Financing New Nuclear Generation

John E. Parsons, MIT
July 9, 2009
EPRG / CEEPR / GDF Suez
European Electricity Workshop

MIT CEEPR
MIT Center for Energy and Environmental Policy Research

Outline

- Broad Overview: Update of the MIT 2003 Future of Nuclear Power
- Updated Economics of New Builds
- Specifics on Financing New Builds

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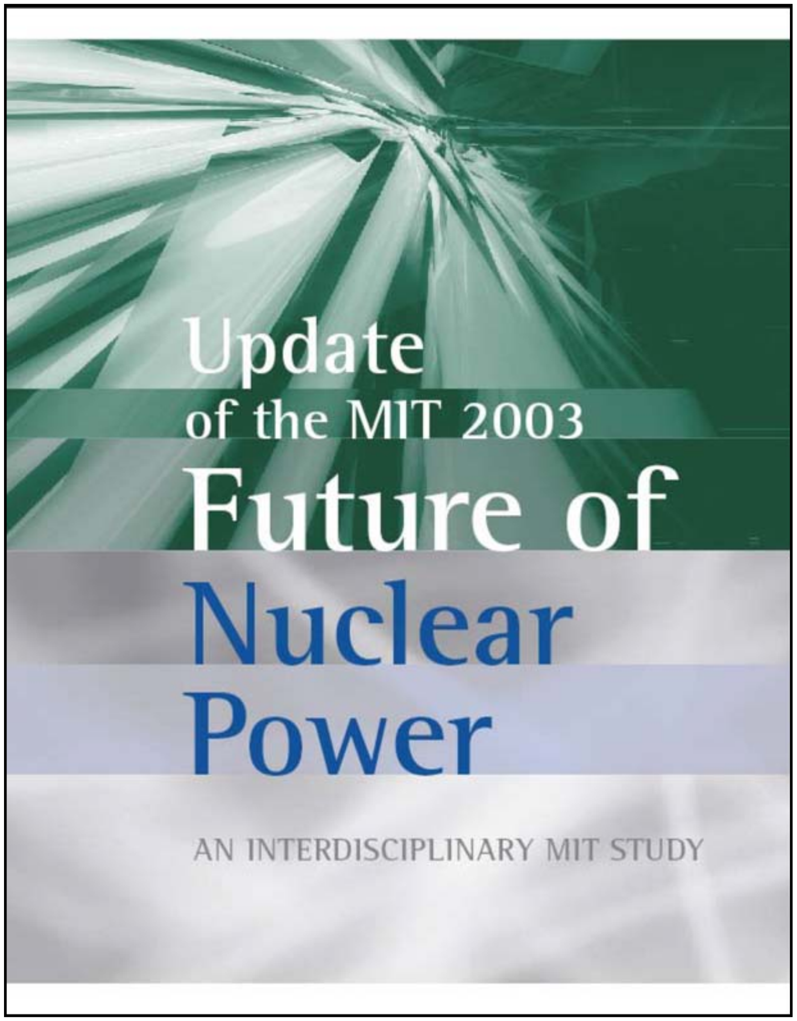

General Conclusion: Progress Has Been Very Slow

"…while there has been some progress since 2003, increased deployment of nuclear power has been slow both in the United States and elsewhere in the world… While the intent to build new plants has been made public in several countries, there are only few firm commitments outside of Asia… to construction projects at this time. Even if all the announced plans for new nuclear power plant construction are realized, the total will be well behind that needed for reaching a thousand gigawatts of new capacity worldwide by 2050. In the U.S, only one shutdown reactor has been refurbished and restarted and one previously ordered, but never completed reactor, is now being completed. No new nuclear units have started construction. In sum, compared to 2003, the motivation to make more use of nuclear power is greater, and more rapid progress is needed in enabling the option of nuclear power expansion to play a role in meeting the global warming challenge. The sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation."

Update of the MIT 2003 Future of Nuclear Power

Positive Steps in the U.S.

- The performance of the 104 U.S. nuclear plants since 2003 has been excellent.
  - The fleet-averaged capacity factor since 2003 has been maintained at about 90%.
- Extended operating licenses.
  - The earlier trend to obtain license extensions has continued. Almost all reactors will have license extensions.
  - Furthermore, modest power uprates have been granted in that period, adding about 1.5 GWe to the licensed capacity.
- Changes in the NRC regulations in the 1990s…
  - a design certification process,
  - site banking, and
  - combined construction and operation licensing.
  - The Energy Policy Act of 2005 authorized DOE to share the cost with selected applicants submitting licenses to the NRC to help test this new licensing approach.
- Energy Policy Act of 2005 limited support for new builds
  - Production tax credits for first 6 GW
  - Loan guarantees, $18B. Authorized
  - License process guarantees
- Seventeen applications for combined construction and operating licenses for 26 reactors have been submitted to the NRC. (now 18 for 28)
  - Preliminary work required before construction is underway for many of these plants.
  - However financing and firm commitment to construction remains ahead. Authority will undoubtedly be slowed by the current dismal economic situation.

Updated Economics of New Builds

MIT Center for Energy and Environmental Policy Research

General conclusion in re economics

- 2003 report:
  - "In deregulated markets, nuclear power is not now cost competitive with coal and natural gas.
  - However, plausible reductions by industry in capital cost, operation and maintenance costs and construction time could reduce the gap.
  - Carbon emission credits, if enacted by government, can give nuclear power a cost advantage."
- "The situation remains the same today.
  - While the US nuclear industry has continued to demonstrate improved operating performance, there remains significant uncertainty about the capital costs, and the cost of its financing, which are the main components of the cost of electricity from new nuclear plants."

Update of the MIT 2003 Future of Nuclear Power

Disparate Estimates of the Cost of Construction

REUTERS

10 August 2007

"NRG Energy has signed Toshiba Corp. to head a $6 billion to $7 billion project to install two reactors in Texas…"

St. Petersburg Times

31 January 2008

"FPL's estimates for [the] two-reactor project run from $12-billion to $18-billion."

