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Electricity Policy Research Group

Investment in Nuclear Energy

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Some things change and some things stay the same…

Let us start with the relatively fixed realities of nuclear power

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Capital costs dominate

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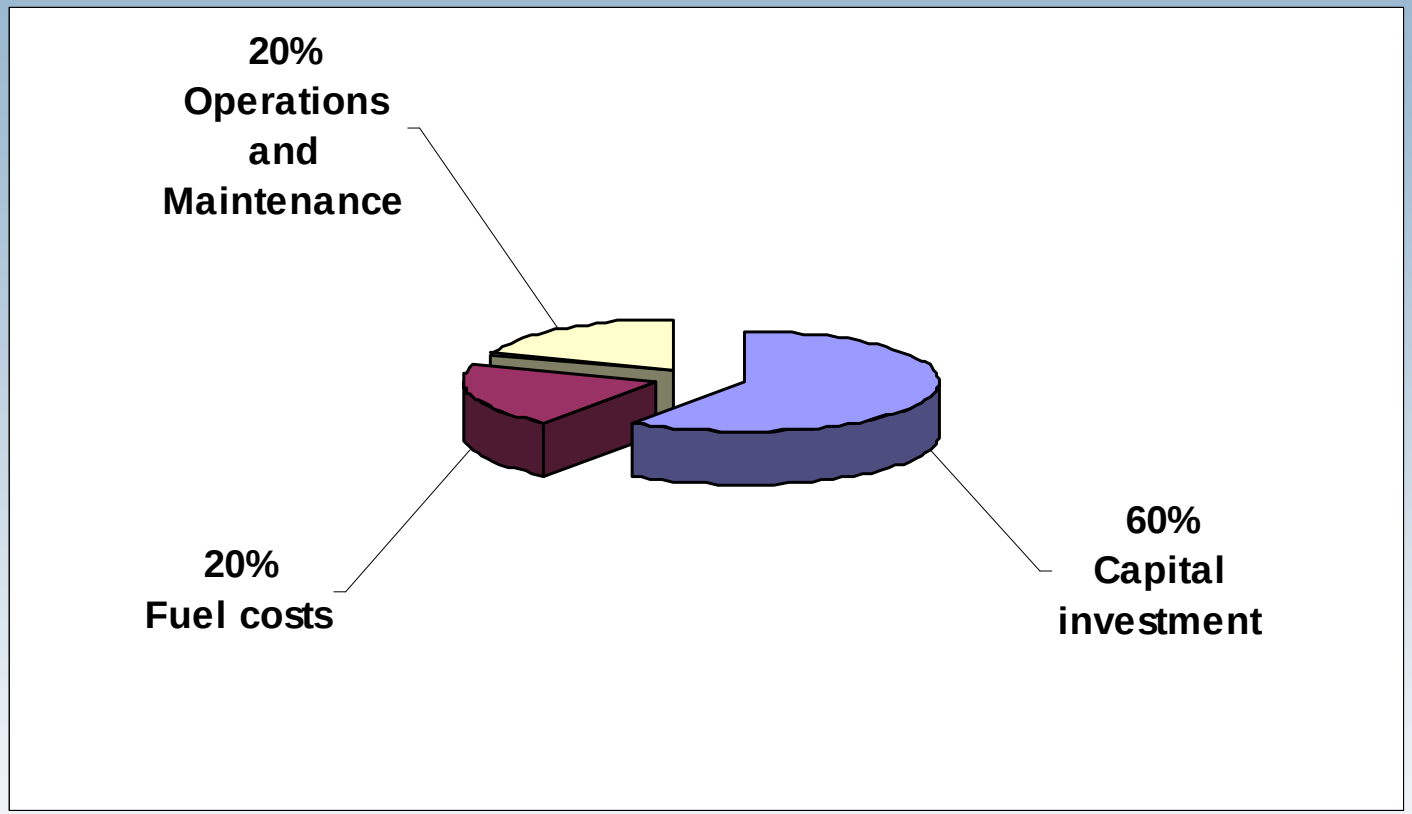

Approximate breakdown of lifetime costs of a nuclear power plant. Capital investment is the most significant factor in the economics of nuclear power. See: Nuclear Energy Agency, *Reduction of Capital Costs of Nuclear Power Plants,* OECD, Paris (2000)

