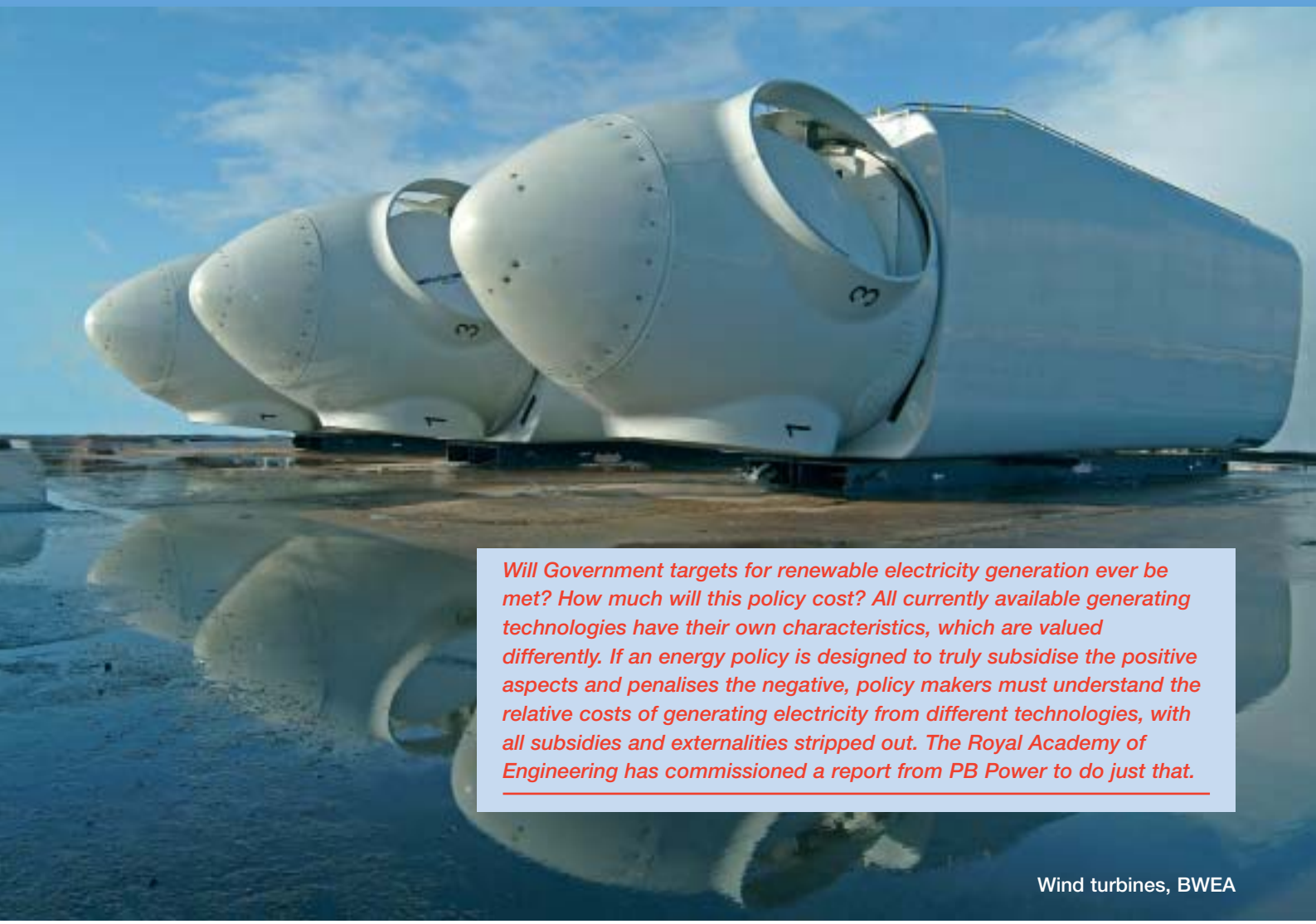
Electricity costs
start with a level playing field



Will Government targets for renewable electricity generation ever be met? How much will this policy cost? All currently available generating technologies have their own characteristics, which are valued differently. If an energy policy is designed to truly subsidise the positive aspects and penalises the negative, policy makers must understand the relative costs of generating electricity from different technologies, with all subsidies and externalities stripped out. The Royal Academy of Engineering has commissioned a report from PB Power to do just that.