$6 billion ÷ (2*1,350MW) = $2,200/kW

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2.1–3.7 times

Different Estimates Largely Reflects Different Quotation Methods: Illustration

Table 2: Alternative Cost Quotation Methods for Nuclear Power Plants Illustrated with a Hypothetical Example

		[A]	[B]	[C]	[D]	[E]	[F]
[1]	Project Period (relative to start)	-4	-3	-2	-1	0	
[2]	Year	2009	2010	2011	2012	2013	Total
[3]	Construction Schedule as a Fraction of EPC Cost, $2007	10%	25%	31%	25%	10%	100%
[4]	Vendor EPC Overnight Cost, $2007	318	833	1,030	833	318	3,333
[5]	Vendor EPC Cost, Nominal Dollars as Expended @ 3% Inflation	337	911	1,160	966	380	3,753
[6]	Owner's Costs, Nominal Dollars as Expended	67	182	232	193	76	751
[7]	Transmission System Upgrades, Nominal Dollars as Expended				145	57	202
[8]	Total Cost, excl. Capital Recovery Charge, Nominal Dollars as Expended	405	1,093	1,391	1,304	513	4,706
[9]	Capital Recovery Charge @ 11.5%		47	178	358	549	1,131
[10]	Total Cost, incl. Capital Recovery Charge	405	1,139	1,569	1,662	1,062	5,837
[11]	Total Cost, incl. Capital Recovery Charge, Cumulative	405	1,544	3,113	4,775	5,837	
[12]	Total Outlay, Nominal Dollars as Expended	405	1,093	1,391	1,159	456	4,504
[13]	Total Cost (incl. capital charge), $2013	626	1,515	1,730	1,292	456	5,619
[14]	Overnight Cost, $2007	382	1,000	1,236	1,000	382	4,000
[15]	Overnight Cost, $2013	456	1,194	1,476	1,194	456	4,776

From Du and Parsons, CEEPR Working Paper 09-004.

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Different Estimates Largely Reflects Different Quotation Methods: NRG & FPL

- NRG South Texas Project estimate
  - EPC only; excludes owner's costs.
  - Overnight cost, 2006 dollars; excludes inflation to dates of build.
- FPL Turkey Point estimate
  - Includes transmission system upgrades needed independent of the plant built.
  - Includes inflation to the completion of the build.
  - Includes financing costs (AFUDC).
- Consistent basis:
  - Overnight cost, 2007$, exclusive of transmission & financing.
  - NRG: $3,480/kW
  - FPL: $3,530/kW

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  - FPL: $3,530/kW

<u>identical</u> !!!

Comparison of 5 Nuclear Build Proposals in the US

Table 4: Overnight Costs for Some Proposed Nuclear Plants in the US

	Owner [A]	Name of Plant [B]	Design [C]	Capacity MW [D]	Projected Commercial Operation Date [E]	Overnight Cost US 2007 $/kW [F]
[2]	FPL	Turkey Point 5 & 6	ESBWR	3,040	2018-2020	3,530
[3]	Progress Energy	Levy County 1 & 2	AP1000	2,212	2016-2017	4,206
[4]	SCEG/Santee-Cooper	V.C. Summer 2 & 3	AP1000	2,234	2016-2019	3,787
[5]	Southern	Plant Vogtle 2 units	AP1000	2,200	2016-2017	4,745
[6]	NRG	South Texas 3 & 4	ABWR	2,700	2014-2015	3,480

From Du and Parsons, CEEPR Working Paper 09-004.