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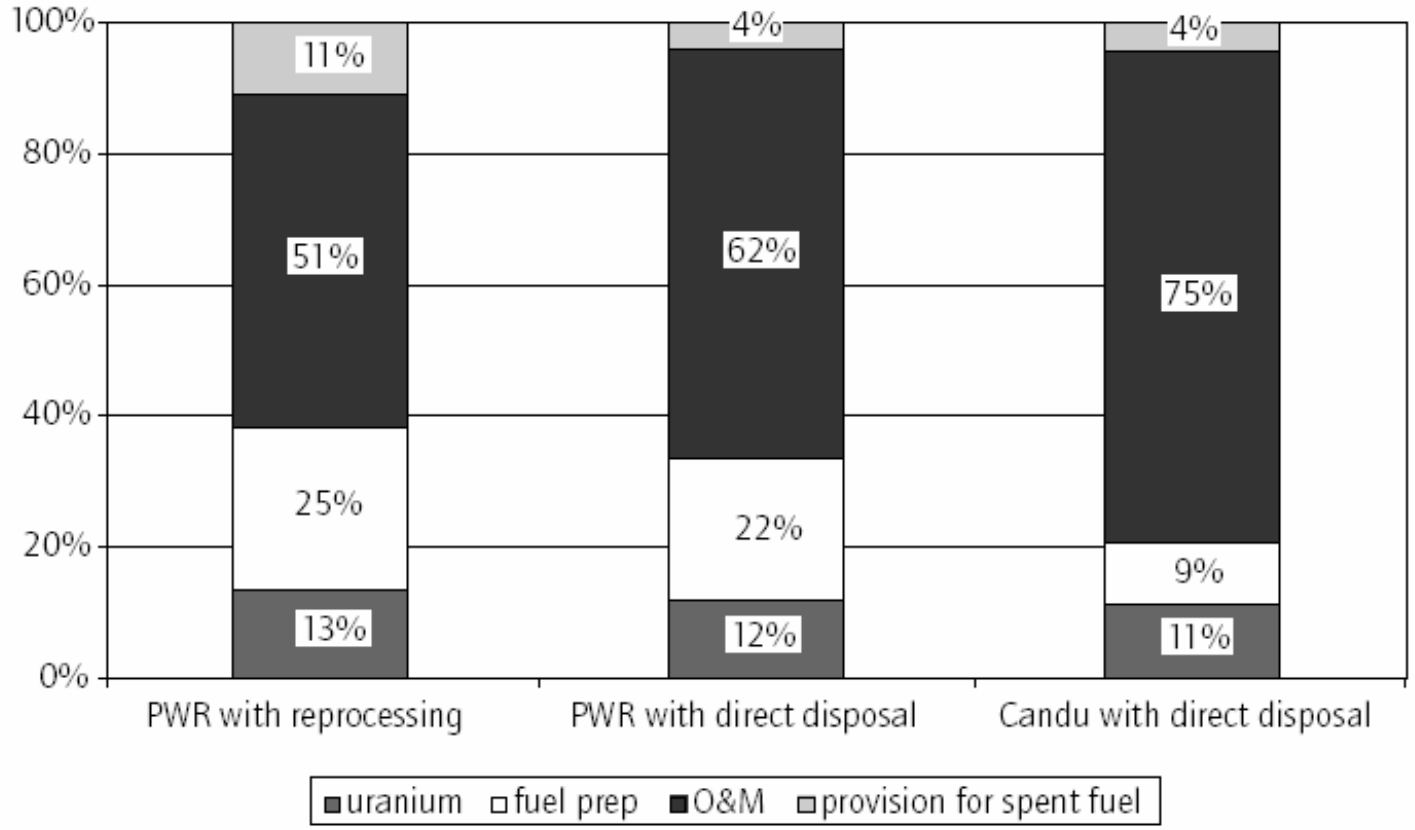
Fuel and O&M Costs



Average nuclear plant operating cost breakdowns excluding capital additions, and assuming levelised cost shares at a 10% discount rate. Note typically decommissioning costs are less than 1% of ongoing operating costs

Nuclear Power in the OECD, IEA (2001)

