Costs of Electricity Production

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Competing claims by proponents of the various means of electricity production are nowhere more contentious than on the question of costs. Although wishful thinking and deliberate misrepresentation play a part, the major sources of disagreement and unreliable cost information are the choice of factors which are included in the calculation and those that are ignored. Ideally, a 'cradle to grave' approach should be taken, but this is rarely, if ever, done. Costs may be internalised or externalised. Externalised costs include health and environmental detriments (not always expressed in monetary terms) which do not contribute to the electricity price. Externalities are fuzzy around the edges. While most people would agree that all inputs such as mining, refining and construction costs in addition to waste management and the decommissioning of generating plant should be included, it is less obvious when the land degradation and adverse health effects from mining occur in a foreign (i.e. exporting) country or whether road building, land clearing and loss of amenity in remote pristine areas, government-sponsored R&D, direct subsidies to generating companies, tax exemptions, guaranteed prices, government underwriting of accident insurance or those aspects of foreign policy related to energy (especially oil) security can be, or should be, included. Until now, problems caused by greenhouse gas and particulate emissions and solid waste (coal ash) from coal-fired plants have been externalised, and are therefore uncosted and untaxed in contrast to nuclear where the costs of waste disposal and decommissioning are included in the electricity price (www.world-nuclear.org, January 2006).

Coal and nuclear are currently the major means of baseload electricity generation although hydro and possibly geothermal (hot dry rock) can make major contributions in some circumstances. Capital costs for nuclear plant average about US$1500/kW installed and are similar to or slightly higher than for coal-fired plants and about twice the cost of gas-fired plants but fuel and operating costs are much less. Fuel costs for nuclear plants in OECD countries average US 0.48 cents/kWh and are typically about a third of those for coal-fired plants and between a quarter and a fifth of those for combined cycle gas plants (www.world-nuclear.org, January 2006). Decommissioning costs for nuclear plant are about 9–15% of the initial capital cost but, with cost discounting, represent only a small investment cost and contribute only about 0.1–0.2 cents/kWh to electricity prices. New Generation III and IV reactors will have lower capital and operating costs than current Generation II reactors. The 1100MWe Westinghouse AP1000, for example, has a projected overnight capital cost of US$ 1200/kW, a construction time of 36 months, simplified licencing, a 60 year operating life, a capacity factor of 90% or more and generating costs of about US 3.5 cents/kWh. On the other hand, the capital cost for coal-fired stations increases significantly if flue gas desuphurisation (FGD) is mandated to reduce acid rain or if geosequestration is used to reduce carbon dioxide emissions to meet Kyoto greenhouse targets. The

imposition of a carbon tax will significantly increase electricity costs from fossil fuels. A carbon tax of $50/ton will add 3.6 cents/kWh to the coal-fired electricity price in the US. The current price (€22/t CO_2) of an allowance to emit carbon dioxide under the EU Emissions Trading Scheme adds about 2 €cents/kWh (1 €cent = 1.21 US cents). Another report estimated in 2003 that, with emission trading at €20/t CO_2, electricity from nuclear will cost 2.37 €cents/kWh, electricity from coal will increase from 2.81 €cents/kWh to 4.43 €cents/kWh and electricity from gas will increase from 3.23 €cents/kWh to 3.92 €cents/kWh (www.world-nuclear.org, January 2006). At least 9 European countries have introduced a carbon tax ranging from US$19 to $114/t CO_2 and planned to rise to $142 (Switzerland) or $279 (France) by 2010. The New Zealand Government recently announced a carbon tax of NZ$15/t CO_2 to apply from April 2007 and has reserved the option of emissions trading in the future.

Costs for nuclear are generally higher than for coal where there is abundant cheap coal but lower if the coal has to be transported long distances. Fuel costs represent about 5% of electricity generating cost from nuclear and about 50% from coal. Whereas a 20-fold increase in the price of uranium would double the cost of electricity from thermal (i.e. fission) reactors, the price of coal would only need to increase by about 3 times to double the cost of electricity from coal. Another study finds that a doubling of fuel prices would increase costs for nuclear power by about 9%, increase costs from coal by 31% and increase costs from gas by 66%. If health and environmental costs not presently factored into the electricity price are included, the production cost for nuclear in European countries would rise by 0.2–0.7 €cents/kWh, the cost for coal would rise by 2–10 €cents/kWh and the cost for gas would rise by 1–4 €cents/kWh. On the current electricity generating cost of 4 €cents/kWh, the inclusion of external costs (not including the adverse effects of global warming) would, on average, double the cost of electricity from coal, increase the cost from gas by 30% and increase the cost from nuclear by 10% (www.world-nuclear.org, November 2005).

The industry paper, *Nucleonics Week*, reported that the average cost of power generation by [amortised] US nuclear reactors in 2004 was 1.7 cents/kWh. A recent UK study found that new nuclear plants will generate electricity at about 2.3 p/kWh compared with 2.3–3.3 p/kWh for coal (1p = 1.80 US cents). An OECD report found that in the US, electricity costs were: nuclear: 3.33 c/kWh, coal: 2.48 c/kWh, gas: 2.33–2.71 c/kWh. In France, electricity costs were: nuclear: 3.22 c/kWh, coal: 4.64 c/kWh, gas 4.74 c/kWh. An OECD/IEA NEA international survey in 2005 found that, at the 5% discount rate, electricity from nuclear costs 2–4 c/kWh and is cheaper than from coal in 7 of the 10 countries surveyed and cheaper than from gas in 9 of the 10 countries. At the 10% discount rate, electricity from nuclear costs 3–5 c/kWh and is cheaper than from coal in 7 of the 10 countries and cheaper than from gas in 8 of the 10 countries. A 2004 British report by the Royal Academy of Engineering on electricity generation found that nuclear costs were comparable to gas (2.2–2.3 p/kWh), cheaper than coal (2.5–3.2 p/kWh) and much cheaper than wind (3.7–7.2 p/kWh).