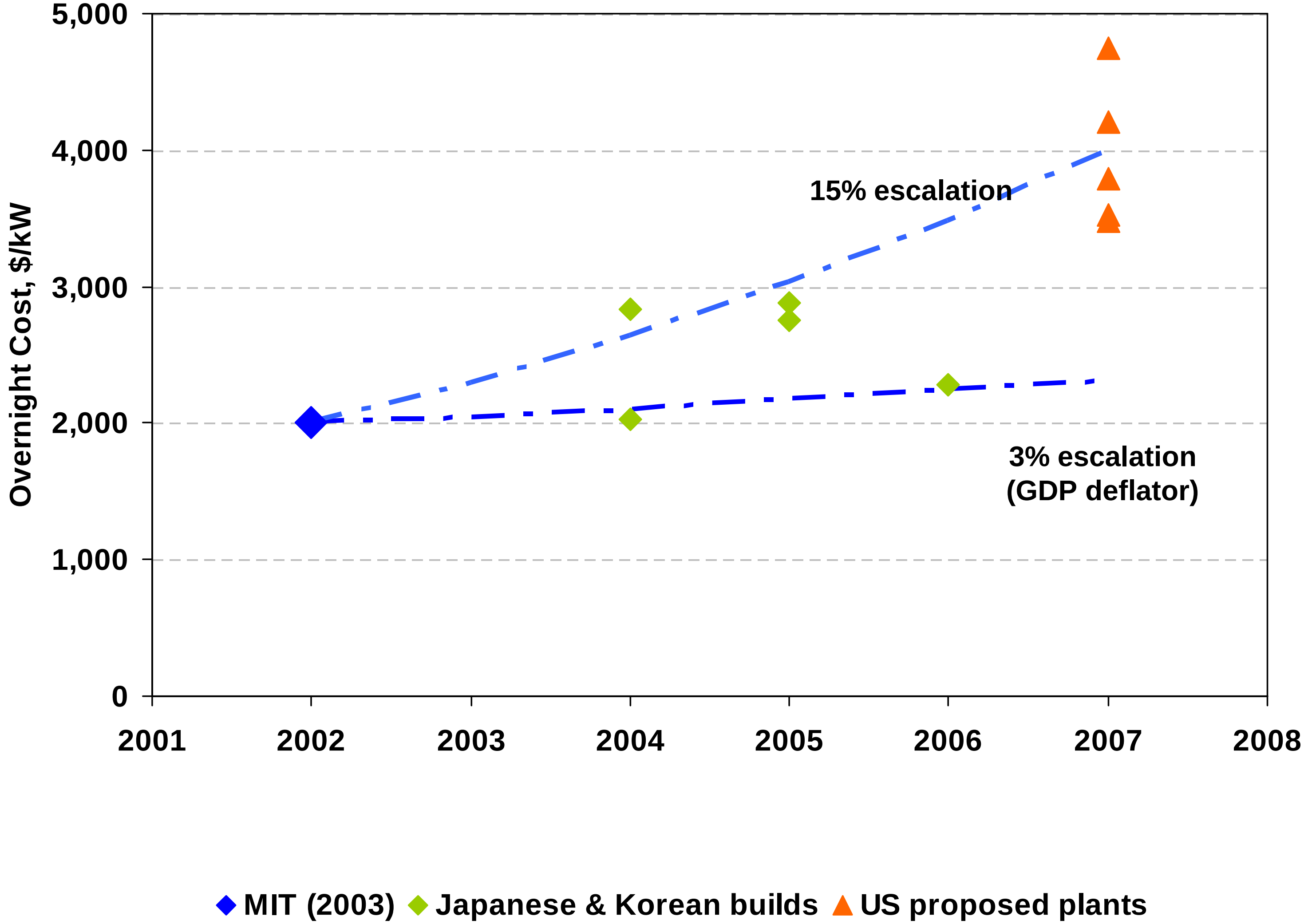
Recent Builds in Japan and Korea

Table 3B: Overnight Costs for Actual Builds in Japan and Korea 2004-2006

	Owner	Name of Plant	Design	Capacity MW	Commercial Operation Date	Total Project Cost: Domestic Currency millions	Total Project Cost: PPP Factor	Total Project Cost: US Equivalent $/kW	Overnight Cost: Overnight Cost Factor	Overnight Cost: US various yrs $/kW	Overnight Cost: Inflation Factor	Overnight Cost: US 2007 $/kW
	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]
[7]	Chubu Elec	Hamaoka-5	ABWR	1,325	2004	360	134	2,023	90%	1,820	1.52	2,759
[8]	Tohoku Elec	Higashidori-1	BWR	1,067	2005	390	130	2,821	90%	2,539	1.32	3,351
[9]	Hokuriku Elec	Shika-2	ABWR	1,304	2006	370	124	2,280	90%	2,052	1.15	2,357
[10]	KHNP	Ulchin-5	OPR	995	2004	2,236	794	2,830	78%	2,207	1.52	3,346
[11]	KHNP	Ulchin-6	OPR	994	2005	2,234	789	2,849	78%	2,222	1.32	2,932

From Du and Parsons, CEEPR Working Paper 09-004.

Overnight Cost Summary: Nuclear



From Du and Parsons, CEEPR Working Paper 09-004.

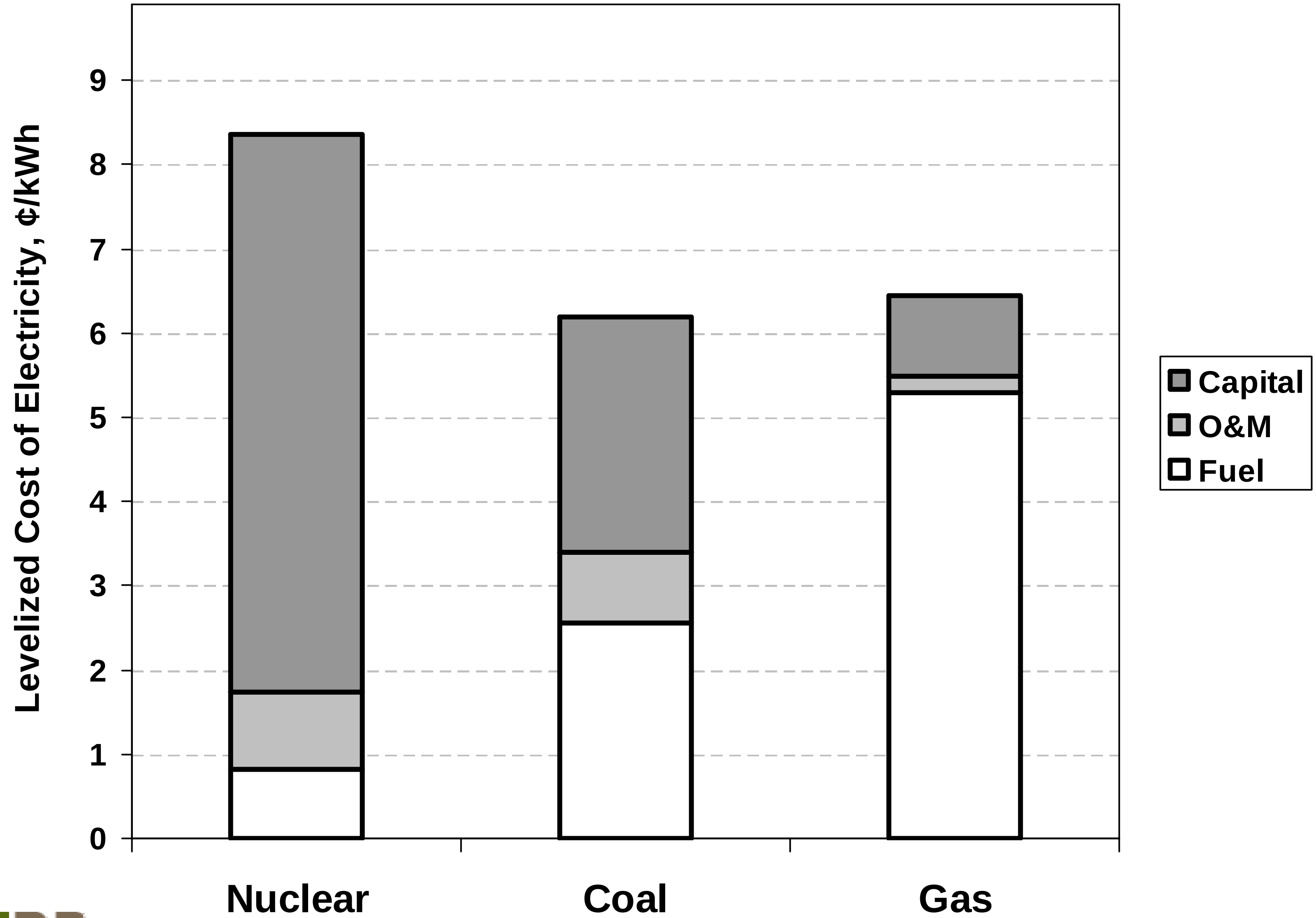
Update of the economics to reflect climbing costs (cont.)

Table 1: Summary of Results

	MIT (2003) $2002					Update $2007				
			LCOE					LCOE		
	Overnight Cost	Fuel Cost	Base Case	w/ Carbon Charge $25/tCO2	w/ same cost of capital	Overnight Cost	Fuel Cost	Base Case	w/ Carbon Charge $25/tCO2	w/ same cost of capital
	$/kW	$/mmBtu	¢/kWh	¢/kWh	¢/kWh	$/kW	$/mmBtu	¢/kWh	¢/kWh	¢/kWh
Nuclear	2,000	0.47	6.7		5.5	4,000	0.67	8.4		6.6
Coal	1,300	1.20	4.3	6.4		2,400	2.60	6.2	8.3	
Gas	500	3.50	4.1	5.1		900	7.00	6.5	7.4	

From Du and Parsons, CEEPR Working Paper 09-004.