Real Construction Costs (Japan) approx. US$ 2,500/kWe

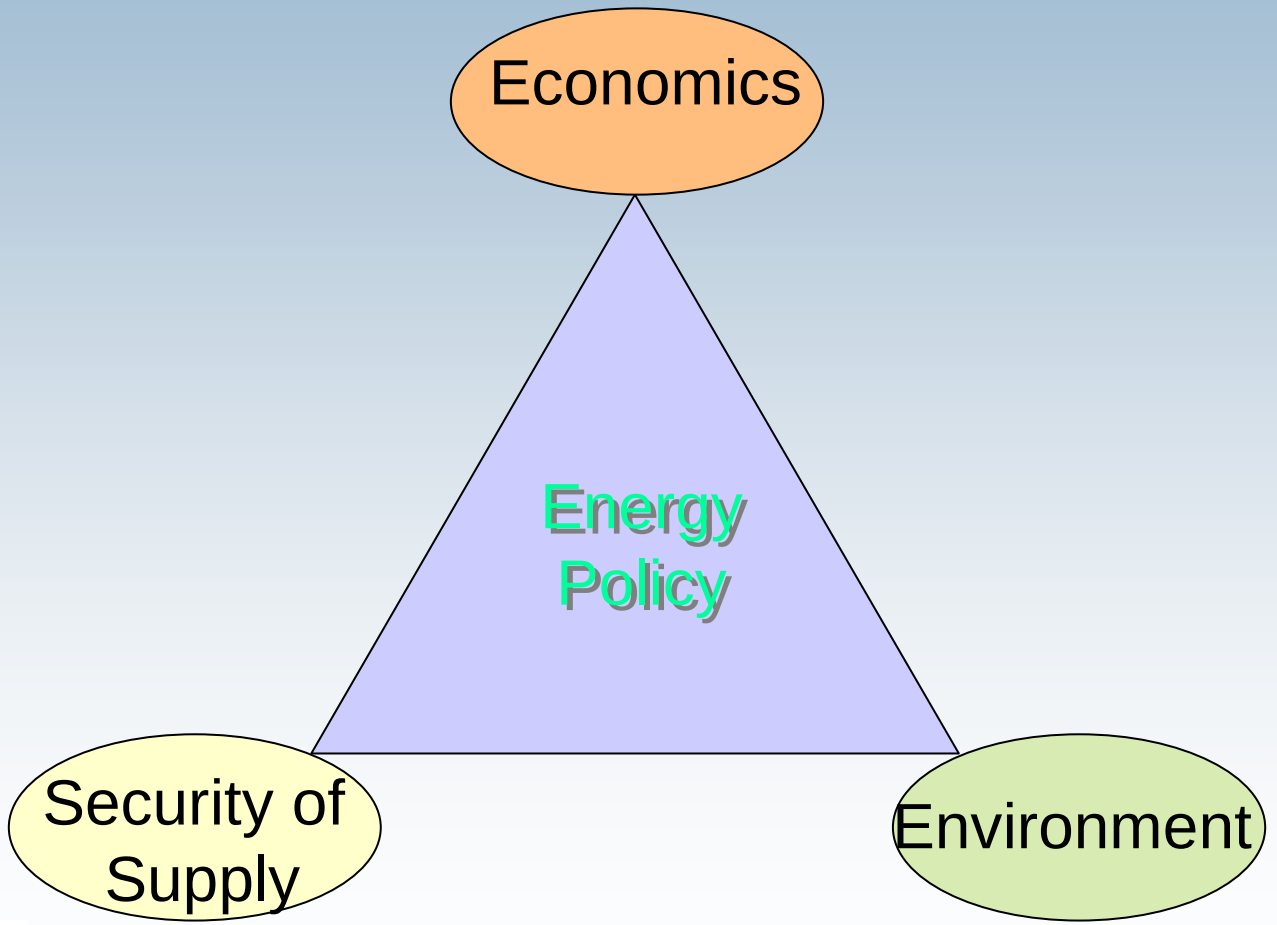
Table A-5.B.3

OWNER	NAME OF PLANT	CAPACITY	COMMERCIAL OPERATION DATE	TOTAL PROJECT COST (10⁹ YEN)	U.S. EQUIVALENT[a]
Tohoku Electric	Onagawa 3 (BWR)	825 MWe	January 2002	314	$2,409/kWe
Kyusyu Electric	Genkai 3 (PWR)	1,180 MWe	March 1994	399	$2,818/kWe
	Genkai 4 (PWR)	1,180 MWe	July 1997	324	$2,288/kWe

Note: Compiled from public information by the MIT Center for Energy and Environmental Policy Research.
a: Using PPP of 158 yen / U.S. dollar.