Apart from hydro, the two promising forms of renewable energy are wind and solar—others are unproven, unlikely or feasible in few situations. Wind and solar power both rely on intermittent dispersed energy sources and suffer from the same problems of unreliable supply and high costs which have led authorities in most countries to recommend a practical limit to electricity production from these sources of about 20% of supply (Germany and Sweden are notable exceptions). A press release by the Global Wind Energy Council (GWEC) reported that the 11.77GW of wind energy installed worldwide in 2005 had a "total value of . . . over €12 billion" (US$14.5 billion) giving an average capital cost of over US$1220/kW of capacity. However, when the average European capacity factor of less than 20% (range: 14.7% (Germany) to 24.1% (UK)) is factored in, the capital cost per kilowatt of electricity generated is several times higher than for nuclear, coal and gas. At present, 48 countries have introduced some form of subsidised renewable energy target or obligation which recognises the higher cost and additional problems in balancing the grid when renewable energies are involved in substantial amounts.

Under the Renewable Energy Law (EEG) introduced in Germany in 2001, utilities are required to guarantee access to the power grids and pay 5.5–9.1 €cents/kWh for electricity from wind and 54.0–57.4 €cents/kWh for electricity from solar for 20 years after commissioning. From 1999 to the end of 2004, 90,324 photovoltaic (PV) systems totalling 642MWpeak capacity were installed under the '100,000 Roofs Program', creating a claimed 160,000 new jobs. If so, each system bears, with other costs, the employment costs and income of 1.8 persons. The total installed capacity is little more than half that of one medium-sized nuclear power reactor, but with a much lower overall performance due to the relatively low solar intensity at German latitudes and the small number of 'sun hours' per day. Although there are no losses or costs associated with transmission and distribution, this is offset by ongoing maintenance costs which are borne by the householder. Subsidies under the EEG for all renewables are currently 5 billion marks (US$2.3 billion) per year and are paid for by all electricity consumers in the retail electricity price. As part of the government's "environmental tax reform" the EEG was preceded in 1999 by new taxes on oil, gas and electricity which increased yearly to 2003. In Denmark, subsidies for wind energy paid by electricity consumers are estimated at DKK10–15 billion (US$1.6–2.4 billion) per year. In Australia, the subsidy for renewable energies is AU 5 cents/kWh which is roughly equal to the generating cost from coal or about half the retail price of electricity. A UK government report released in September 2005 found that subsidies for renewables will total £6.5 billion by 2010 (without achieving the objective of providing 10% of UK electricity) and will reach £30 billion by 2030.

Because supply from wind and solar generators cannot usually be guaranteed, they are at a competitive disadvantage in deregulated (i.e. privatised) electricity markets employing power pool systems in which generating companies bid high prices in a round of bidding called the balancing market conducted to meet imminent shortfalls in supply. Even without deregulation, losses in dumping unwanted electricity (84% of wind production in West Denmark in 2003) in neighbouring countries and the high

cost of importing electricity to make up for shortfalls in wind production have contributed to making Denmark's electricity the most expensive in Europe (nearly double the UK price) and have prompted recent decisions to abandon the obligatory purchase scheme and further construction of wind farms in the country while continuing the profitable manufacture and export of turbines. Estimates of Denmark's losses from wind power range from DKK1.5 billion per year to more than DKK3 billion (US$242–483 million).

Proponents of renewable energies frequently attribute the large discrepancy between promise and performance of their chosen technology to a much smaller R&D investment in this sector compared to R&D investment in other forms of energy production, especially nuclear. While this may have once been true, investigation by the OECD International Energy Agency (IEA) shows that expenditure on nuclear fission R&D in IEA countries has fallen steadily since 1980 and that expenditure on renewables R&D is now roughly double that for nuclear in all countries except France and Japan. A similar study in the US found that since 1976 financial support by government for wind and solar R&D was greater than for nuclear and coal. The amount spent on photovoltaics was more than twice that spent on light water reactors. The Australian government's Mandatory Renewable Energy Target (MRET) provides over $2 billion for renewable energy investment plus an additional $134 million for R&D on specific aspects and $75 million for the Solar Cities Program. No money is spent on nuclear power R&D in Australia. The disparity is the more remarkable when the nature of the R&D and the potential and production of each is considered. While most of the expenditure on nuclear R&D is devoted to basic science and the development of a complex technology, much of the R&D into renewables is focussed on optimisation and commercialisation of essentially simple existing technologies. Also, while nuclear provides approximately 23% of electricity in OECD countries and about 16% in all countries, non-hydro renewables make only a tiny contribution to electricity production. Germany, with 18.4GW of installed wind capacity has nearly a third of total world wind capacity (59.3GW at end of 2005) is the world leader delivering 6.2% of the country's electricity. Despite the billions spent on support for solar and wind energies, together they provide only 3.3% of Denmark's electricity, 0.5% of America's, 0.1% of Britain's and 0.04% of Australia's.

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