Figure 1: Summary Results for the Levelized Cost of Electricity from Alternative Sources



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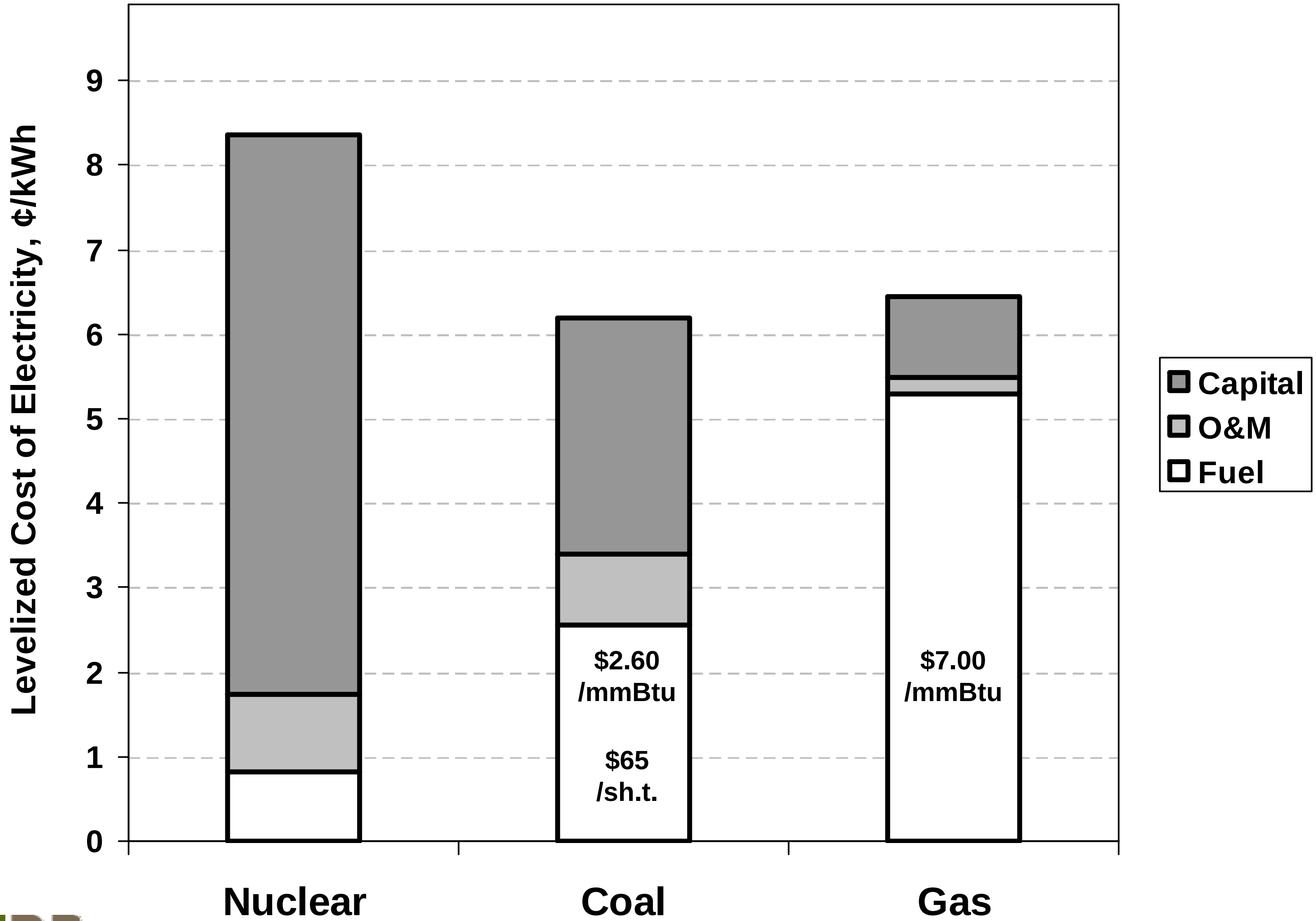

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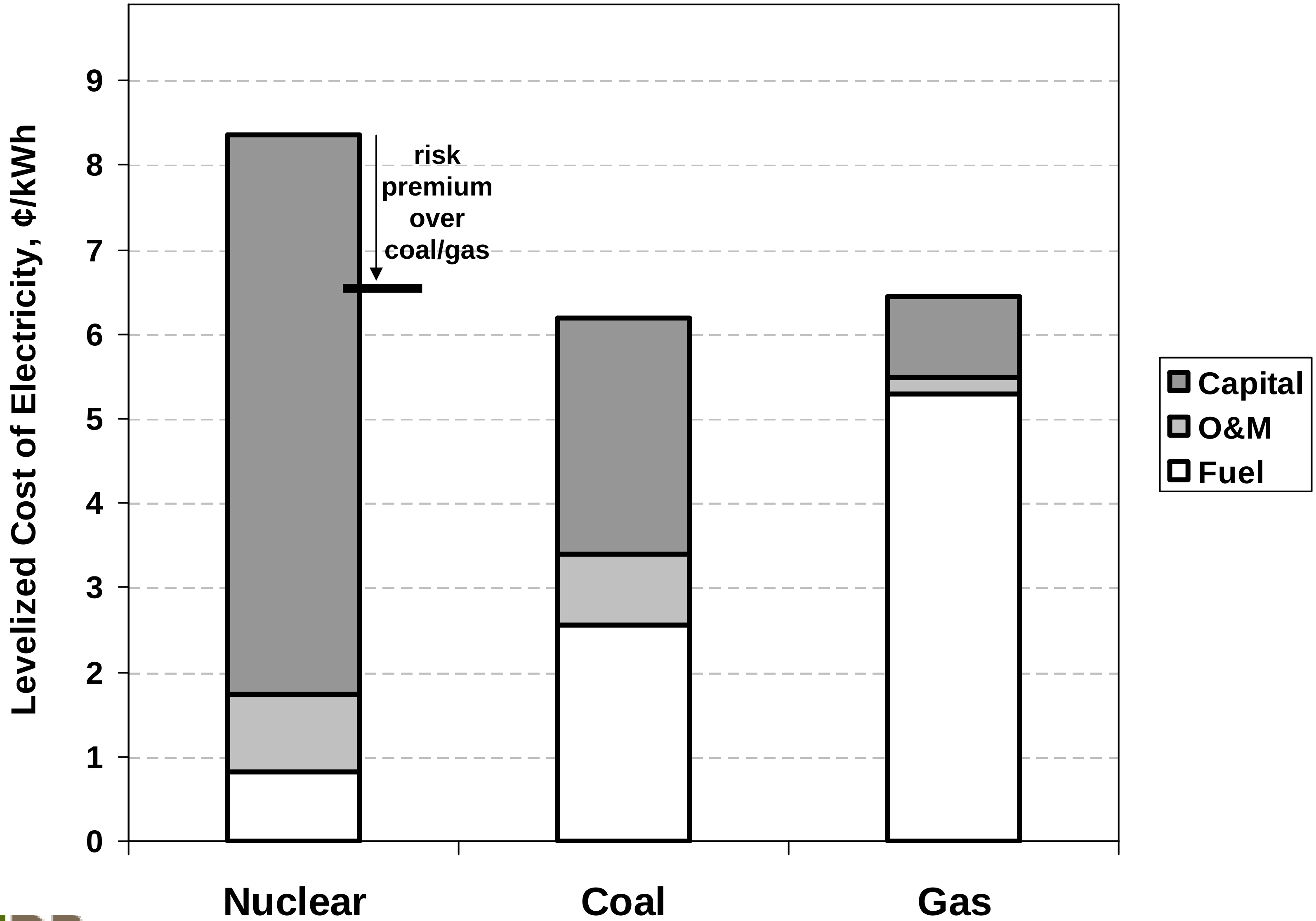