MIT Report, *The Future of Nuclear Power* (2003)

The Energy Policy Triangle



"The day I hear that Britain is really to build seven large new nuclear power plants is the day I know that cheap British electricity will not return in my lifetime"

Bill Nuttall

Economic risks

The fundamental economic risks of nuclear power are:

- High costs of capital (high discount rates and rates of return)
- Overrun of construction phase (lost time is lost money)
- Future electricity prices (as for any power technology)
- Changes of safety or environmental regulation during planning and construction
- Political risk and public acceptance problems
- Risk of a low carbon price
- Poor plant reliability in operational phase (low load factor)

Data Source: World Nuclear Association

http://www.world-nuclear.org/info/inf41.html#App1

Economic Non-Risks

For nuclear power the following factors are relatively minor:

- **Decommissioning costs** (40-60 years in the future)
- **Fuel costs** (raw U_3O_8 is only a few % of total costs)
- **Geopolitical risks** (fuel is easily stored and is regarded as “domestic” for energy security)

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Risks in construction

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Most of the big risks apply before the plant is generating, shown here in red:

- High costs of capital (high discount rates and rates of return)
- Overrun of construction phase (lost time is lost money)
- Future electricity prices (as for any power technology)
- Changes of safety or environmental regulation during planning and construction
- Political risk and public acceptance problems
- Risk of a low carbon price
- Poor plant reliability in operational phase (low load factor)

This makes existing plant much more attractive than planned plant

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First signs of the renaissance

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Summer 1999, the 670 MWe Pilgrim plant was sold to **Entergy**, by **Boston Edison**, for $14 million: **US$20/kWe**

March 2000, **Entergy Corporation** reached agreement to buy the New York Power Authority's Indian Point-3 (965 MWe) and Fitzpatrick (778 MWe) nuclear power plants for US$ 967 of which $636 million was for the two mid 1970s units: **US$ 364/kWe**

In August 2000 **Dominion Resources** agreed to pay US$ 1.3 billion in cash for the Millstone nuclear plant, about **US$600/kWe**

November 2000 **Entergy** purchased ConEd's 939 MWe Indian Point-2 unit (including the shut down unit 1 and 76 MWe of gas turbine capacity). The price was $502 million: **US$494/kWe**

August 2001 **Entergy Corporation** became the successful bidder for the 29-year old Vermont Yankee power station. Entergy paid $180 million for the 522 MWe plant; **US$344/kWe**

April 2002: Sale of 88.2% of Seabrook PWR NPP, New Hampshire USA. Plant operational 1986. Sale price for the plant US$749M equating to US**$ 730/kWe**

November 2003 **Dominion** agreed to pay $220 million cash for Kewaunee, a 540 MWe Wisconsin reactor, the figure including $36.5 million for fuel. **US$339/kWe**

November 2003, **Constellation Energy** agreed to buy the R E Ginna nuclear power plant for $401 million.A planned uprate enabled by 1996 steam generator replacement will increase capacity to 580 MWe: **US$ 691/kWe**

March 2004 Cameco Corp. agreed to buy 25.2% of the South Texas Project - two 1250 MWe PWRs which started up 1988-89 - for $279 million plus fuel, but two of the owners then exercised right of first refusal, leaving Cameco with a $7 million consolation fee **US$453/kWe**

July 2006 **Entergy** agreed to buy the 798 MWe Palisades nuclear power plant from CMS subsidiary Consumers Energy for US$ 242 million: **US$301/kWe**

December 2006 **FPL Energy** agreed to buy the Point Beach nuclear plant. The two units total 1012 MWe - price $719 million for the plant: **US$1407/kWe**