Wind turbines, BWEA

When we consider the costs of generating electricity, major external cost issues and social implications are raised. These issues must be addressed if we are to meet government targets for renewable electricity generation by 2020. The best mix of electricity generation capacity is likely to be diverse with each technology being valued for its own particular characteristics. A sensible energy policy must balance a number of competing needs that are not always compatible. It must provide security of supply and affordable energy at a low environmental cost without damaging national competitiveness.

The useful or desirable characteristics of various generating technologies are well known, as are their deficiencies. Wind power emits no CO_2, but is randomly intermittent. Nuclear power provides excellent base load, but is inflexible and has a low socio-political acceptance. Somewhere, there is a middle ground and something that might approach an optimum mix.

The idea that some technologies should be subsidised for their beneficial characteristics and some penalised for their detrimental effects is well understood and accepted. Another ideal is that such subsidies and penalties should relate directly to the technologies they are aimed at,

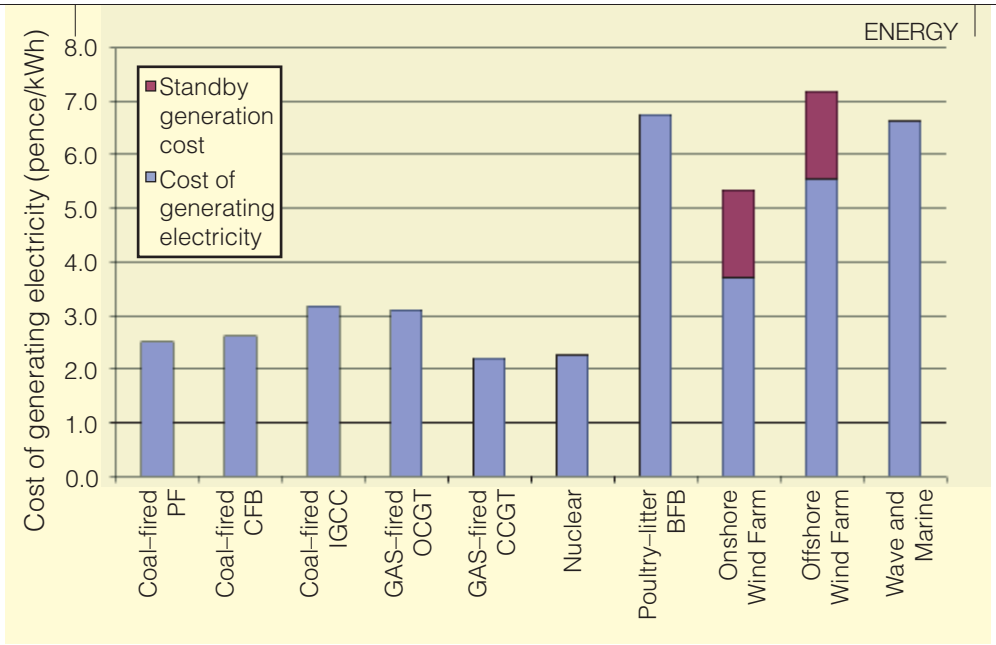


Figure 1 Cost of generating electricity (pence per kWh)