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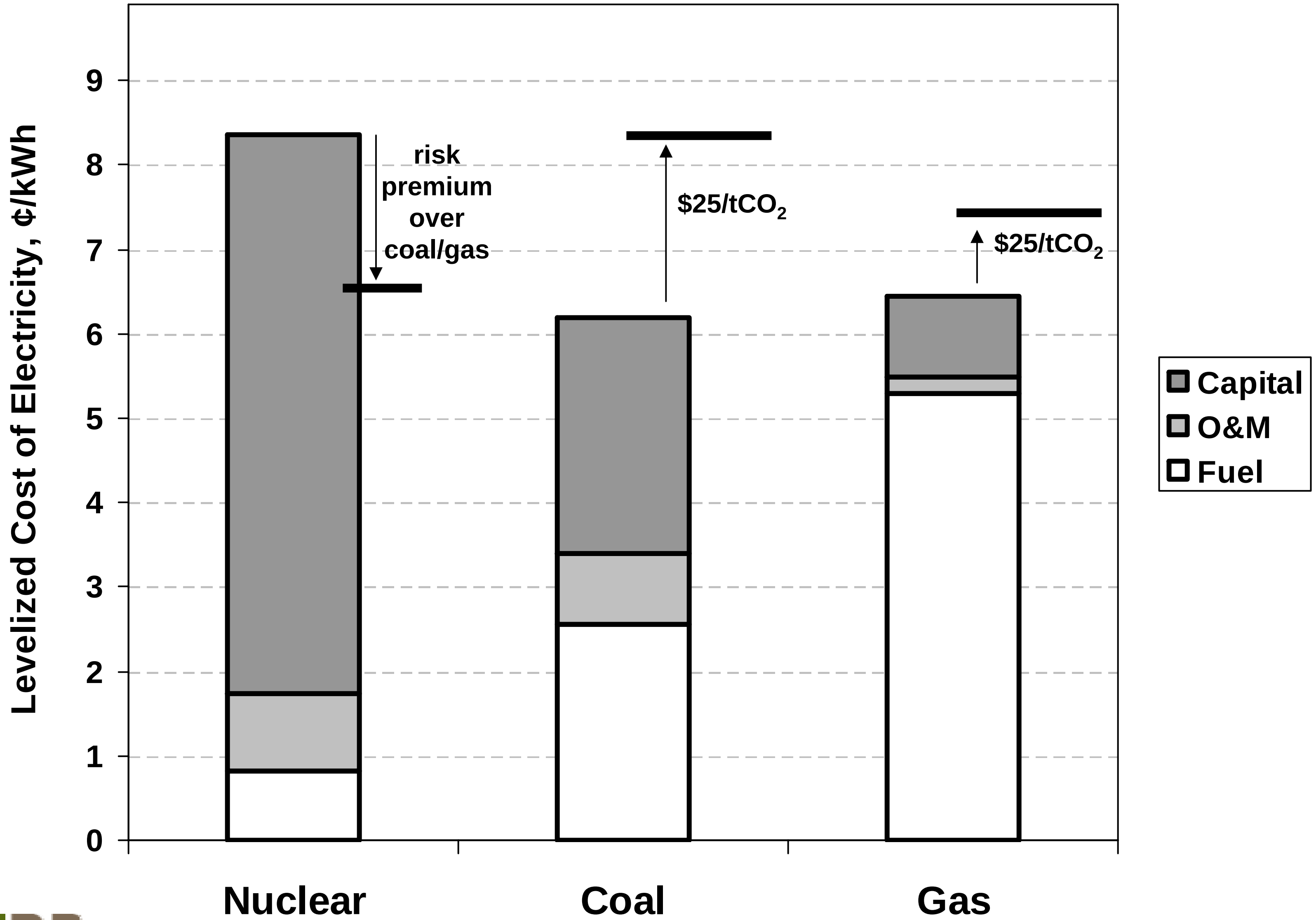

Lowering capital costs and risks is a key challenge still before us

- The track record for the construction costs of nuclear plants during the 1980s and early 1990s was poor. Actual costs were far higher than had been projected. Construction schedules experienced long delays, which resulted in high financing charges. New regulatory requirements also contributed to the cost increases, and in some instances, the public controversy over nuclear power contributed to some of the delays and cost overruns.
- While the plants in Korea and Japan continue to be built on schedule, some of the recent construction cost and schedule experience, such as with the plant under construction in Finland, has not been encouraging.
- Whether the lessons learned from the past have been factored into the construction of future plants has yet to be seen. These factors have a significant impact on the risk facing investors financing a new build.
- For this reason, the 2003 report applied a higher weighted cost of capital to the construction of a new nuclear plant (10%) than to the construction of a new coal or new natural gas plant (7.8%).

Update of the MIT 2003 Future of Nuclear Power

Lowering capital costs and risks is a key challenge still before us (cont.)