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Data Source: World Nuclear Association

http://www.world-nuclear.org/info/inf41.html#App1

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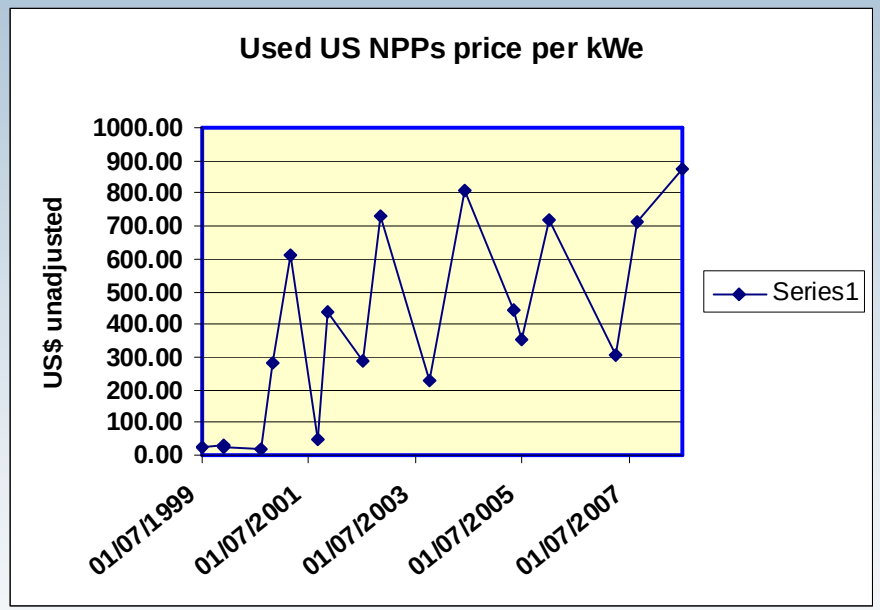
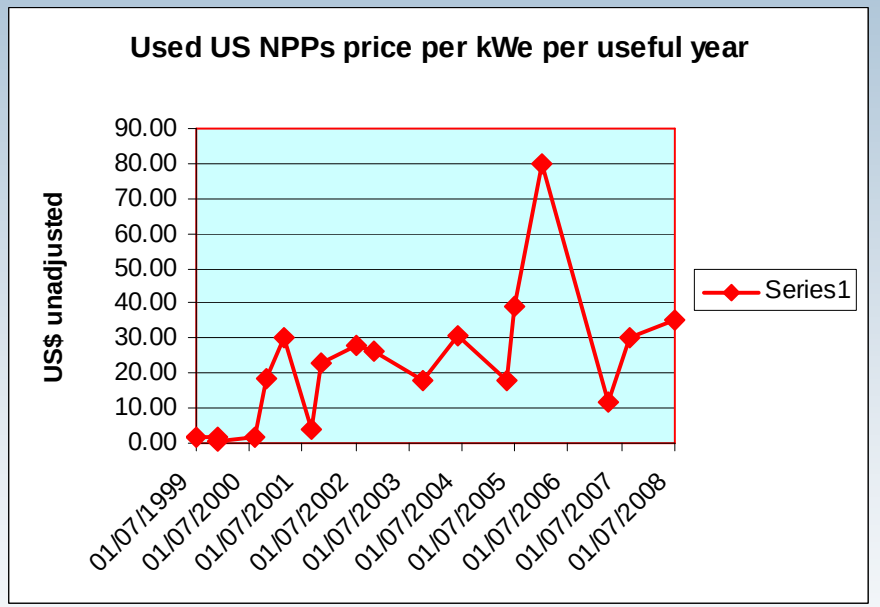
In the 1990s used NPPs were cheap, then …



