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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 Technc	logical C	evelc	opment
Clageo				

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
	Early British (Magnox); almost extinct
I	Almost all operating commercial reactors. 'Commercial' (but rarely built within scheduled time and budget)
	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.

Gl	Global Status of Nuclear & Renewable Technologies			
				Energy efficiency; solar hot water; hydro; Genll nuclear
atio				On-shore wind
netr				Biomass combustion
set pel			Off-shore wind	Conventional PV
Mar	Novel PV; Integral Fast Reactor	Marine; hot rocks; fast reactor (GenIV)	Solar thermal; GenIII nuclear	Conventional tidal & geothermal
	R&D	Demonstration	Pre-commercial	Commercial
A	fter Foxon (2005)	Technolog	y 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	17.5–21	
	10,500 projected	25–30	
* Cost of energy depends on assumed discount rate & capacity factor;			



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?	

#### Costs of Renewable Electricity, 2010 & 2020

#### 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 guote 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 scaleup of production; however they assume scale-up benefits for nuclear.







## 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