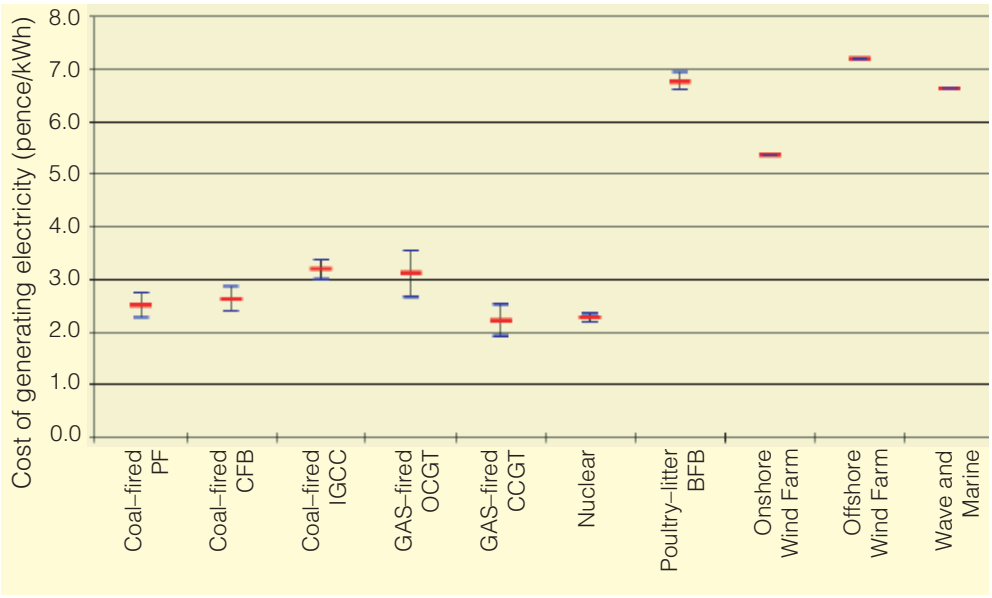


Figure 2 Effect of ± 20% change in fuel price on the cost of generating electricity

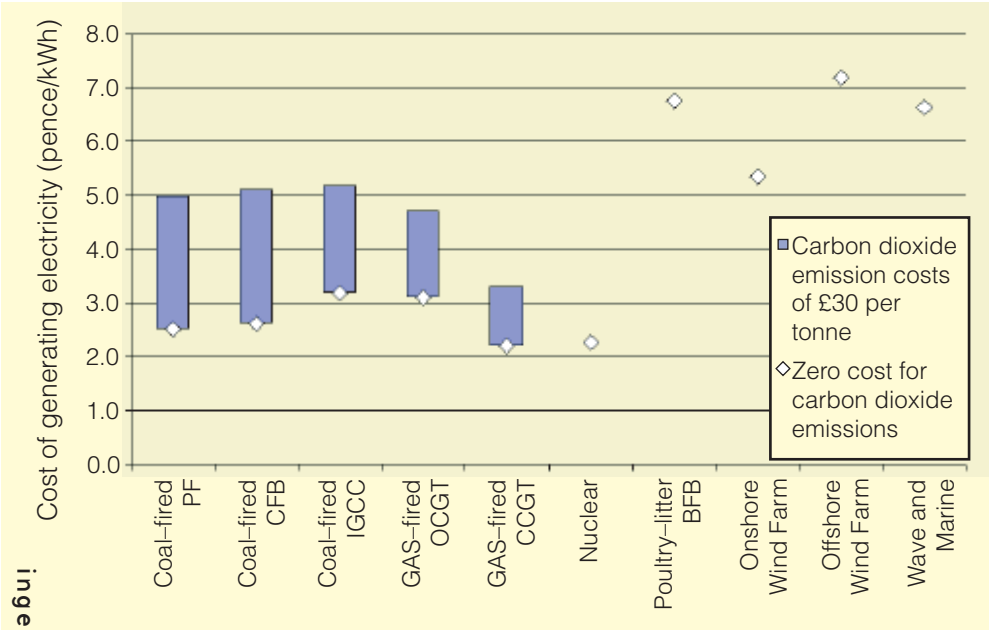


Figure 3 Cost of generating electricity with respect to carbon dioxide emission costs. (£0–30 per tonne)

and thus no cross subsidies will exist. To reach such a utopian solution, policy makers need to understand the real, financial costs of firm, reliable electricity generation from various technologies with all externalities stripped away. Then, rational, targeted subsidies can be designed and implemented.