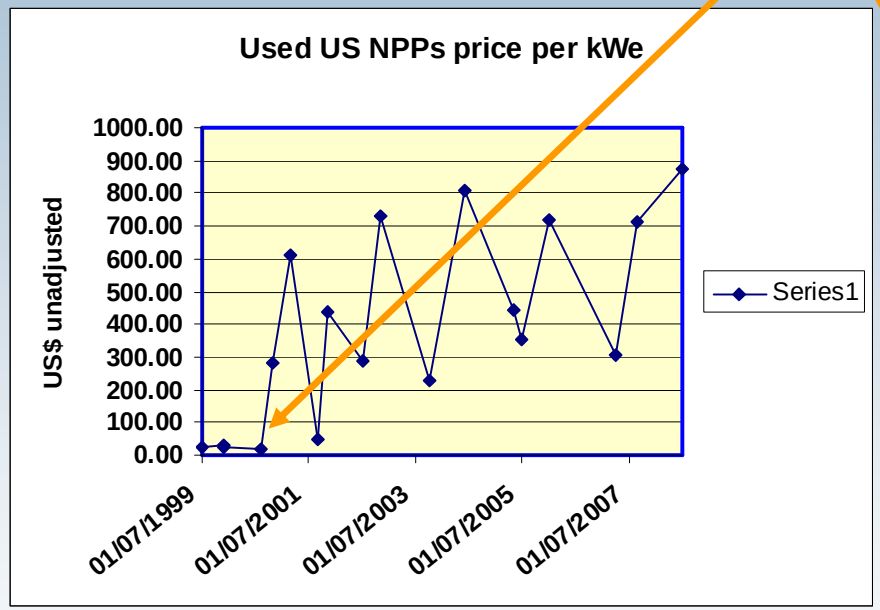


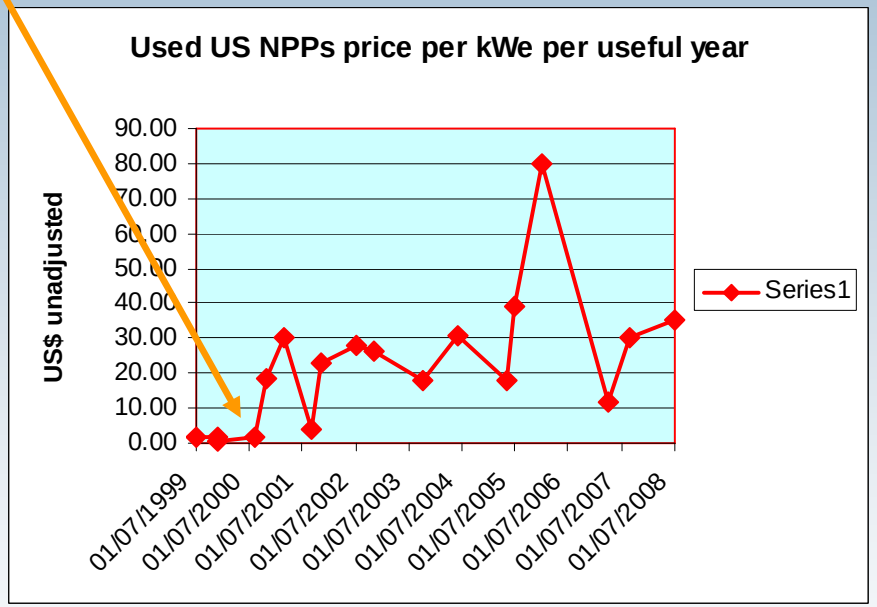
Data Source: World Nuclear Association

http://www.world-nuclear.org/info/inf41.html#App1

Graphs above are based upon directly on WNA tabulated data rather than the related information on the previous slide

Nuclear Renaissance?





In the US in the 1990s:

Oil, gas and coal were inexpensive

There was no hint of a carbon tax

US liberalising markets were compensating for NPP stranded assets

US NPP load factors were not yet impressive

Another early sign of the renaissance

2002:

Decision made for Browns Ferry Unit 1 Restart, Alabama USA. The background was:

Boiling Water Reactor operational from 1973

Shutdown by fire for one year in 1975

The fire prompted much general concern about fire safety

Extended safety-based shutdown from 1985

But … after major investment unit restarted 2007.

This story features in the 2003 MIT Report, *The Future of Nuclear Power,* page 140 (appendix to chapter 5)

But what about New Build?

WNA Meta-Study December 2005

Table 3: Studies of comparative costs of new generating plants

	MIT (2003) $	DGEMP (2003) euros	T&L (2003) euros	RAE (2004) £	UofC (2004) $	CERI (2004) Can$
Capital Cost per kW						
Nuclear	2000	1280	1900	1150	1500	2347
Gas	500	523	600	300	590	711
Coal	1300	1281	860	820	1189	1600
Construction period - years						
Nuclear	5	5	5	5	5	5
Gas	2	2	2	2	2	2
Coal	4	3	3	4	4	4
Cost of capital or D rate %						
Nuclear	11.5	8	5	7.5	12.5	8
Gas	9.6	8	5	7.5	9.5	8
Coal	9.6	8	5	7.5	9.5	8
Gas price	3.50/MBTU	3.30/MBTU	3.00/GJ	2.18/GJ	3.39/MBTU	6.47/Mcf
Electricity price per MWh						
Nuclear	67	28	24	23	51	53
Gas	38	35	32	22	33	72
Coal	42	34	28	25	35	48
Electricity price, nuclear=100						
Nuclear	100	100	100	100	100	100
Gas	57	125	133	96	65	136
Coal	63	121	117	109	69	89

