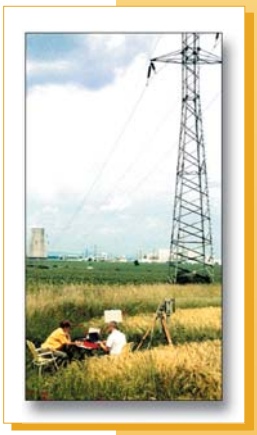
The Economics of Nuclear Energy



Nuclear energy is characterised by low production costs, high capital costs, insensitivity to variations in fuel prices, long operational life and significant regulatory costs.

Existing nuclear power plants are generally competitive even in deregulated markets and particularly when initial investment costs have been amortised. Mainly because of high capital costs, decisions to build new nuclear power plants may depend significantly on public policy factors.

A difference between nuclear energy and other forms of electricity production is that some costs that are mainly external to other energy sources are internalised in the case of nuclear.

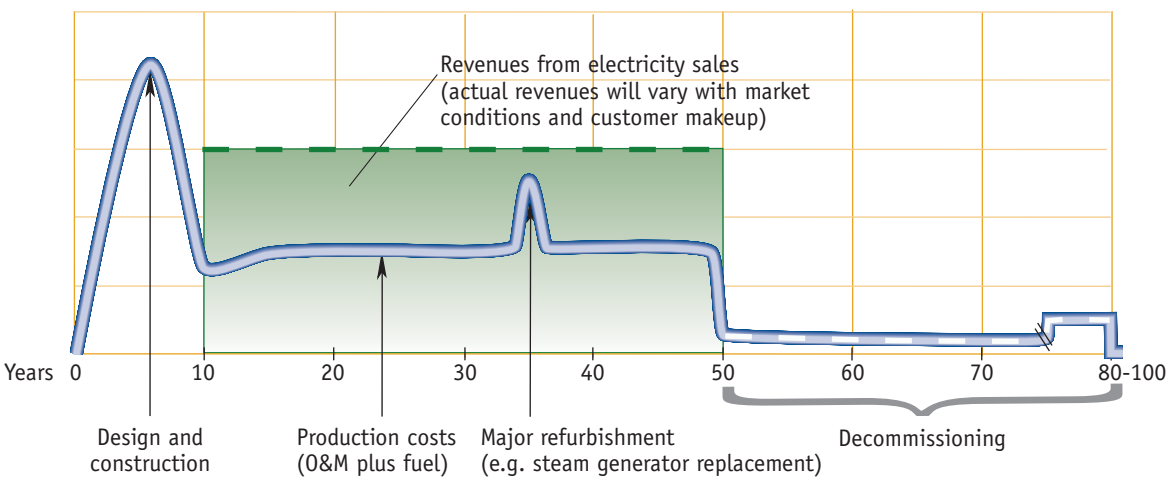
Costs, risks and liabilities

Factors influencing the economics of nuclear energy

Figure 7.1 shows the life cycle revenues and costs for a typical nuclear power plant. It demonstrates the factors that characterise the economics of nuclear energy, viz:

- high capital investment costs;
- long planning horizons and operational life;
- low fuel, operating and maintenance (O&M) costs;
- significant costs incurred after cessation of power generation (notably management and disposal of radioactive waste and decommissioning).

Figure 7.1: Illustrative life cycle cash flow for a nuclear power plant



Elements of nuclear generating costs

Investment costs include those of construction, major refurbishment during the life of the plant and decommissioning.

Operations and maintenance costs include those for operating staff, training, security, health, safety and the costs for management of low- and intermediate-level operational waste. In fact, this category includes all costs that are not considered investment or fuel costs.

Fuel costs include all those related to the fuel cycle. They include the cost of the uranium, its conversion and enrichment, fuel fabrication, spent fuel conditioning and disposal or recycling, as well as disposal of the waste of reprocessing.

The costs of generating electricity are usually broken down into three major categories, the costs of investment (capital); operation and maintenance; and fuel.

Investment costs include those of design and construction, major refurbishing, and decommissioning. The last comprises all the costs incurred from the shutdown of the plant until the site is released in accordance with national policy and includes the costs to manage the radioactive and other waste generated during decommissioning until they are disposed of. To these costs are added those associated with securing regulatory approval to proceed with construction and operation.

