concrete for reactor poured or major refurbishment under way

Planned =

Approvals, funding or major commitment in place, mostly expected in operation within 8 years, or construction well advanced but suspended indefinitely

Proposed =

clear intention or proposal but still without firm commitment.

Source: World Nuclear Association (1/18/08)

2007 Worldwide Highlights…a Year of Growth

- **3 New units added:**
  - **Kaiga 3** (202 MW(e), PHWR, **India**)
  - **Tianwan 2** (1000 MW(e), PWR-WWER, **China**)
  - **Cernavoda 2** (655 MW(e), PHWR-CANDU, **Romania**)
- **1 Unit restarted after a long term shutdown:**
  - **Browns Ferry 1**, (1065 MW(e), PWR, USA)
- **1 Unit started construction reactivation:**
  - **Watts Bar 2 (**1165 MW(e**),** PWR**, USA**)
- **8 Units Construction initiation:**
  - **Qinshan II-4**, (610 MW(e), PWR, **China**)
  - **Severodvinsk - Akademik Lomonosov 1&2**, (2x30 MW(e), PWR-KLT40, **Russia**)
  - **Shin Kori 2**, (960 MW(e), PWR, **S. Korea**)
  - **Hongyanhe 1**,(1000 MW(e), PWR, **China**)
  - **Shin Wolsong 1**, (960 MW(e), PWR, **S. Korea**)
  - **Flamanville 3** (1600 MW(e), PWR, **France**)

