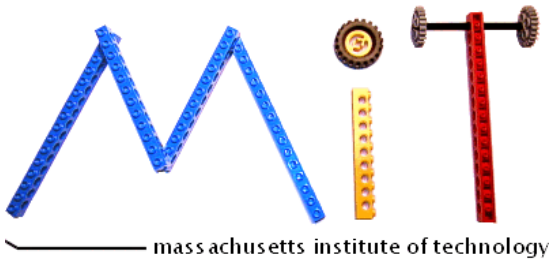
THE FUTURE OF NUCLEAR POWER IN THE U.S.

Paul L. Joskow



January 15, 2007

NUCLEAR POWER IN THE U.S.

- U.S. has 100 GW of nuclear capacity (20% of U.S. electricity generation --- 50% coal, 19% natural gas, 3% oil, 9% renewable)
- Performance has improved dramatically over time in all dimensions
- It is economical to extend the life of the existing fleet and “uprate” some units to increase capacity (3+ GW more)
- Growing interest in the U.S. in promoting investments in new nuclear capacity but economics, waste disposal, and public acceptance are uncertain
- Changes in licensing process and efforts to resolve waste disposal issues support new investment
- 2005 Energy Act contains financial incentives (production tax credits, other subsidies) to encourage “first-movers” to build new plants
- 12 (9 subsidized+ 3) GW of nuclear capacity additions plus 3.2Gw uprates forecast between 2015 and 2030 by EIA (2007 early release)
  - 311 Gw total generating capacity additions forecast by 2030 (EIA 2006)
  - 34 Gw of new nuclear in “low construction cost” sensitivity case
  - 70 Gw of new nuclear in “vendor cost goals” sensitivity case
- Several companies have announced that they will start the licensing process for new plants but no firm orders have been made yet

Source: Nuclear Energy Institute

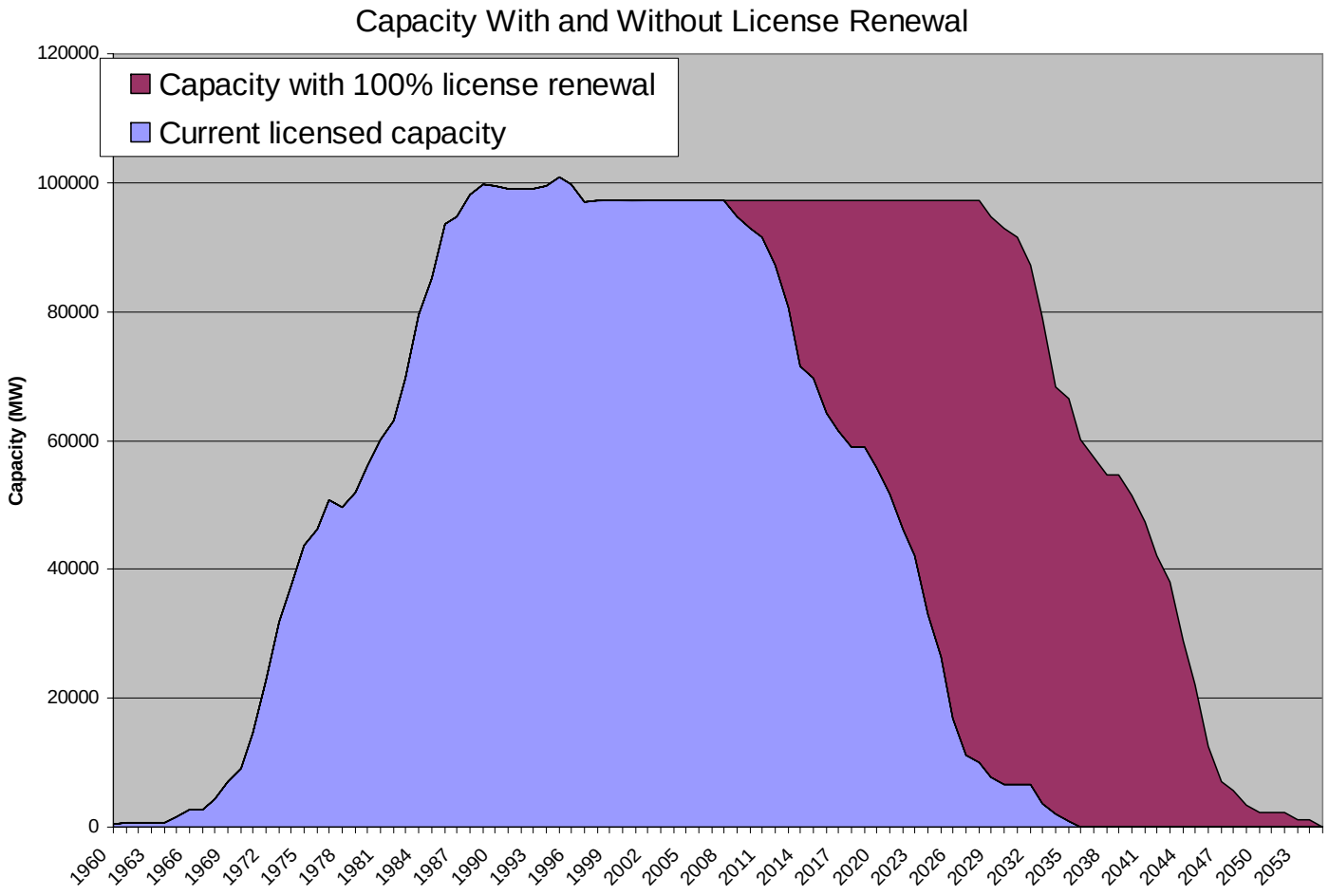
BACKGROUND CONSIDERATIONS

- Need to distinguish existing fleet of plants from investments in new plants
- Economics is only one consideration for viability of investment in new nuclear plants
  - Public and political acceptance
  - Effectiveness of new licensing process
  - Waste disposal policies
- CO_2 policies, natural gas prices, coal prices, government subsidies and competitive/contractual/regulatory framework are important drivers of comparative economics of investments in new nuclear plants for private sector investors