Sources: see Appendix

Much diversity of assumptions:

- Capital costs +/- 25%
- Cost of capital 5%-12.5%
- Gas power to nuclear power price ratio: 0.57 – 1.33

The New Economics of Nuclear Power, available at:
http://www.world-nuclear.org/reference/pdf/economics.pdf

MIT Report Assumptions

Table A-5.A.4 Base Case Input Parameters

YEAR	NUCLEAR	COAL	NGCC
Inflation rate	3%	3%	3%
Interest rate	8%	8%	8%
Expected return to equity investor	15%	12%	12%
Debt fraction	50%	60%	60%
Tax rate	38%	38%	38%
Debt term	10 years	10 years	10 years
Net capacity	1,000 MWe	1,000 MWe	1,000 Mwe
Capacity factor	85%	85%	85%
Plant life	40 years	40 years	40 years
Heat rate	10,400	9,300	7,200
Overnight cost	$2,000/kWe	$1,300/kWe	$500/kWe
Construction period	5 years	4 years	2 years
Post-construction period	—	—	—
Depreciation schedule	Accelerated, 15 years	Accelerated, 15 years	Accelerated, 15 years
Decommissioning cost	$350 million	—	—
Incremental capital costs	$20/kWe/yr	$15/kWe/yr	$6/kWe/yr
Fuel costs	$0.47/mmBTU	$1.20/mmBTU	$3.50/mmBTU
Real fuel escalation	0.5%	0.5%	1.5%
Nuclear waste fee	1 mill/kWh	—	—
Fixed O&M	$63/kWe/yr	$23/kWe/yr	$16/kWe/yr
Variable O&M	0.47 mills/kWh	3.38 mills/kWh	0.52 mills/kWh
O&M real escalation rate	1.0%	1.0%	1.0%
Carbon intensity	—	25.8 kg-C/mmBTU	14.5 kg-C/mmBTU
Carbon tax	—	—	—

Note: Compiled from public information, including reports from the Energy Information Administration.

Nuclear's Challenges

MIT Report, *The Future of Nuclear Power* (2003)