Source: IAEA PRIS Database

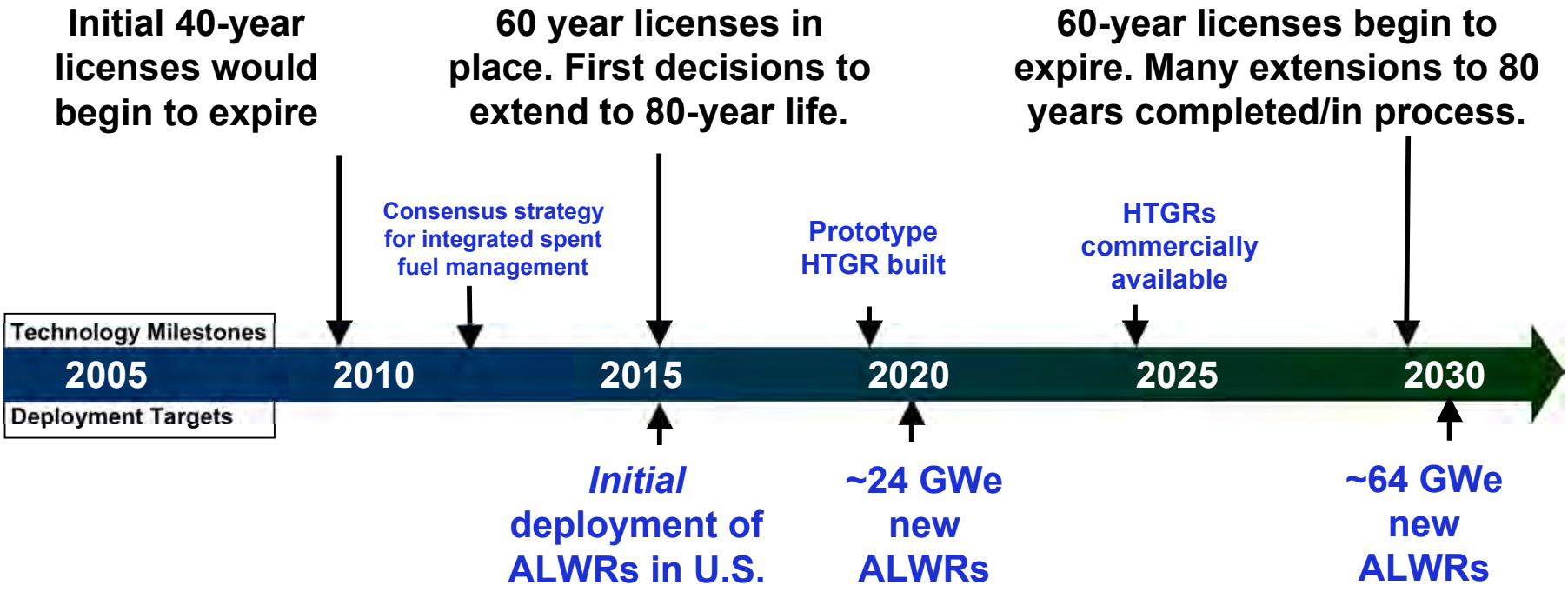
The Nuclear Fleet at Mid-Century

- **Earth's population** expected to expand from 6.4B to over 9.4 B by 2050
- **Energy demand** will likely increase at a faster rate, as improved standards of living increase, longer life expectancy, etc…especially in non-OECD countries
- **Various GEN IV Technologies** being evaluated for various "missions"
  - Coolant is gas or liquid metal
    - Higher temperature, better thermal efficiency, increased safety
- **Integrated Spent Fuel Management Strategy Employed (GNEP)**