Unfortunately, the UK electricity market is complex. The relationship between the cost of generating electrical power from various sources and the price consumers pay is blurred by direct and indirect subsidies, market mechanisms, transmission and distribution costs. The true costs of generating electrical power are often obscured by commercial sensitivities and competing claims that make the determination of sensible energy policy difficult and often imprecise.

In reality, this means that policies designed to reduce environmental impacts unfairly penalise non-CO_2 emitting sources because of arbitrary definitions of 'what is renewable' and 'what is non-renewable'. Large hydro-electric plant do not benefit from the policy, although they are renewable sources by any reasonable definition. Similarly, nuclear plant do not profit, despite being non-emitting. Paradoxically, co-firing sources benefit from the policy, even if the biomass being burned has to be transported many thousands of miles from its country of origin to the power plant.

The complex financial structures of commercial projects mean that it is often impossible to compare the capital costs[1] of generating plant in a meaningful manner. Therefore, this study addressed the actual costs of building, maintaining and running various types of power station in the UK and derived costs of producing electricity by using a common, simple financing model with a nominal discount rate 7.5 per cent. It compared new build power stations on a level playing field and examined their sensitivities to emission costs and fuel prices. The figures presented were

therefore illustrative rather than predictive. However, unlike many other compilations of costs, they compare like with like and will be of immense use to policy makers.

Results

The study examined a number of different technologies:

- **Coal plant**
  - Pulverised fuel (PF) steam plant
  - Circulating fluidised-bed combustion (CFBC) plant
  - Integrated gasification combined-cycle (IGCC) plant
- **Gas plant**
  - Open-cycle gas turbine (OCGT) plant
  - Combined-cycle gas turbine (CCGT) plant
- **Nuclear fission plant**
- **Biomass (poultry litter)**
  - Bubbling fluidized-bed combustion (BFBC) plant
- **Wind turbines**
  - Onshore
  - Offshore
- **Wave and Marine**

The cost of generating electricity, as defined within the scope of the study, was expressed in terms of a unit cost (pence per kWh) delivered at the boundary of the power station site. This cost value, therefore, includes the capital cost of the generating plant and equipment; the cost of fuel burned (if applicable); and the cost of operating and maintaining the plant in keeping with UK best practices. Within the study, however, the 'cost of generating electricity' is deemed to refer to providing a dependable (or 'firm') supply. For intermittent[2] sources of generation, such as wind, an additional amount was included for the provision of standby generation. The findings of this study are summarised in Figure 1, which illustrates the present-day costs of generating electricity from different types of technology appropriate to the UK.

Sizewell B Dome, British Energy

For base load operation (those plants operated continuously) the cheapest way to generate electricity in the future from new plant, ignoring rehabilitation of existing plant, is by constructing CCGT plant designed to burn natural gas.

Table 1 summarises the cost of generating electricity for the different 'base load' plants considered by this study.

For peaking operation (generating for limited periods of high demand and providing standby capacity) OCGT fired on natural gas are the most appropriate new plant candidates. OCGT is ideally suited for the role of peaking duty, which requires flexibility, reliability and can be started quickly should the need arise. The Academy estimates that the cost of a gas-fired OCGT generation will be about 3.1 pence per kWh if operated continuously. However, the average cost will rise to about 6.2 pence per kWh if only operated for limited periods of time consistent with peaking duty – for only 15 per cent of the time, for example.