- Lowering or eliminating this risk-premium makes a significant contribution to making nuclear competitive.
  - With the risk premium and without a carbon charge, nuclear is more expensive than either coal (without sequestration) or natural gas (at $7/mmBtu). If this risk premium can be eliminated, nuclear cost decreases from 8.4 to 6.6 ¢/kWe-h and becomes competitive with coal and gas, even in the absence of carbon charge.
- The 2003 report found that capital cost reductions and construction time reductions were plausible, but not yet proven – this judgment is unchanged today. The challenge facing the U.S. nuclear industry lies in turning plausible reductions into reality.
  - Will designs truly be standardized, or will site-specific changes defeat the effort to drive down the cost of producing multiple plants?
  - Will the licensing process function without costly delays, or will the time to first power be extended, adding significant financing costs?
  - Will construction proceed on schedule and without large cost overruns?
  - The first few U.S. plants will be a critical test for all parties involved. The risk premium will be eliminated only by demonstrated performance.

Government incentives and regulation

- Both government and industry have their part to play in lowering this risk premium. The 2003 report advocated limited government assistance for "first mover" nuclear plant projects. Three principles underpinned the proposed government assistance:
  - First, financial assistance for nuclear should be comparable to assistance extended to other low-carbon electricity generation technologies, for example wind, geothermal, and solar.
  - Second, an appropriate degree of risk should remain with the private sector so as to motivate cost and schedule discipline.
  - Third, government assistance should be limited to the first mover cohort without the expectation of longer-term assistance. That is, different power generation technologies should compete based on economics in a world where CO_2 emissions are priced, and where technologies are not mandated by required quotas for certain types of generation.

Update of the MIT 2003 Future of Nuclear Power

Government incentives and regulation (cont.)

- The Energy Policy Act of 2005 authorized assistance for new nuclear plant construction including loan guarantees, insurance against delays, and production tax credits for the first 6 GWe of new plants.
- However, implementation of the first mover assistance program as proposed in the 2003 study has not yet been effective in moving utilities to make firm reactor construction commitments for three reasons.
- First, the DOE has not moved expeditiously to issue the regulations and implement the federal loan guarantee program.
- Second, renewable portfolio standards (RPS) are the mechanism of choice for encouraging carbon-free technologies.
  - Unfortunately, most RPS programs exclude two important low-carbon technologies, nuclear and coal with CO2 sequestration, confusing the objective of reducing carbon emissions with encouraging renewable energy in electricity generation.
  - When a RPS specifies the technology (example: wind) rather than the goals (low-carbon emissions), the utility can no longer choose the most economic method to produce electricity within the constraint of low-carbon emissions.
  - If a carbon emission tax or cap and trade system is implemented in parallel, other inefficiencies may result. The RPS requires utilities to adopt specific technologies rather than select the most economic method to achieve lower carbon emissions. As a consequence, the emission permit prices in the parallel cap and trade system will be lower than prices without a RPS, possibly inhibiting the introduction of low-carbon technologies not included in the RPS.

Government incentives and regulation (cont.)

- Third, in a change from 2003, the nuclear industry facing increased cost estimates is arguing that more assistance is needed to demonstrate the economic viability of nuclear.
  - While some modification of the “first mover” program is likely necessary because of the impact of the financial crisis on capital markets, the justification for government “first-mover” assistance is to demonstrate technical performance, cost, and environmental acceptability, not to extend a government subsidy for nuclear (or any other energy technology) indefinitely into the future. Consequently, any expansion of such a federal program should have limited duration.

Update of the MIT 2003 Future of Nuclear Power

Waste Management

- There is no plan for high-level wastes; but the administration has committed to a comprehensive review of waste management. In conclusion, the progress on high-level waste disposal has not been positive.

Update of the MIT 2003 Future of Nuclear Power

Specifics on Financing New Builds

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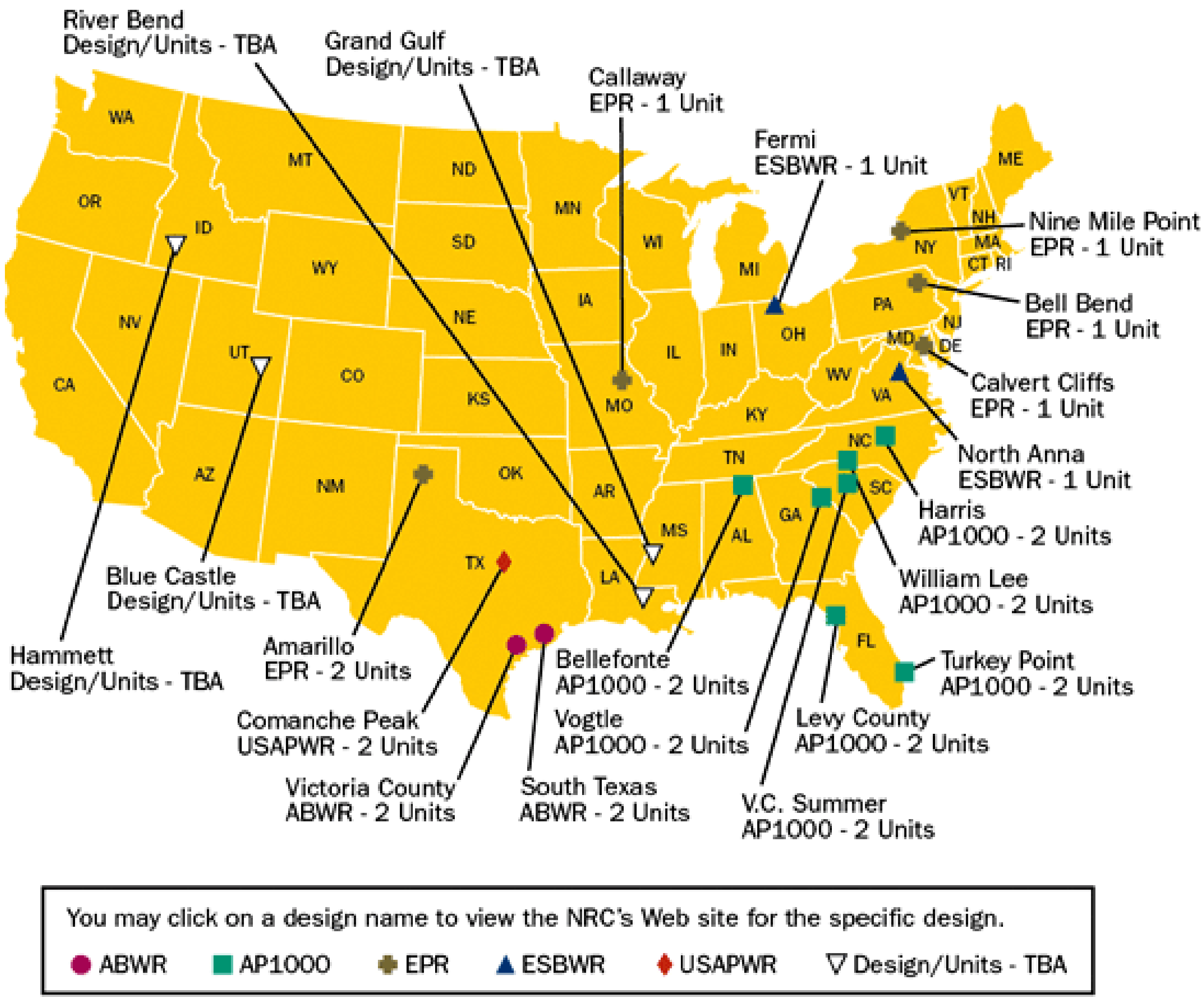
Proposed Plants: US NRC
28 Units with COL Applications Filed