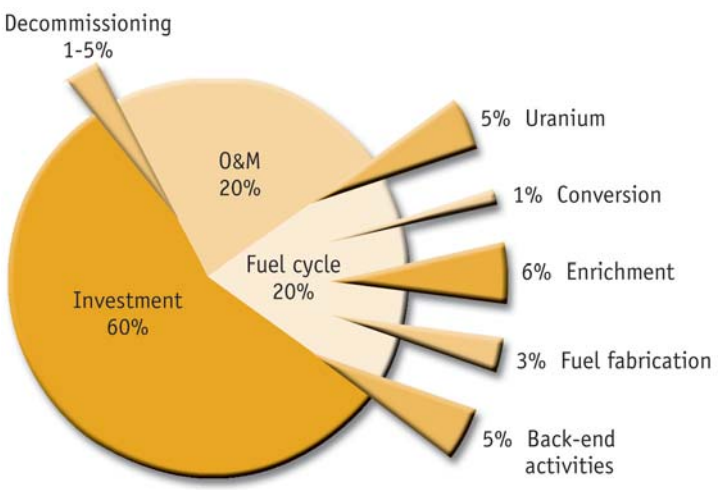
Investment costs must be financed, and they thus incur interest charges. These are amortised over some set period, perhaps on the order of 20-25 years, and the debt service becomes part of the costs of electricity generation. Provisions are also required to be set aside or paid by plant operators for decommissioning and disposal of its associated waste – processes that can take many decades.

Operation and maintenance (O&M) costs include all costs that are not considered investment or fuel costs, the main elements being the costs of operating and support staff, training, security, health and safety, and management and disposal of operational waste. The costs of day-to-day and periodic maintenance and inspection (during which plants usually have to be taken off-line) are also included. Because investment costs are essentially fixed after construction, O&M costs represent a major opportunity for cost-reduction in an existing power plant.

Fuel costs include costs related to the fuel cycle, including the costs of purchasing, converting and enriching uranium, fuel fabrication, spent fuel conditioning, reprocessing, disposal of the spent fuel or the high-level waste resulting from reprocessing and transport. Fuel costs make up only about 20% of the costs of nuclear-generated electricity, which is therefore relatively insensitive to fuel price fluctuations – in contrast to the position of fossil fuels.

Although generating costs are country-specific, Figure 7.2 shows the relative importance of the components in the cost of nuclear generation of electricity.

Figure 7.2: Typical nuclear electricity generation cost breakdown



Long-term financial risks and liabilities

A decision to build or to continue to operate a nuclear power plant represents a greater commercial risk than is normally associated with alternative energy sources, for several reasons:

- The long planning timescale and operational life provides greater potential for long-term changes in the market to impact revenues negatively or positively.
- The high fixed-cost element, due largely to the high investment costs, produces greater vulnerability to short-term fluctuations in market conditions.
- The strong regulatory framework reduces operational flexibility and introduces the possibility of changes in regulatory requirements that could impact adversely on costs (and historically have done so).
- Uncertainties associated with the costs of decommissioning and long-lived waste disposal, including the time periods involved.
- Whereas non-nuclear plants can trade or sell much of their cost base under negative economic conditions, this is in practice largely

ruled out for nuclear power plants (e.g. a gas-fired power plant can sell its gas supply on the open market).

Although decommissioning costs and the costs of managing its associated waste are high, they are a relatively small component of total life-cycle costs, not least because the long time periods involved produce considerable discounting. Uncertainties in the accuracy of predicted future costs are possible given the long service lives of reactors and the potential for changing and usually strengthening regulatory requirements. Therefore, allowances for uncertainty are made a part of the provisions to cover decommissioning costs.

If these costs are provided for based on projected income over the expected life of a plant, there is a risk of shortfall should economic conditions force early closure or should the plant produce revenues below projected levels. In practice, however, these funds have been collected over projected lifetimes considerably shorter than those actually achieved. The potential also exists for advances in the relevant technologies to reduce costs below those envisaged.

Competitive aspects

Comparative costs of generating electricity

Figure 7.3 gives a comparison of the representative generating costs of electricity from nuclear and some fossil fuel sources.

