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Comparing the Economics of Nuclear and Renewable Sources of Electricity

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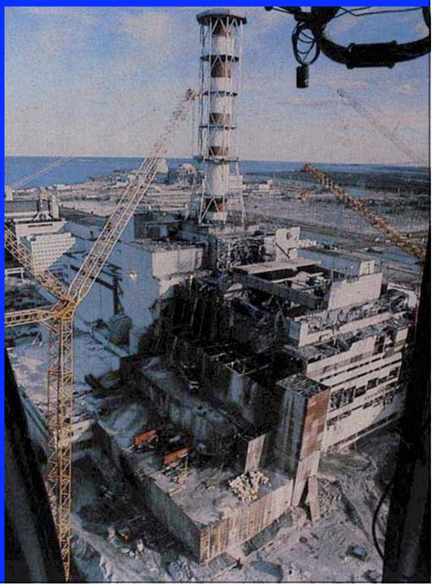
Current Global Status of Nuclear Energy

- At end 2009, 438 operating reactors, total capacity 371 GW, generating 2600 TWh p.a.
- Slight decline since 2005
- % of generation has declined from 17% in 2001 to 13.7% in 2009
- Main growth in China, Russia, India and South Korea
- Only 2 reactors (Gen III) under construction in western countries (Finland, France); both over time & budget
- Many retirements expected over next 20 years
- Further decline in % generation inevitable
- Economic implications



Stages of Technological Development

Stage	Definition
R & D	Experimental technology or systems on lab or small field scale; not designed for mass production
Demonstration	Only a few medium scale units exist; designed with future upscaling & mass production in mind
Pre-commercial	Limited mass production; some optimisation of design still required
Commercial	Large-scale mass production. Not necessarily economically competitive with dirty coal power.

Sources: simplified from Grubb; Foxon

Four Generations of Nuclear Power Stations

Generation	Description
I	Early British (Magnox); almost extinct
II	Almost all operating commercial reactors. 'Commercial' (but rarely built within scheduled time and budget)
III	EPR (Europe) & AP1000 USA under construction. Slightly improved versions of Gen II. Some 'passive' systems. Pre-commercial.
IV	Mostly fast (neutron) reactors; capacity to 'breed' plutonium. R&D & Demonstration

Technological Status of Nuclear Reactors

Economics only credible at commercial and pre-commercial stages

- Very few conventional 'commercial' (GenII) reactors have been built to time within budget
- GenIII reactors under construction (eg, Olkiluoto, Finland) are unproven commercially – still at pre-commercial stage and no operating experience.
- Fast breeder (GenIV) reactors are still at demonstration stage. Many fires, partial meltdowns & breakdowns.
- Integral fast reactor system (GenIV), comprising fast breeder + on-site pyro-processing, doesn't exist and has never passed the R&D stage.

Global Status of Nuclear & Renewable Technologies

Market penetration ↑

			Energy efficiency; solar hot water; hydro; GenII nuclear
			On-shore wind
			Biomass combustion
		Off-shore wind	Conventional PV
Novel PV; Integral Fast Reactor	Marine; hot rocks; fast reactor (GenIV)	Solar thermal; GenIII nuclear	Conventional tidal & geothermal
R&D	**Demonstration**	**Pre-commercial**	**Commercial**

After Foxon (2005)

Technology status →

Problems & Errors in Estimating Nuclear Costs

- Limited data: best from UK and USA
- Accepting manufacturers' cost estimates
- Choice of unrealistically low discount rate
- Using accounting methods that shrink capital cost
- Overestimating operating performance (capacity factor)
- Ignoring subsidies and other life-cycle costs

Subsidies to Nuclear Energy in USA

- Research & development
- Uranium enrichment
- Waste management
- Decommissioning
- Stranded assets paid for by ratepayers and taxpayers
- Loan guarantees covered by taxpayers
- Limited liabilities for accidents covered by communities
- Accumulated total estimated = 2006US$100 B (Public Citizen) and $9 B p.a. (Koplow 2007)