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4 Lead Units for U.S. Gov't Loan Guarantees

May 2009, US Department of Energy selected 4 projects for more intense due diligence on their application for loan guarantees:

- Constellation Energy's Calvert Cliffs Unit #3 (EPR)
- NRG's South Texas Units #3 & #4 (ABWR)
- South Carolina Electric & Gas' V.C. Summer Units #2 & #3 (AP1000)
- Southern Company's Vogtle Units #3 & #4 (AP1000)

- While the law allows guarantees for more units, the DoE says that the current $18.5 billion budget authorization will probably be exhausted by these projects.

NRG's South Texas Units #3 & #4

NRG's South Texas Units #3 & #4

- ABWR design by GE, Hitachi & Toshiba
  - 1,350 MW capacity
  - Design certified by US NRC
  - 4 built in Japan
- Combined Construction & Operating License application filed
  - Hoped for "notice to proceed" in 2012
- EPC contract negotiated with Toshiba
  - Time and materials basis until "Final Notice to Proceed" is issued when it converts to a lump sum turnkey contract.
- Projected in service 2016 & 2017

Financing Plan for South Texas

Current ownership

- 50% City of San Antonio (CPS)
- 50% NRG/Toshiba Joint Venture
  - NINA LLC, Nuclear Innovation North America
  - 88% NRG, 12% Toshiba at end of 6 years

Funding expenditures before licensing (2012)

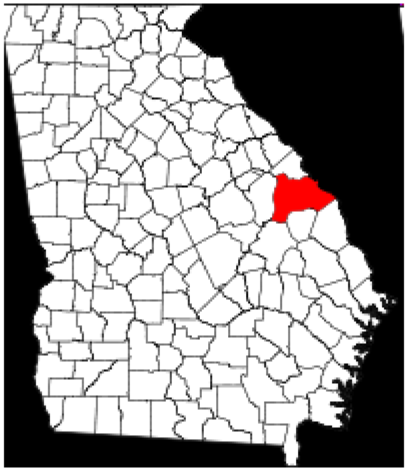
- $150 million from Toshiba's cash contribution to NINA
- NRG's management contribution to NINA
- $500 million credit from Toshiba for long lead time material purchases during open book phase; to be taken out by debt financing at "Final Notice to Proceed"

Financing Plan for South Texas (cont.)

Ultimate financing vision

- $4.7 billion per unit ($2007), MIT est.
- 80% debt, 20% equity
- Debt to be guaranteed piecewise by US and Japanese governments
- Equity
  - 40% San Antonio
  - 40% NRG/Toshiba (NINA)
  - 10% hoped for new equity owner
- Lump sum turnkey EPC from Toshiba
- PPAs
  - San Antonio equity stake equals 40% of capacity
  - MOUs signed for 40% of capacity, mix of industrials & load serving entities
- Production tax credits from Energy Policy Act of 2005
  - $18/MWhr or $125mm per year per 1000 MW maximum
- Licensing insurance under Energy Policy Act of 2005

Southern's Vogtle Units #3 & #4



Southern's Vogtle Units #3 & #4

- AP1000 design by Westinghouse
  - 1,100 MW capacity
  - Design certified by US NRC
- Combined Construction & Operating License application filed
  - Hoped for "notice to proceed" in 2012
- EPC contract negotiated with Westinghouse and Stone & Webster
  - Details are confidential. Escalation clauses assumed.
- Projected in service 2016 & 2017

Financing Plan for Vogtle

- $5.2 billion per unit ($2007), MIT est.

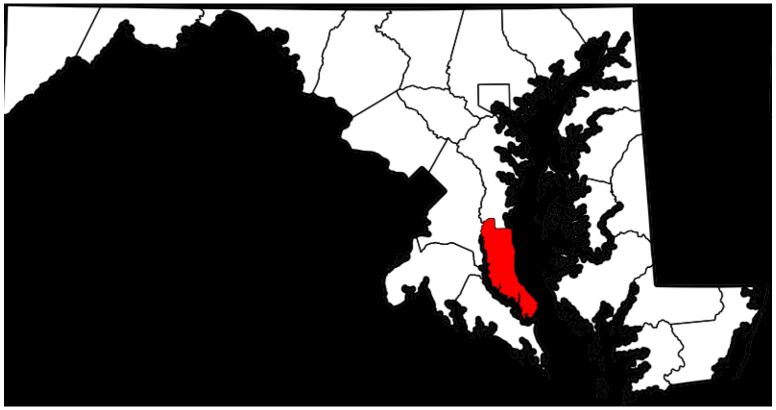
Ownership

- Same as existing Vogtle units…
  - 45.7% Georgia Power (Southern Co.) / Operator
  - 30% Oglethorpe Power, GA (coop of locals)
  - 22.7% Municipal Electric Authority of GA (corp of locals)
  - 1.6% City of Dalton, GA

Funding

- Southern is 56% debt financed; debt to be guaranteed by US government
- Georgia Power is sanctioned to charge 30% of in-service costs as Construction Work in Progress (CWIP)…i.e., advanced rate hike
- Regulated utilities and coops; after construction approval, cost goes into rates
- Production tax credits from Energy Policy Act of 2005
  - $18/MWhr or $125mm per year per 1000 MW maximum
- Licensing insurance under Energy Policy Act of 2005