Prospects for Expanding/Extending Capacity of Existing U.S. Fleet

- License renewals/extensions (as of September 1, 2006)
  - 44 units approved
  - 8 units under review
  - 26 letters of intent (multiple units)
- Power uprates
  - Additional 3.2 GW forecast by EIA
- Refurbishment:
  - Browns Ferry 1 on track for 2007
  - 1,280 MW plant
- Capacity factors:
  - Further improvement will be difficult

Without New Investments U.S. Nuclear Capacity Declines Quickly After 2030



Source: Dominion Resources, 2005

WHAT IS NEEDED TO STIMULATE SIGNIFICANT NUCLEAR INVESTMENT IN THE U.S.?

- Stable regulatory, competitive and commercial framework that will support capital intensive projects with relatively long construction expenditure cycles
- Stable and efficient nuclear plant licensing framework
- Achieve credible $1500/kW ($2002) (or $1700/kW in $2006) overnight cost including all relevant owner's costs, 5-year construction period and ≥ 85% life-time capacity factor
- Placing a significant "price" on carbon emissions helps a lot
- Realize credible and economic nuclear waste disposal policy

CONSTRUCTION AND FINANCING COSTS

- No new nuclear plants completed in the U.S. for over 10 years
- There are few new nuclear plants under construction in the world
  - Mostly in less developed countries
- Recent credible construction and cost data are limited
- Competitive, regulatory and contractual environment is very uncertain and varies widely across the U.S. (and the world)
- The U.S. has not (yet) adopted policies to place a price on CO2 emissions

CONSTRUCTION COST ESTIMATES

- Construction cost estimates should include all costs, including engineering, construction management and owner's costs (~ 20%)
- The best estimates are drawn from actual experience rather than engineering cost models
- Construction cost estimates for PC and CCGT can be verified from actual experience
- Publicly available data on recent nuclear plants completed suggest that $2,000/Kw ($2002) or $2,300/kW ($2006), including all owner's costs, with a 5-year construction period is a good base case cost estimate
- Competitive power markets induce truthful revelation of costs and associated uncertainties
  - Need to convince investors not me

RECENT CONSTRUCTION COST EXPERIENCE ($2002)

Genkai 3	$2,818/kW (overnight)
Genkai 4	$2,288/kW (overnight)
Onagawa	$2,409/kW (overnight)
KK6	$2,020/kW (overnight)
KK7	$1,790/kW (overnight)
Yonggwang 5&6	$1,800/kW (overnight)
Browns Ferry RESTART	$1,280/kW (overnight estimate)
Finland EPR (AREVA-Seimens contract only)	$2,300/kW (nominal estimate 2005) (before cost of delays)
Bruce RESTART	$1,425/kW (nominal estimate 2005)
Flammanville 3 (EDF)	$2,600/Kw (nominal estimate 2006)

Source: MIT and Trade Press

FINLAND

- Teollisuuden Voima Oy (TVO) is building Olkiluoto 3
  - EUR 3 billion fixed-price contract with Areva and Siemens (~$2300/kw) [unspecified cost overruns due to delays and cost increases to date but TVO is insulated from them]
  - 1600 MWe
  - Permit application in 2000, construction started September 2005 and commercial operation now forecast for start 2011 [2 delays announced]
- Ownership and Long Term Contract Shares