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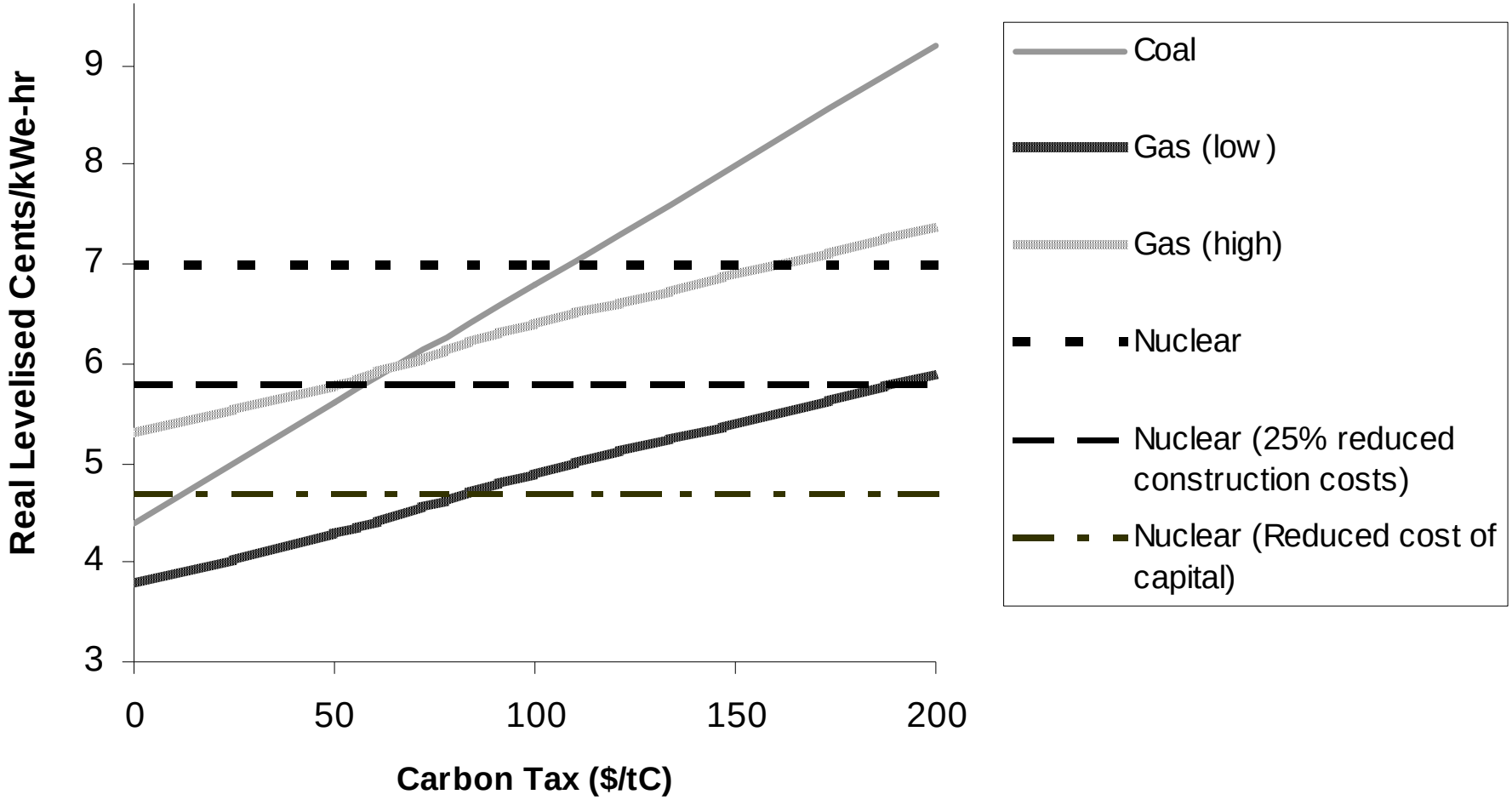
Cost & Price Competitive?

Nuclear Power economics with carbon charging



Fabien Roques – linearised data from MIT report: *Future of Nuclear power*

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New Build in Britain

Europe's most liberalised electricity market

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Live Issues in Britain April 2008

- **Sites** (enough to "replace nuclear with nuclear", but interestingly there is *no cap on nuclear.* Several good sites belong to British Energy)
- **Waste** (Has the Committee on Radioactive Waste Management really fixed that problem with its progressive approach?)
- **Generic Design Approvals** (limited safety regulatory capacity)
- **Financing** (no chance of merchant new build, consortia will be led by large international energy companies with much of the costs on the balance sheet: See S.Taylor's EC-CESSA paper: http://www.cessa.eu.com/sd_papers/wp/wp2/0204_Taylor.pdf)
- **Global Supply Chain** (where will UK NPPs be in the queue?)
- **Nuclear skills** (probably OK, but beware it's a global market for talent, also note Royal Navy-related requirements going forward)
- **Carbon Price & EU-ETS** (UK government ability *"to build investor confidence in the existence of a long-term multilateral carbon price signal"* See Nuclear White Paper January 2008)
- **British Energy** (M&A target? Much feverish speculation)

Conclusions & Closing Observations

- **Nuclear power Plants can be built in liberalised markets and they will probably yield a decent return for investors.**
- **A fully liberalised electricity market should not be a 100% natural gas electricity market**
- **Mature markets will be diverse markets**
- **Climate change and emissions policies will be key to the future of nuclear power.**
- **In Britain the debate is shifting from might we *replace nuclear with nuclear* to might we *decarbonise the electricity system*. They are very different things.**
- **Free market economies build much bigger things than nuclear power stations e.g. BAA Heathrow Terminal 5 (Cost roughly GBP 4 billion, 60000 people having worked on the project). NPPs are not even the biggest energy projects on the drawing board.**

Acknowledgements

With thanks to:

EPRG, CMI and CESSA

Dr Simon Taylor (Judge Business School, Cambridge)

Dr Fabien Roques (IEA)

All responsibility for errors and omissions rests with the author.