  - Maximizing energy extraction from used U^{238}
  - Transuranic consumers, reducing the demand on geological storage while increasing proliferation resistance
- **Generation 4 (GEN IV) plants are being planned for 2030s** deployment globally to meet increased demand from population growth, current fleet attrition, and diverse "missions"

Next Generation Nuclear Plant

Forward Looking Vision…In the U.S.

Current Fleet…



…New Fleet

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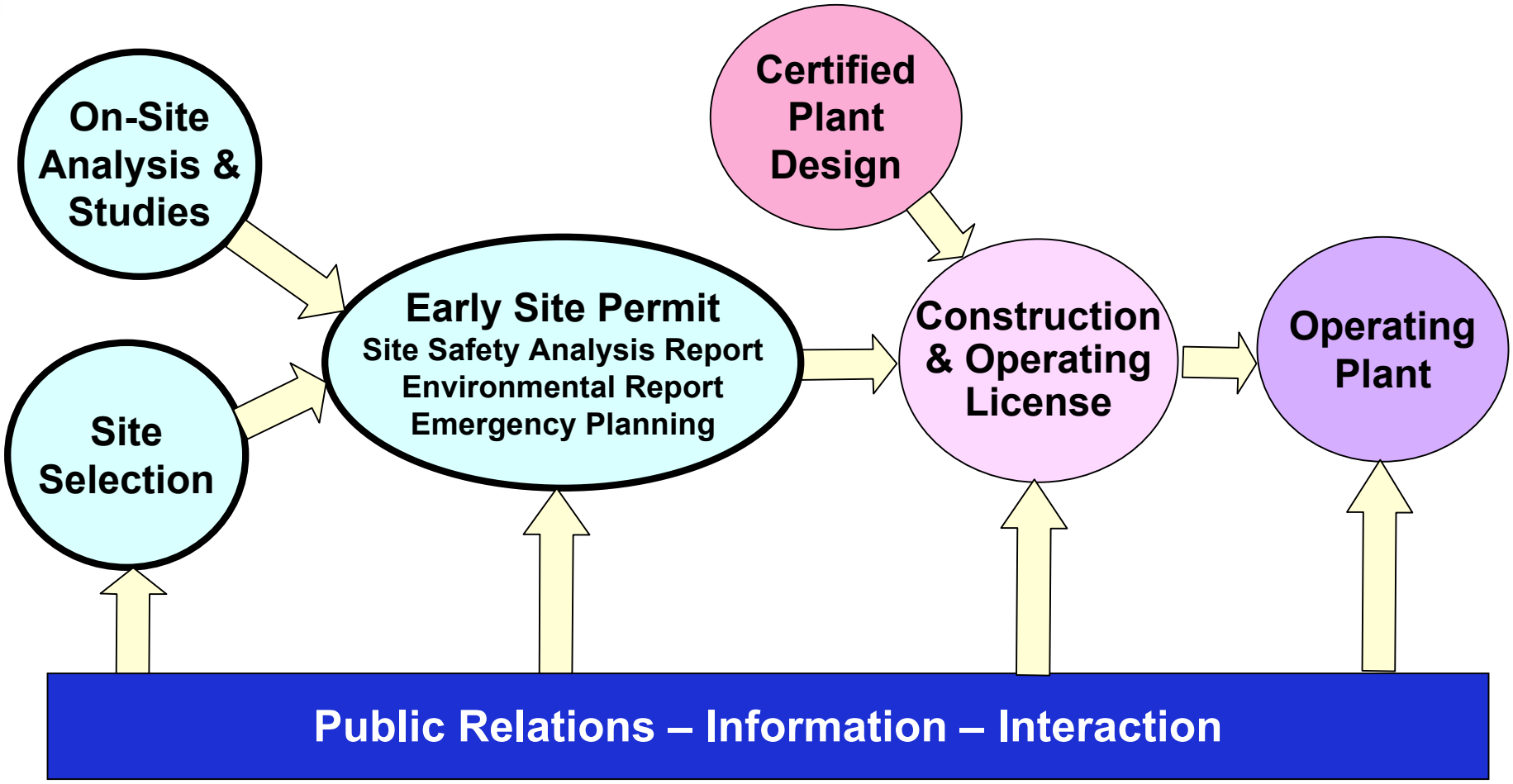
Regulatory Process - New Plant Licensing