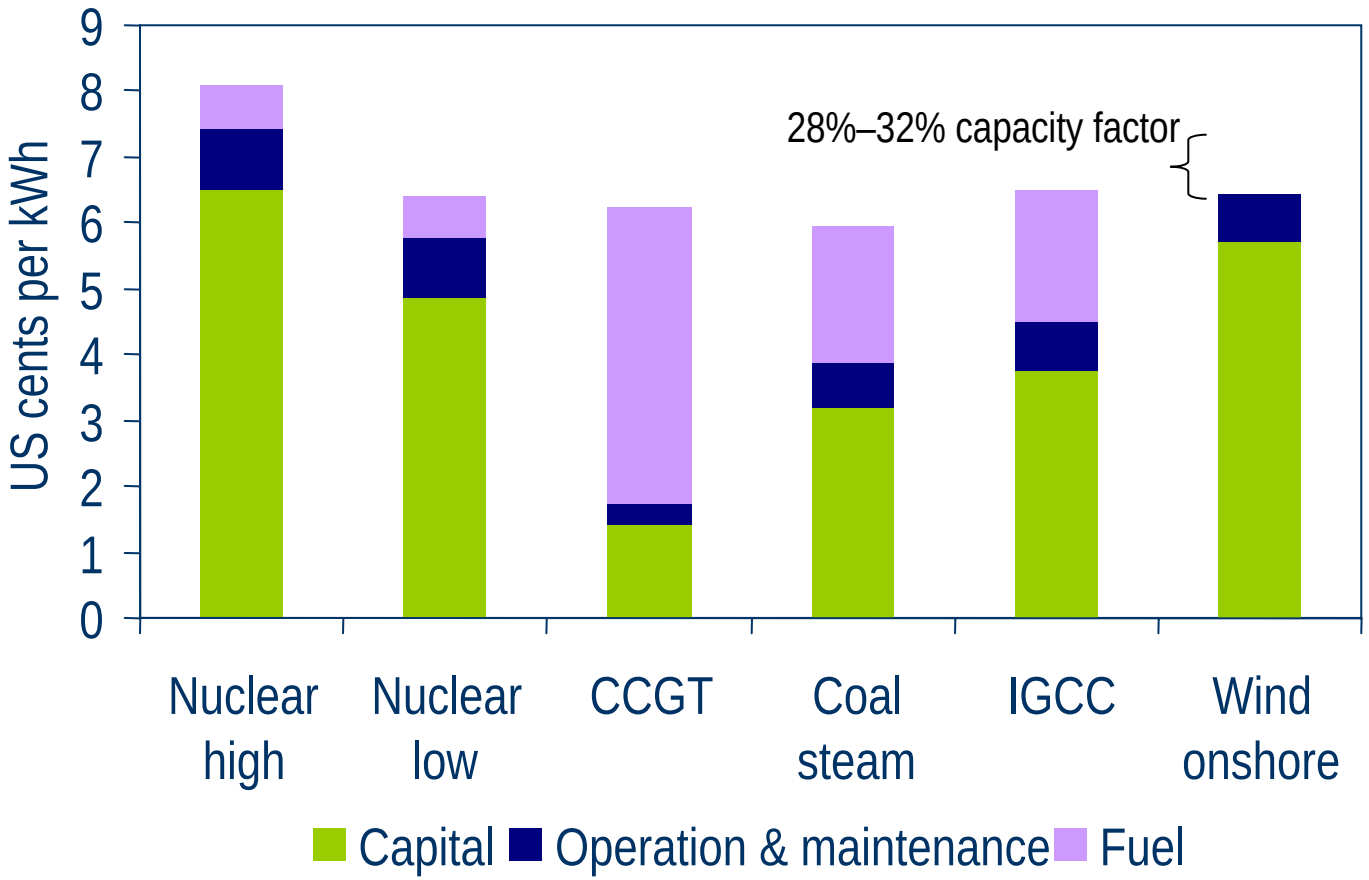
UPM-Kymmene (forestry products via PVO energy company)	25.63%
Stora Enso Oyj (forestry products via PVO energy company)	9.39%
others (forestry products via PVO energy company)	25.18%
Fortum Power & Heat (government controlled power corp)	25.00%
Oy Mankala Ab (city of Helsinki)	8.10%
Etala-Pohjanmaan Voima Oy (distr cos in NW coast of Finland)	6.50%
Graninge Suomi Oy (energy co. in forestry/energy group)	0.10%

COMPARATIVE BASE LOAD COSTS (MIT REPORT)

($2002 cents/kWh)