Table 1 Cost of generating electricity for base load plant (pence per kWh)	
Gas-fired CCGT	2.2
Nuclear fission plant	2.3
Coal-fired pulverised-fuel (PF) steam plant	2.5
Coal-fired circulating fluidized bed (CFB) steam plant	2.6
Coal-fired integrated gasification combined cycle (IGCC)	3.2

Renewables are generally more expensive than conventional generation technologies. This is due, in part, to the immaturity of the technology and the more limited opportunity to take advantage of cost savings caused by economies of scale usually associated with more traditional fossil-fuel types of generation. In addition, fluctuations in the energy source itself may limit the output of generation available from these technologies and thus raise the unit costs of the generator on two

Table 2 Cost of generating electricity for selected renewables		
	Without stand-by generation (pence/kWh)	With stand-by generation (pence/kWh)
Poultry litter-fired bubbling (BFB) steam plant fluidised bed	6.8	6.8
Onshore wind farm	3.7	5.4
Offshore wind farm	5.5	7.2
Wave and marine technologies[4]	6.6	6.6

counts: first, as capacity factor[3] falls, unit costs of generation rise; and second, additional, fast response, stand-by generating plant may have to be provided to maintain system security as the energy source fluctuates.

Table 2 summarises the cost of generating electricity, with and without the additional cost of stand-by generation, from the selection of renewable technologies considered by this study.

Figure 2 illustrates the effect on the cost of generating electricity given a change of ±20 per cent in fuel price, where the base cost of coal is £30 per tonne and natural gas is 23 pence per therm.

At the time of writing this report, no firm commitment has been given by the Government on how carbon dioxide (CO_2) emission allowances will be allocated to new entrant generation plant for the period 2005–2007. In view of this uncertainty, a conservative approach has been adopted by the study to burden 100 per cent of the output from fossil fuelled generation with a notional cost, calculated in terms of pounds sterling per tonne of CO_2 released. For the purposes of this study, a range of values between £0–30 per tonne was used, where the upper limit reflects the reported cost of CO_2 sequestration.

Figure 3 illustrates the potential increase in generating costs brought about by the introduction of carbon emission allowances.

It is clear that CO_2 costs will only affect those technologies burning fossil fuels. The lower efficiency of steam plant, combined with the greater level of carbon found in coal compared to natural gas, means that the gap between CCGT plant and other coal-fired technologies will widen as the cost of CO_2 increases. The cost of nuclear and other renewables (deemed to be carbon neutral) remain unchanged and, therefore, become more competitive as the specific cost of CO_2 emissions increases.

Conclusions

This study has only provided indicative, but comparable, figures. Commercial concerns examining investment prospects in the energy sector would need to take many other factors into consideration, such as financial risk and the availability of subsidies over the long term.

As a tool for policy development, the results show that:

- wind power needs to be properly subsidised if its environmental credentials are to be fully exploited
- gas generation can absorb a high penalty for CO_2 emissions before it becomes uneconomical
- even at quite a high cost, the quick start capabilities of open cycle gas turbines will be valued for balancing and peaking duties
- coal rapidly becomes unattractive with moderate costs for emissions
- nuclear generation costs are very sensitive to the cost of capital. If valued for its zero greenhouse gas emissions, the relatively low generation costs for new build nuclear plant should help to overcome its financial risk.

The optimum mix of generating technologies for the UK electricity system is likely to involve all the technologies we have examined. As policy priorities move towards energy security and control of emissions, nuclear and renewables may come to the fore, both of which have their vocal and dogmatic detractors. However, both should be incorporated into the system and valued for their specific contribution. ■

Further information

A full version of this report can be downloaded from The Royal Academy of Engineering's website at http://www.raeng.org.uk/policy/reports/

Notes

1 With the exception of nuclear, the analysis assumes that decommissioning is cost neutral. The capital cost estimate for nuclear plant includes an allowance for the costs of decommissioning.

2 For the purpose of this study, wave and marine technologies are deemed to be predictable and, therefore, have not been burdened with the additional cost of stand-by generation.

3 'Capacity factor' is an operational term to represent the extent to which the generator is producing electricity over a period of, for example, a year. Wind turbines have typical capacity factors of 25–45 per cent, whilst large coal or nuclear plants may have capacity factors in excess of 90 per cent when operating on base load.

4 The additional cost of standby generation for wave and marine technologies has not been included because only low levels of penetration are expected within the study horizon.