Many Factors Affecting Decisions to Move Fwd

- **NSSS Vendors lack of recent experience**
  - Designs not fully complete
  - Little construction experience
- **Skyrocketing of commodity prices**
  - Steel prices have risen 60% since 2003
  - Copper prices nearly quadrupled between 2003 and 2006
  - Cement prices rose 30% between 2003 and 2006
- **Increased global competition**
  - Worldwide nuclear deployment
    - Finland, France, China, Russia, South Africa, US
  - Equipment availability / supply chain bottlenecks
  - "Other" infrastructure projects -Oil refineries, LNG terminals
  - Labor availability concerns

External Risk Factors…Unknowns

1. **Cost of Construction**
   - Debt / equity financing / materials cost escalation
2. **Water availability -** Climate situation in 40yrs? 80yrs?
3. **Climate change -** Carbon regulation
4. **Nuclear waste policy (only a political problem)**
   - Geologic storage, reprocessing, closed cycle
5. **New administration**
6. **Transmission availability / access**
7. **Fuel costs / U prices & international pressure**
8. **Regulated vs. competitive markets**
9. **Demonstration of NRC's licensing stability may commitments**

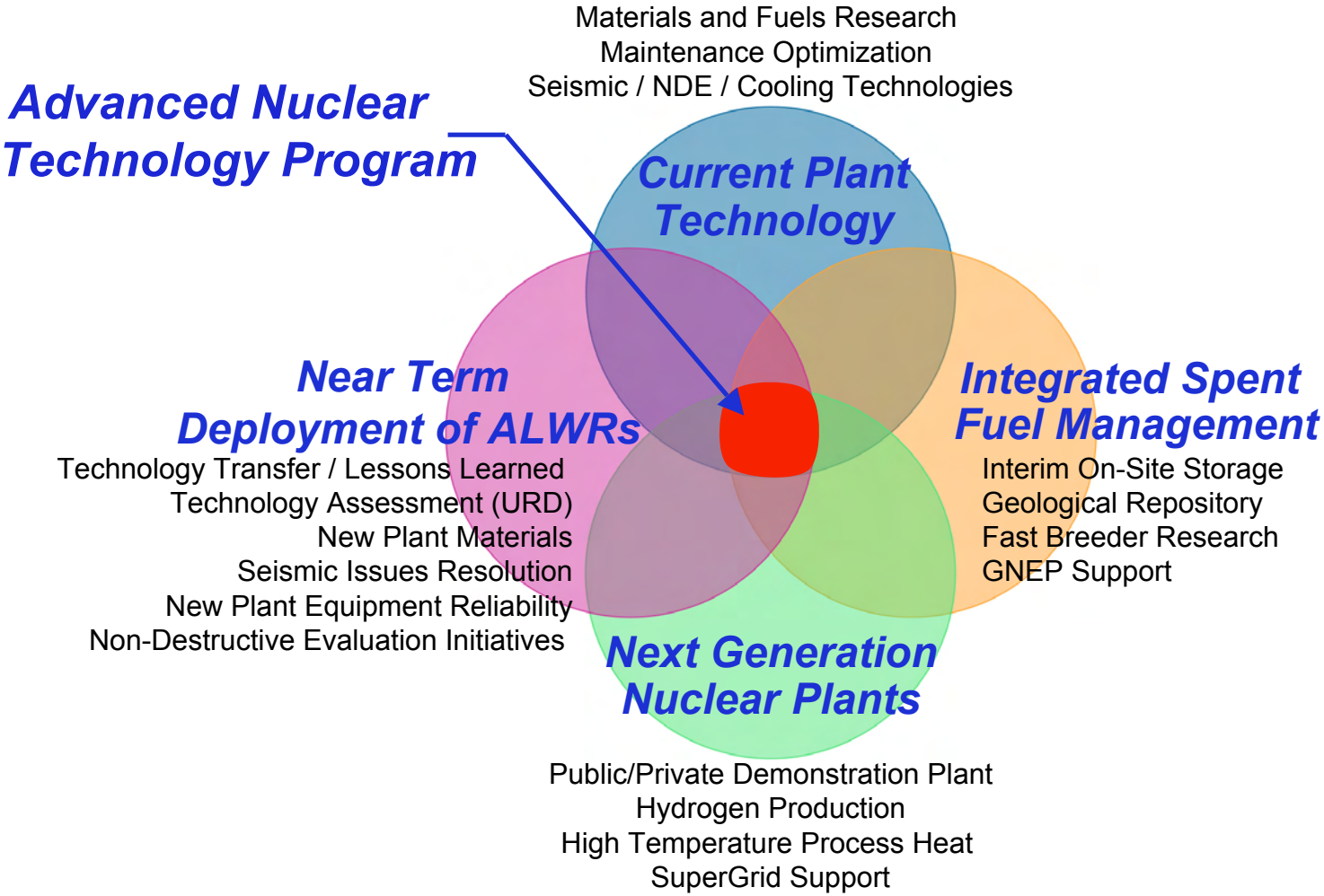
The real test will be to deliver the first few plants in on time and within budget