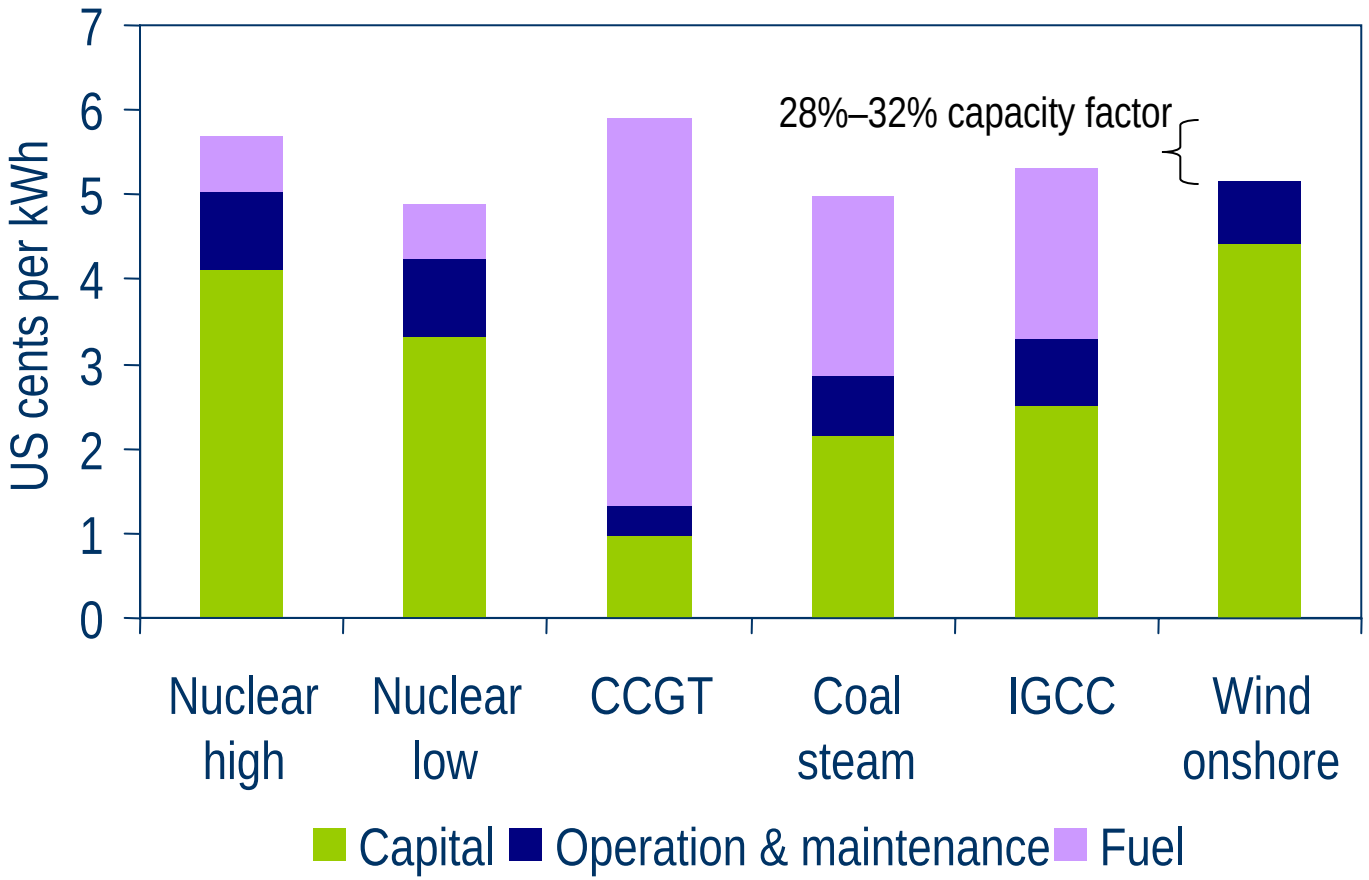
	Merchant	Traditional
Base Case ($2000/kW)	**6.7**	**5.2**
Reduce Construction Costs 25% ($1500/kW)	**5.5**	**4.4**
Reduce Construction time by 12 months	**5.3**	**4.3**
Reduce cost of capital (financing cost)	**4.2**	**3.6**
Coal-PC	**4.2**	**3.5**
Gas-Low ($3.77/MCF)	**3.8**	**3.6**
Gas-Moderate ($4.42/MCF)	**4.1**	**4.0**
Gas-High ($6.72/MCF)	**5.6**	**5.7**

Electricity Generating Costs: High Discount Rate ($2005)



Source: IEA WEO 2006

Electricity Generating Costs: Low Discount Rate ($2005)