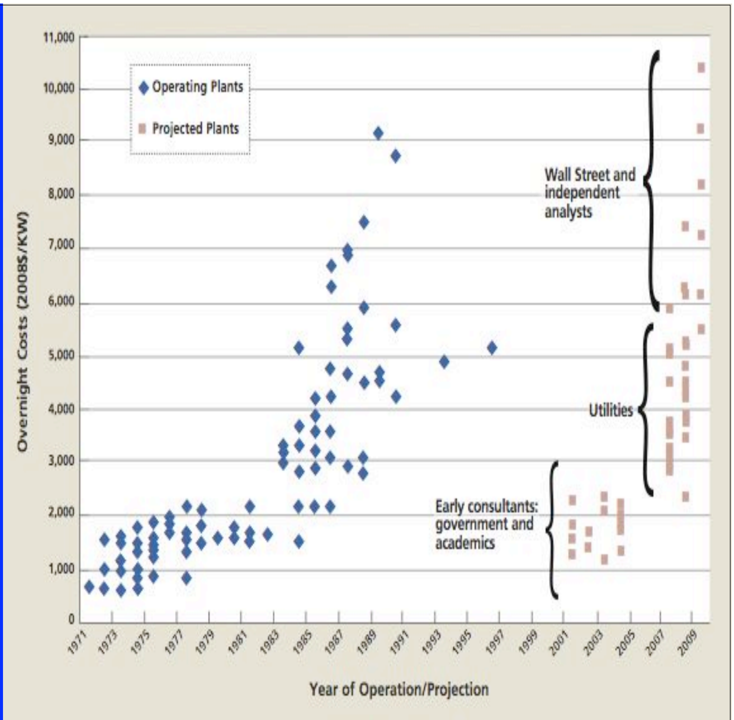
Nuclear Capital Cost Escalation, USA, 2003–09

Study	Capital cost (US $/kW)	Energy cost* (US c/kWh)
MIT (2003)	2000 + IDC	6.7–7.5
Keystone Center (2007)	3600–4000	8.3–11.1
Harding (2007)	4300–4550	10–12.5
MIT (2009) update	4000 + IDC	8.4
Moody's (2008)	7500	—
Severance (2009)	7400 10,500 projected	17.5–21 25–30

* Cost of energy depends on assumed discount rate & capacity factor;
IDC = interest during construction

'Overnight' Capital Costs of Nuclear Power, USA

(Cooper 2009)



Costs of Renewable Electricity, 2010 & 2020

in c/kWh; discount rate 8%; 2010 US$

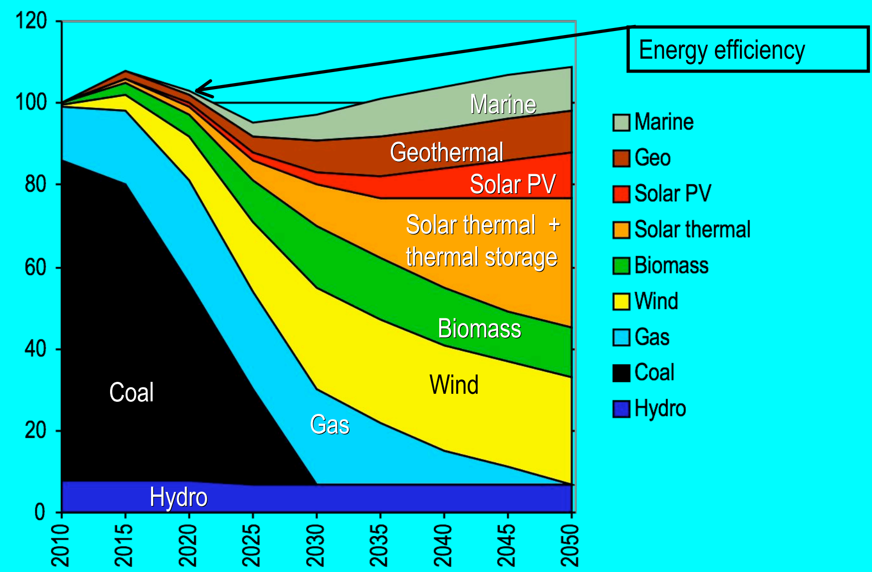
RElec technology	Cost of energy in 2010	Likely cost of energy in 2020
Energy efficiency	-4 to 0	-2 to 4
Wind onshore	7–11	5–8
Biomass residues	8–16	8–12
Geothermal (conventional)	4–6	4–6
Geothermal (hot rock)	n/a	8–12
Wind (offshore)	15–25	8–12
Solar thermal	20–30	10–15
Solar PV (power station)	20–30	12–20
Solar PV (residential)	30–45	15–25
Nuclear	11–15	15–30?