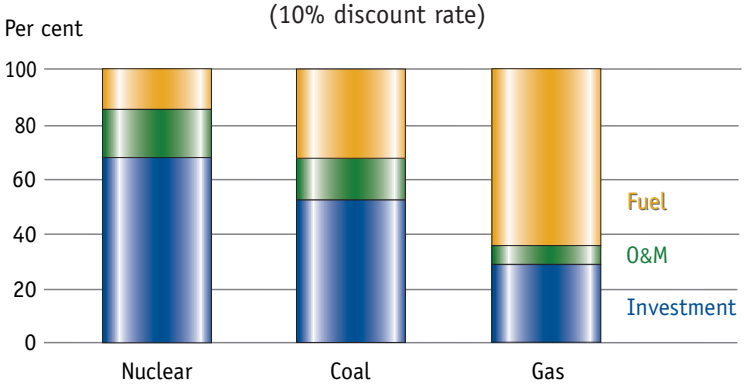
Compared with nuclear energy, natural gas-fired plants are characterised by low capital investment costs and significant fuel costs. Coal-fired plants are characterised by mid-range investment and fuel costs. In general, fuel costs represent a relatively large proportion of fossil-fuel-based generating costs that are, as a result, sensitive to fuel price variations. Renewable sources of energy, e.g. wind and hydropower, are similar to nuclear power in having high investment and low production costs per unit of power produced.

Existing plants

Given the relatively low cost of nuclear fuel, the recent advances in improving efficiency, and the fact that in many cases original investment costs are now substantially amortised, existing nuclear power plants have mainly proved to be competitive worldwide.

Data from the European Commission on electricity production costs (investment, O&M and fuel costs included) show nuclear energy to be competitive even accounting for its large investment costs (see Table 7.1).

Figure 7.3: Breakdown of representative generation costs (10% discount rate)



Source: NEA. *Projected Costs of Generating Electricity* (Paris: OECD, 1998). Average of values for Canada, France, Japan, Spain and the United States.

Table 7.1: Electricity production costs for 7 000 hours of production (1990 Euro cents/kWh)

	Coal	Oil & lignite	Gas	Nuclear	Biomass	Photovoltaic	Wind
Minimum	3.2	4.9	2.6	3.4	3.4	51.2	6.7
Maximum	5.0	5.2	3.5	5.9	34.5	85.3	7.2

Source: European Commission. *Green Paper: Towards a European Strategy for Energy Supply* (Brussels: EC, 2000), Annex 2, Table 1 without excise taxes and subsidies.

External costs are costs that are imposed on society and the environment that are not accounted for in the cost to producers and consumers of energy, and omitted when calculating the market price.

Data from the United States on energy operating costs (only O&M plus fuel costs) show a similar result. In 1999, operating expenses were reported as US 1.92 cents/kWh for nuclear, US 2.02 cents/kWh for fossil fuel sources, US 0.68 cents/kWh for hydro and US 3.87 cents/kWh for gas turbines.

The outlook for existing plants on economic grounds is therefore one of continuing use of these facilities, particularly as the costs for lifetime extension or capacity upgrade are typically much lower than those for building new plant.

Nuclear energy in deregulated markets

An OECD/NEA study on *Nuclear Power in Competitive Electricity Markets*, published in 2000, found that nuclear power plants in Finland, Germany, the Netherlands, Spain, Sweden, the United States and the United Kingdom had been competitive in their respective deregulated markets.

Generally, the response to market deregulation had been an improvement in operating efficiency and profitability. The pressure to manage a plant properly to meet stringent nuclear safety regulations appears to provide a sound basis for competitive performance.

Construction of units 6 and 7 at the Kashiwazaki-Kariwa nuclear power station in Japan was accomplished in under six years.

New plants

The 1998 OECD/NEA study on *Projected Costs of Generating Electricity* compares the levelised costs of electricity for various fuel types. The results showed that the attractiveness of building new plants is dependent on country-specific factors including the prevailing discount rate. For example, according to the study, nuclear power is cheapest in 5 of 12 countries at a 5% per year rate while at 10% per year it is cheapest in none.