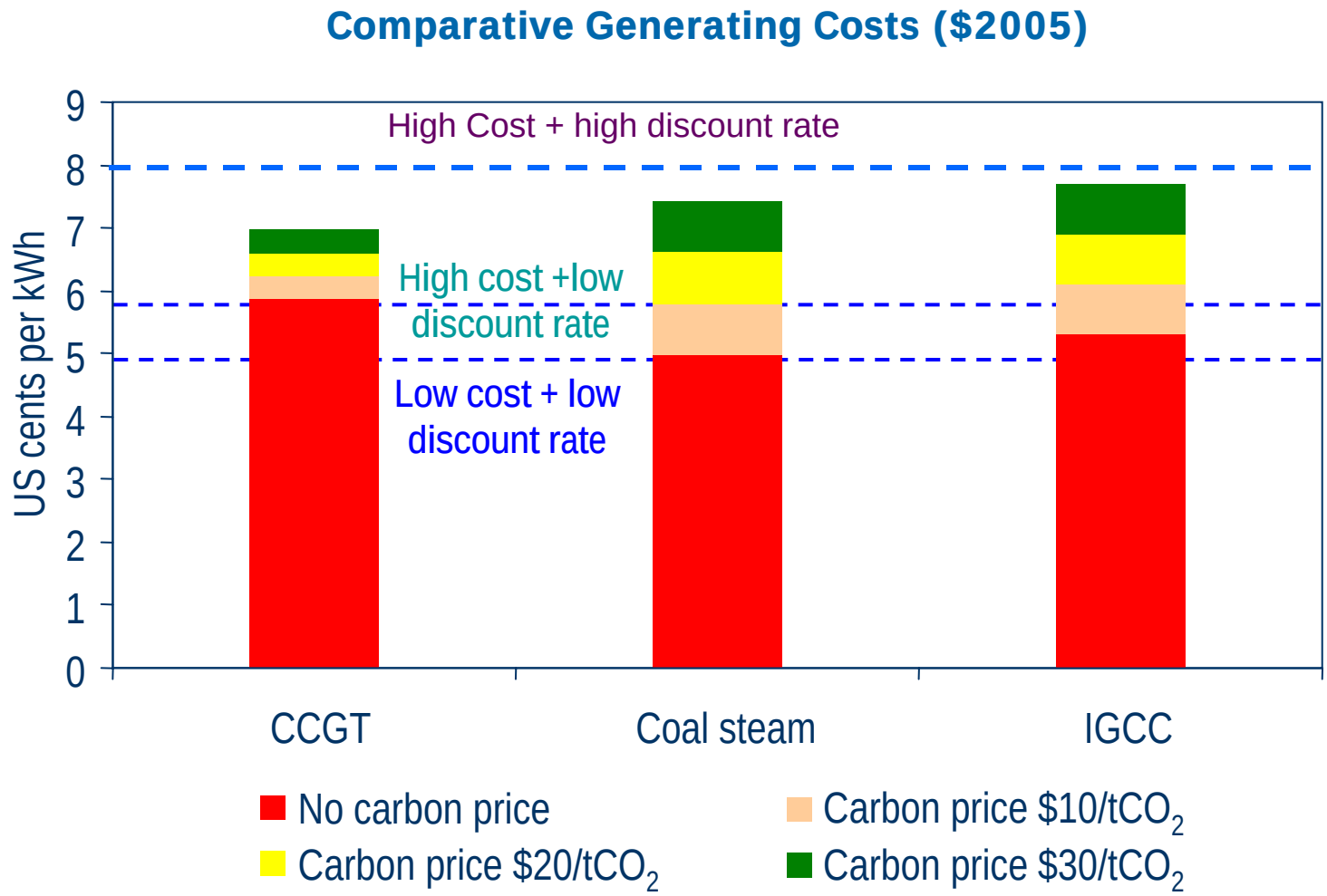


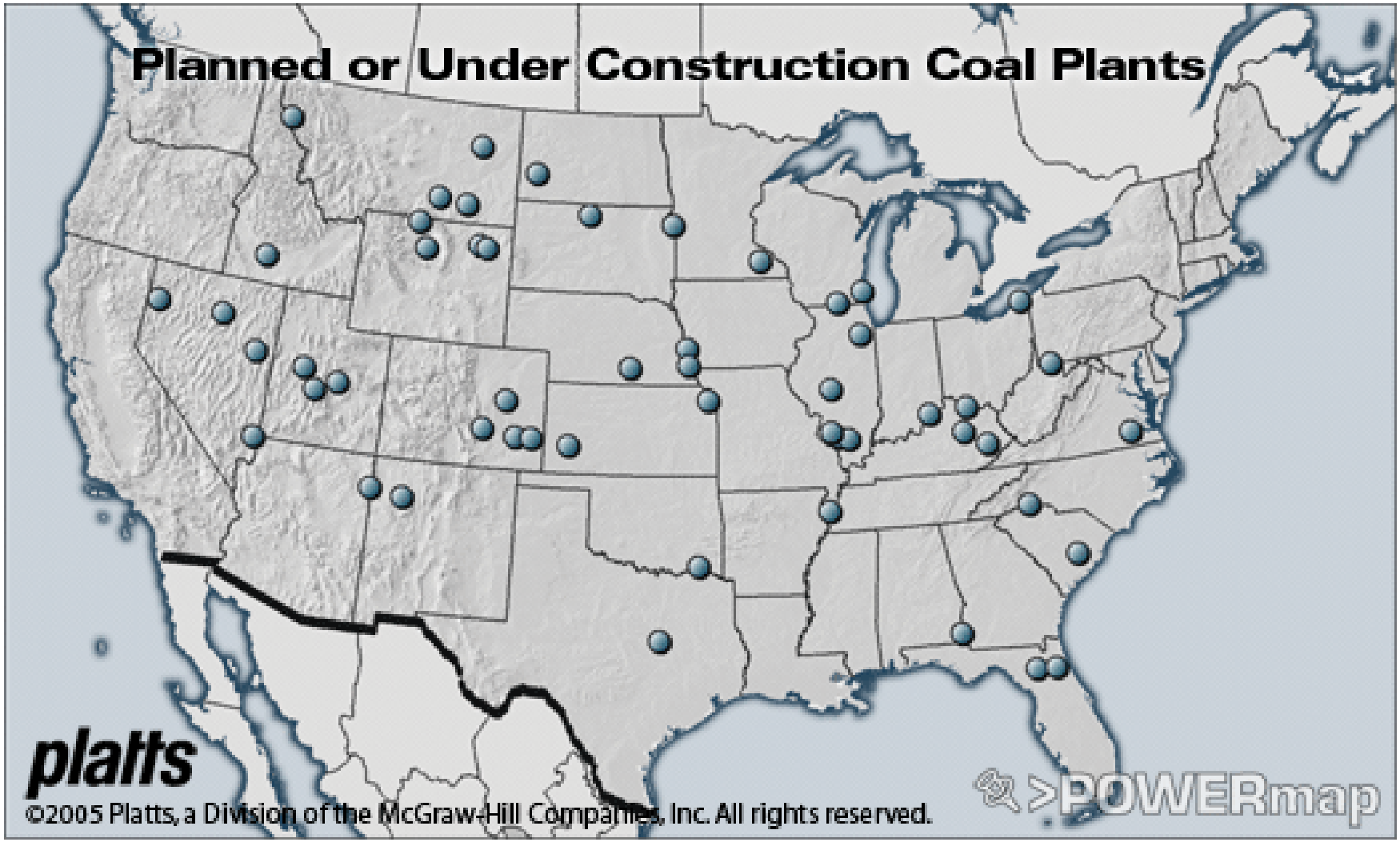
Source: IEA WEO 2006

FOSSIL GENERATION COSTS WITH CO_2 PRICES
($2002 levelized cents/kWh - Merchant)