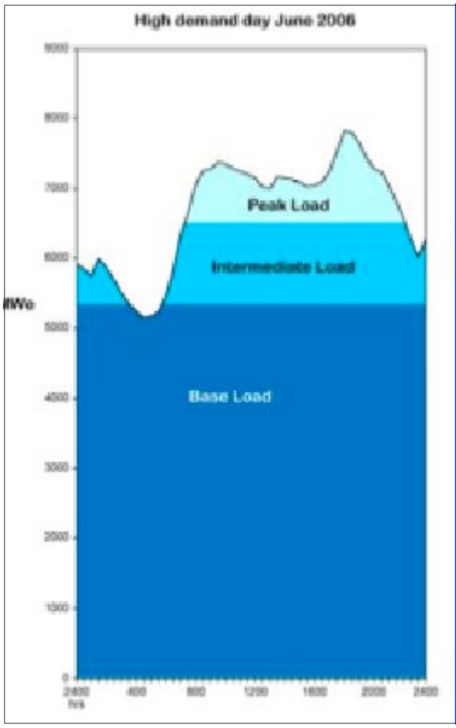
A Pro-Nuclear Analysis: NBB (2010)

Nicholson, Biegler & Brook (2010, in press) *Energy*

- NBB claim to give an 'objective, unbiased' assessment.
- NBB exclude wind without electrical storage on criterion that it's not dispatchable
- A more realistic criterion should be that the pre-RElec generation reliability of the whole supply system is maintained in the RElec system
- This can be achieved cheaply by increasing ratio of peak to base, either by reducing base-load (by energy efficiency & solar hot water) or by slightly increasing peak-load supply. Electrical storage is not needed.
- NBB quote recent nuclear capital cost claims from World Nuclear Association website! None of these plants is operating yet! No hint of recent cost escalation.
- NBB take costs of CST from 2003–10 studies, without allowing for future scale-up of production; however they assume scale-up benefits for nuclear.

Scenario for RElec, Australia, 2010–2050





Daily Demand met by 100% RElec Supply by 2050

Peak-load: Hydro; CST + thermal storage; biofuelled gas turbines; PV

Int.-load: CST+ storage, bioenergy; PV

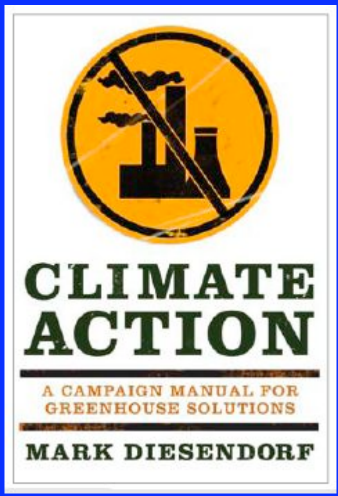
Base-load:

- Demand reduction by solar hot water and energy efficiency;
- CST + long-term thermal storage;
- Bioenergy
- Wind with supplementary peak-load
- Geothermal

Conclusion

- No operating experience with Gen III & IV nuclear ==> little basis for costing
- True costs of Gen II nuclear >> costs claimed by proponents
- Nuclear has received much greater total subsidies than RElec
- Since 2002 capital costs of nuclear have escalated much faster than those of fossil; meanwhile costs of renewables are declining
- In 2010, nuclear mid-range Wall St 'overnight' cost estimates cannot compete with most energy efficiency, solar hot water, landfill gas, on-shore wind, most large-scale hydro, or bioelectricity from residues
- By 2020, on level playing field, it's unlikely that nuclear will be able to compete with off-shore wind, concentrated solar thermal with thermal storage, or PV
- Nuclear involves huge construction projects and so is a very slow technology to grow

Further Reading For Activists



UNSW Press, 2009