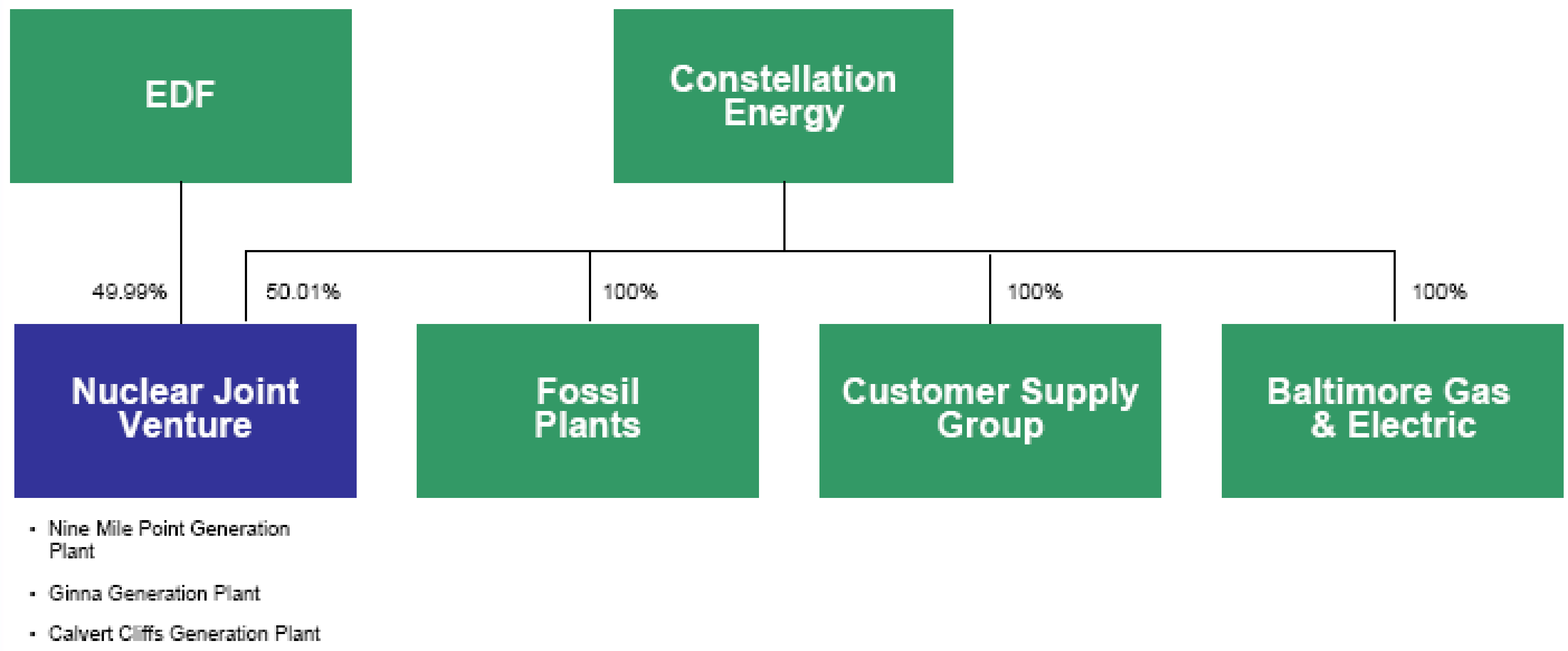
Constellation's Calvert Cliffs Unit #3



Constellation's Calvert Cliffs Unit #3

- EPR design by AREVA
  - 1,600 MW capacity
  - Application made for design certification to US NRC
- Combined Construction & Operating License application filed
  - Hoped for "notice to proceed" in 2012
- Unistar JV includes, in addition to Constellation and EDF, AREVA, Bechtel and Alstom
  - AREVA and Alstom making plant investments in US now.
- Projected in service 2016.

Financial Structure of Constellation / EDF



Unistar

- **Calvert Cliffs #3**
- **Future EPRs**

Financing Plan for Calvert Cliffs

- Costs and financing plan are unknown.
- Construction and operating costs are divided 50/50 by Constellation and EDF.
- Project is to be 100% merchant. No PPAs.
  - Initially, Constellation will market the power.

Conclusions on Financing

- All conclusions are tentative. No decisions in favor of actual construction have been made.
- Most of the early new-build proposals were in states with traditional cost-of-service regulations where the capital costs incurred, possibly including cost overruns, could be passed along to customers. However, some key proposed plants are being built in states with restructured wholesale markets.
- Long-term commitments for the sale of power currently play a key role, whether through the regulatory process or through negotiated bilateral contracts. Constellation's Calvert Cliffs Unit #3 is an exception in this regard and it will be interesting to see how this proceeds.
- Vendor commitments and financing appear key to the initial builds. This is true both in the degree of risk that vendors and contractors are willing to assume, and also in explicit financial support. This is not likely to be a long-term element of a vibrant industry.

The End

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LCOE Assumptions Update

Table 5: Base Case Assumptions and Inputs for the Levelized Cost of Electricity

	Input	Units	Nuclear [A]	Coal [B]	Gas [C]
[1]	Capacity	MW	1,000	1,000	1,000
[2]	Capacity Factor		85%	85%	85%
[3]	Heat rate	Btu/kWh	10,400	8,870	6,800
[4]	Overnight Cost	$/kW	4,000	2,300	850
[5]	Incremental capital costs	$/kW/year	40	27	10
[6]	Fixed O&M Costs	$/kW/year	56	24	13
[7]	Variable O&M Costs	mills/kWh	0.42	3.57	0.41
[8]	Fuel Costs	$/mmBtu	0.67	2.60	7.00
[9]	Waste fee	$/kWh	0.001		
[10]	Decommissioning cost	$ million	700		
[11]	Carbon intensity	kg-C/mmBtu		25.8	14.5
[12]	Inflation Rate		3.0%	3.0%	3.0%
[13]	O&M real escalation		1.0%	1.0%	1.0%
[14]	Fuel real escalation		0.5%	0.5%	0.5%
[15]	Tax Rate		37%	37%	37%
[16]	Debt fraction		50%	60%	60%
[17]	Debt rate		8%	8%	8%
[18]	Equity rate		15%	12%	12%
[19]	WACC (weighted avg cost of capital)		10.0%	7.8%	7.8%