	$13.5/tonne CO2	$27/tonne CO2	$54/tonne CO2
Coal	**5.4**	**6.6**	**9.0**
Gas (low)	**4.3**	**4.8**	**5.9**
Gas (moderate)	**4.7**	**5.2**	**6.2**
Gas (High)	**6.1**	**6.7**	**7.7**
Nuclear (base)	**6.7**	**6.7**	**6.7**
Nuclear (-25%)	**5.5**	**5.5**	**5.5**
Nuclear (low)	**4.2**	**4.2**	**4.2**

Impact of CO_2 Penalty on Competitiveness of Nuclear Power




Planned or Under Construction Coal Plants
platts
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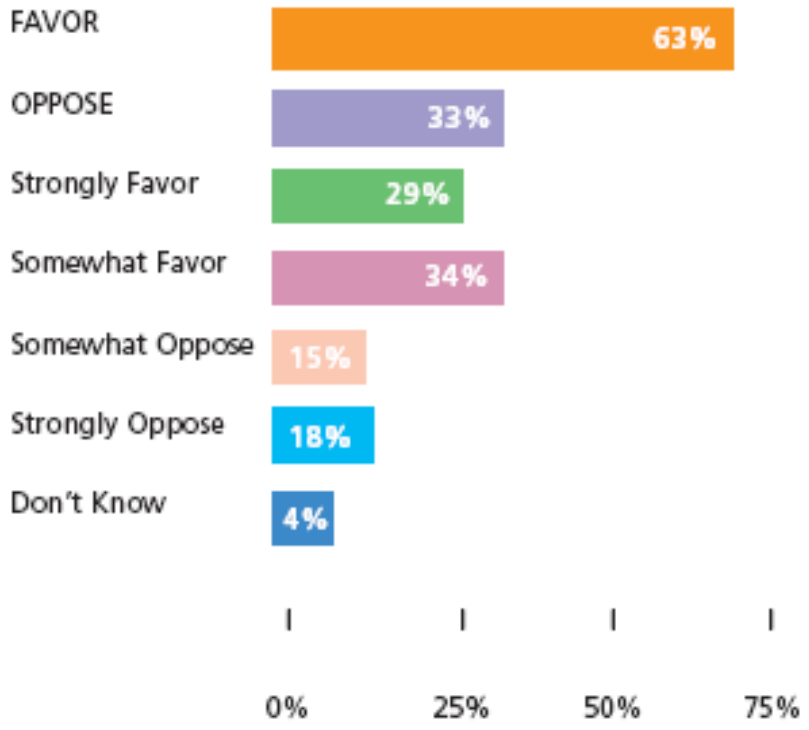
>POWERmap

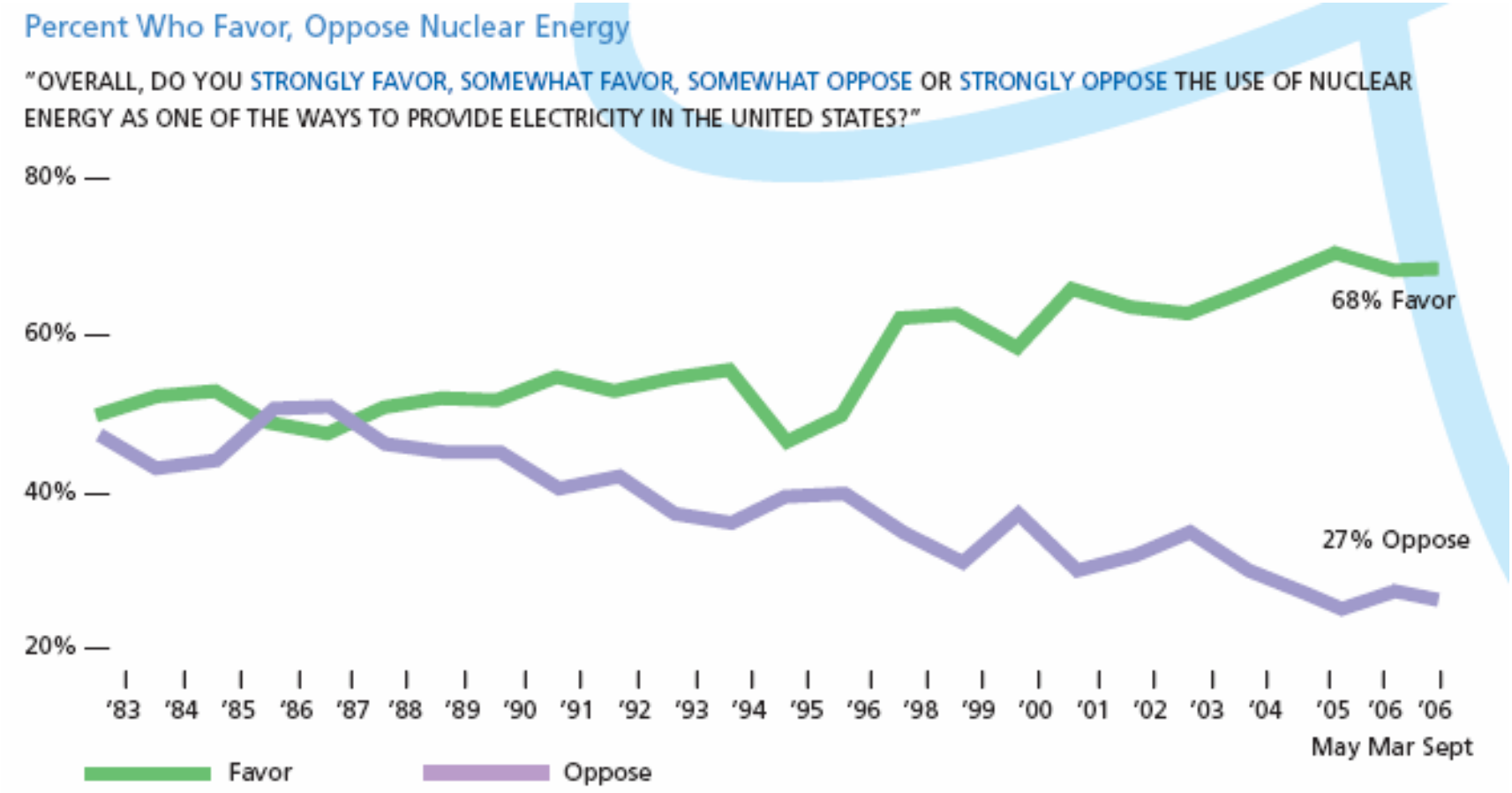
WHAT IS THE U.S. DOING TO ENCOURAGE INVESTMENT IN NUCLEAR?