Summary of other potential obstacles

- Position in the NRC licensing queue
- Construction workforce availability
- Long lead-time on forgings
- Vendor design resources
- Other local and state issues
- Future problems with operating plants

What Is EPRI Doing? Focal Point New Plant Activities

Linking Lessons Learned to Future Opportunity



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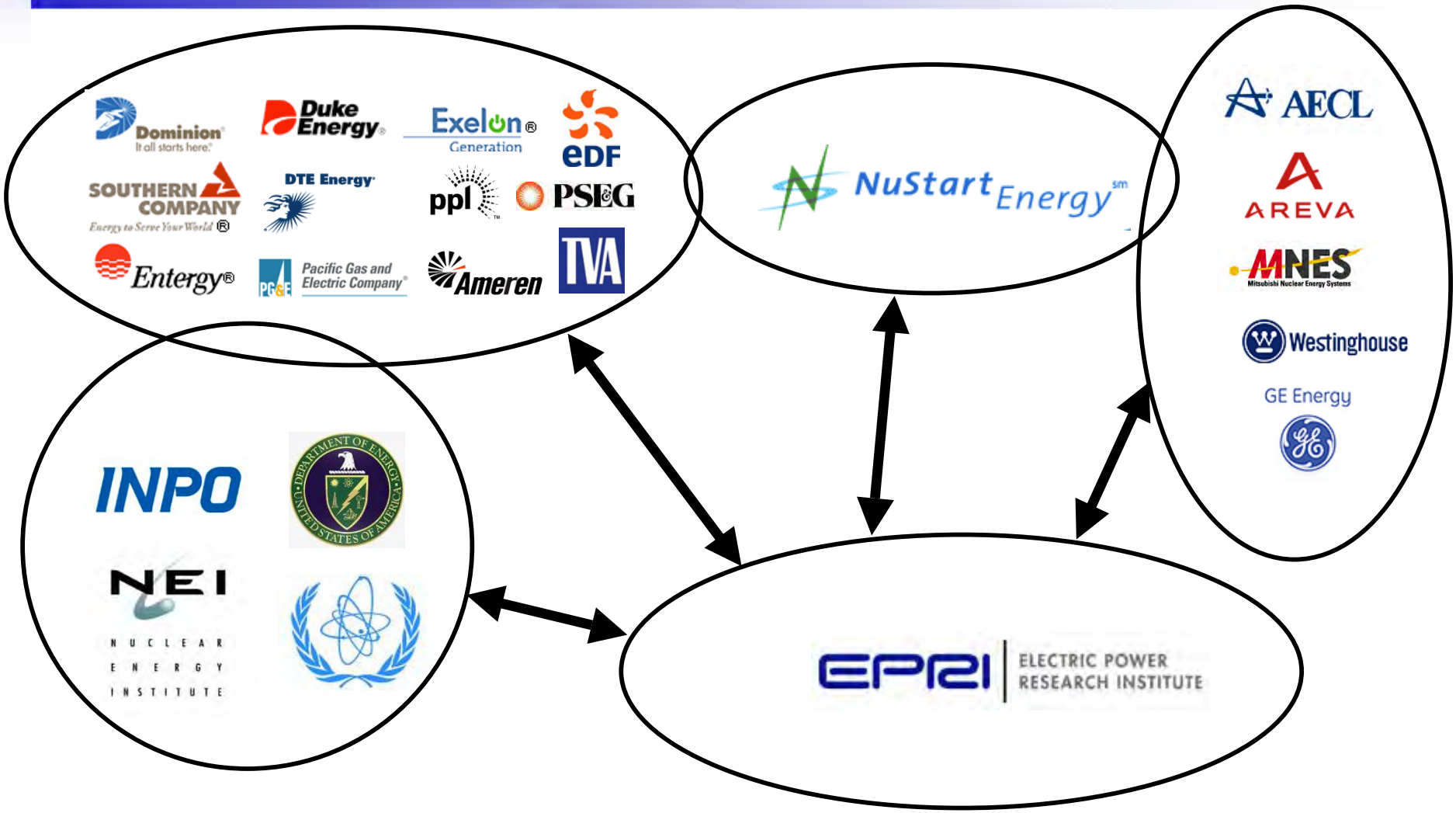
EPRI's ANT Program…Leveraging the Industry



Conclusions
- Positive Factors Influencing Building

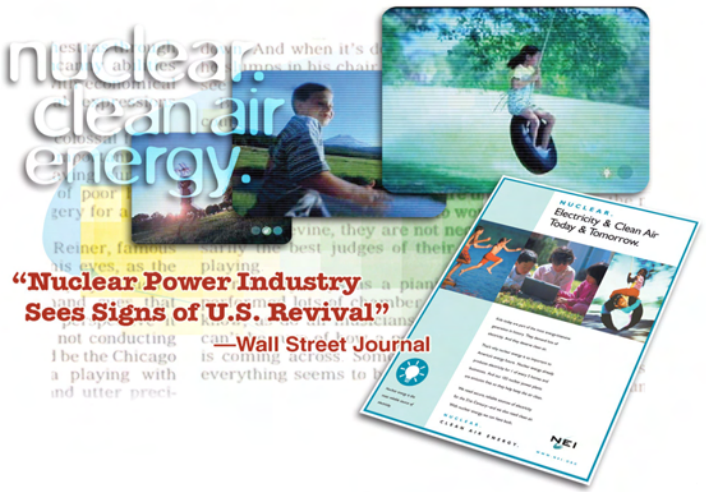
- **Clean Air** generation
- **Safe & Reliable** Baseload Capacity (must continue)
- **Affordable** Power
- **Cost of Natural Gas** (1999 $2/MBTU 2008 $6-7/MBTU)
- **Energy Security** is enhanced
- **Informed Public** Removes Barriers
- **Reduced Financing Risks** (EP Act of 2005)
- **Future** move to a Hydrogen Economy

The Electricity "TRILEMA"

Quality of Life vs. Environment vs. Resources

Final Thoughts

- Nuclear is ***clean*** air energy **(70% of emission free power)**
- Nuclear energy is safe & ***reliable***
- Nuclear energy is ***affordable***
- Provides **"energy security"**
- Fuel is abundant and relatively cheap **(~0.5cents/KWh)**



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What Do You Think?

- SIR Opinions !!!
- Questions ???

Together…Shaping the Future of Electricity