- Streamline licensing process
- “First mover” financial incentives
- Resolve waste disposal deadlock
- “Moral support” for nuclear investment

BBC World Service Poll: 63 Percent of Americans Favor New Nuclear Plants

"PLEASE TELL ME IF YOU STRONGLY FAVOR, SOMEWHAT FAVOR, SOMEWHAT OPPOSE OR STRONGLY OPPOSE EACH OF THE FOLLOWING ... BUILDING NEW NUCLEAR POWER PLANTS TO REDUCE RELIANCE ON OIL AND COAL."




Percent Who Favor, Oppose Nuclear Energy
"OVERALL, DO YOU STRONGLY FAVOR, SOMEWHAT FAVOR, SOMEWHAT OPPOSE OR STRONGLY OPPOSE THE USE OF NUCLEAR ENERGY AS ONE OF THE WAYS TO PROVIDE ELECTRICITY IN THE UNITED STATES?"
80%
60%
40%
20%
68% Favor
27% Oppose
'83 '84 '85 '86 '87 '88 '89 '90 '91 '92 '93 '94 '95 '96 '98 '99 '00 '01 '02 '03 '04 '05 '06 '06
May Mar Sept
Favor
Oppose

NEI (2006)

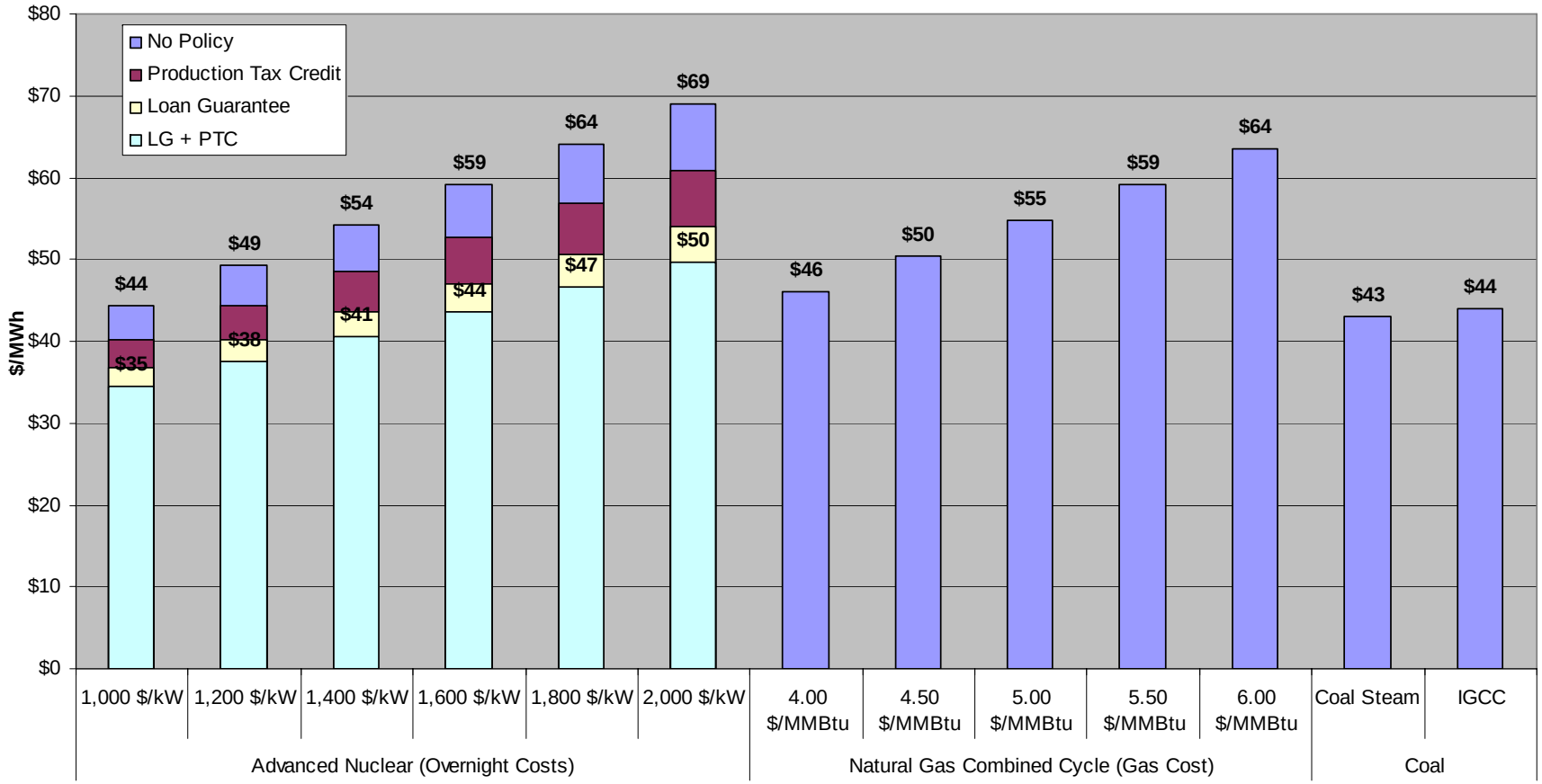
b) Building new nuclear power plants, to reduce reliance on oil and coal.

	Strongly favor	Somewhat favor	Somewhat oppose	Strongly oppose	Don't know / No answer
Australia	19	34	20	24	3
Brazil	23	24	15	35	3
Canada	22	30	18	25	6
Chile	18	24	20	24	15
Egypt	30	39	21	9	1
France	10	28	23	34	5
Germany	9	26	26	36	3
Great Britain	21	29	17	26	7
India	36	30	11	10	13
Israel	20	29	18	23	10
Italy	26	27	18	25	5
Kenya	36	30	12	15	8
Mexico	19	35	20	13	13
Philippines	27	33	20	18	2
Poland	13	18	26	30	14
Russia	5	23	36	24	12
South Korea	15	50	27	4	4
Ukraine	6	18	31	36	9
United States	29	34	15	18	4
Average	20	29	21	23	7

Energy Policy Act of 2005

- Loan guarantees for up to 80% of project cost
  - Valid for all GHG-free technologies
  - Higher leverage, lower debt cost reduces overall project cost
- Production tax credit of $18 per MWh for 8 years for new nuclear capacity through 2021, subject to 2 limitations:
  - $125 million per 1,000-MW per year
  - 6,000-MW eligible, allocated among available capacity
- Insurance protection against delays during construction and until commercial operation caused by factors beyond private sector's control
  - Coverage: $500 million apiece for first two plants, $250 million for next four
  - Covered delays: NRC licensing delays, litigation delays

The Energy Policy Act of 2005 Reduces Costs for First Movers



Source: Berger and Parsons (MIT CEEPR 2005)

NEW NUCLEAR PLANTS UNDER CONSIDERATION

Company	Site	Early Site Permit	Design	File Construction/ Operating License
Dominion	North Anna	Under Review	ESBWR	Pending (2007)
TVA (NuStart)	Bellefonte	N/A	AP1000 (2)	Pending (2007)
Entergy (NuStart)	Grand Gulf	Under Review	ESBWR	Pending (2007)
Entergy	River Bend	N/A	ESBWR	Pending (2008)
Southern	Vogtle	Submitted	AP1000	Pending (2008)
Progress Energy	Harris + TBD	N/A	AP1000 (2)	Pending (2007/08)
SCE&G	Summer	N/A	AP1000 (2)	Pending (2007)
Duke	South Carolina	N/A	AP1000 (2)	Pending (2007)

Source: Nuclear Energy Institute

NEW NUCLEAR PLANTS UNDER CONSIDERATION

Company	Site	Early Site Permit	Design	File Construction/ Operating License
Exelon	Clinton	Under Review	ND	ND
Constellation (Unistar)	Calvert Cliffs or Nine Mile Point	N/A	EPR (5)	Pending (Q4-07)
FP&L	Florida (TBD)	N/A	ND	ND
Duke	North Carolina	ND	ND	ND
Duke	South Carolina	ND	ND	ND
NRG	South Texas Proj	N/A	ABWR(2)	2007
TXU	ND	N/A	ND	2008

Source: Nuclear Energy Institute

ATTRIBUTES OF ACTIVE U.S. PROJECTS

- Companies with good nuclear operating experience (consolidation in the U.S.)
- First movers are likely to be on existing sites
- Energy Policy Act subsidies have stimulated a lot more interest
- Projects are primarily in states that have not deregulated
  - What will the regulatory framework be?
  - Construction cost caps and operating performance incentive mechanisms are likely
- No firm financial commitments have yet been made to build a new plant
  - Companies are buying options at the moment
  - Uncertainty about the competitive, regulatory, and contractual framework continue to be major issues

U.S. OUTLOOK

- EIA 2007 Reference Case for 2030
  - + 3 GW of uprates of existing plants
  - + 9 GW of new plants stimulated by federal financial incentives (shared)
  - + 3.5 GW in later years without financial subsidies
  - - 2.6 GW of retirements of older plants
  - Nuclear generation share falls from 19% to 15%
  - Lower construction costs required to stimulate more nuclear investment absent CO_2 emissions prices
- Some of the most attractive economics are in states where new nuclear plants will be opposed by local authorities (California, New England, New York)
- Realistic best case scenario would have first new nuclear plant in operation in 2015 on an existing site