The relatively large investment cost for new nuclear plants is a main factor. To make construction of new plants commercially more attractive under competitive conditions, investment costs must be reduced. New more cost-effective designs, improved construction methods, standardisation and series construction and multiple unit construction are all means to reduce the investment costs of nuclear power plants. Improvement is possible. For example, in Japan during the 1990s, use of a standardised advanced design together with duplication of construction on a single site enabled the construction of new plants to be completed in under 6 years as compared with a previous range of 7-10 years, the construction of two advanced boiling water reactors (ABWR) at Kashiwazaki-Kariwa having been accomplished (from start to commercialisation) in 62 and 65 months.

However, the high levels of financial commitment and risk in a competitive market can make it difficult for the private sector alone to finance new nuclear power plants, even given the potential time and cost savings. Historically, the exploitation of nuclear energy on a highly innovative basis has been driven by public-private sector relationships. The question now is whether this relationship can or should exist under deregulated conditions.

External costs

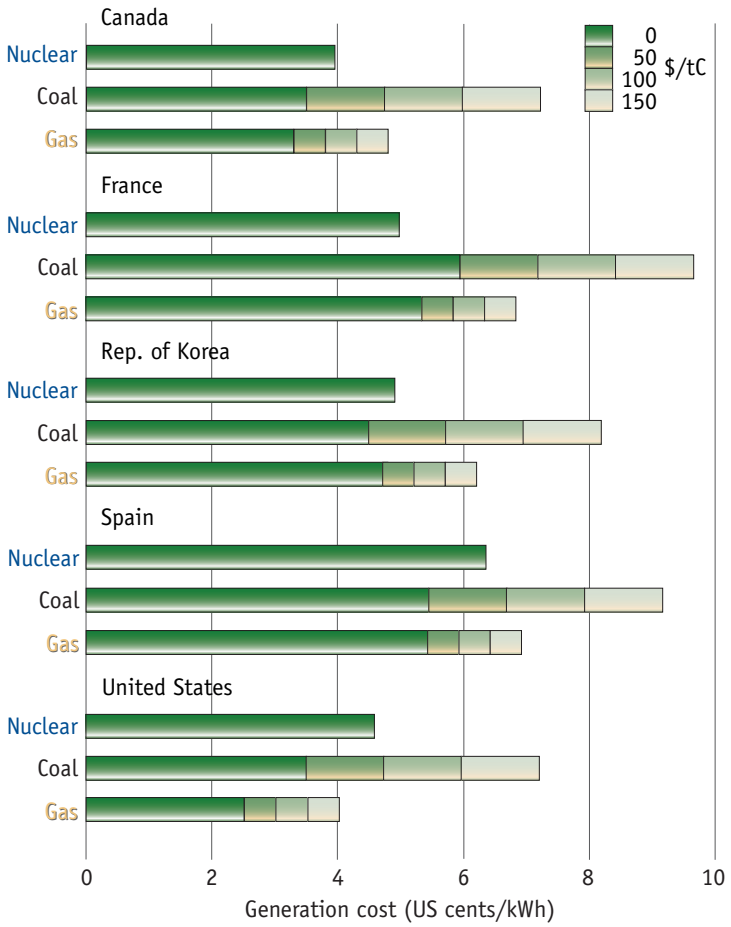
A difference between nuclear energy and other forms of electricity production is that nuclear energy bears some costs that are not included in (are external to) the costs of other sources of electricity. Some of the costs associated with nuclear electricity generation included in the prices at which the resulting electricity is sold on the open market include radioactive waste management and disposal. Fossil fuel energy bears

certain costs for reducing its emissions to air and water, as does nuclear, but a considerable part of the waste is disposed of to the atmosphere, imposing costs on the community that are not reflected in the price of its electricity. Table 7.2 represents the outcome of a major study by the European Commission on the external costs of electricity production by fuel source, including not only the costs of waste deposition but also the impacts on public health, together with certain other detriments whose costs are generally borne by society rather than the consumer.

The economic competitiveness of nuclear power might be dramatically shifted if the external costs of fossil fuel generation were to be internalised. For example, if the external costs for carbon emissions alone were internalised through the imposition of a "carbon tax", the effect on levelised generation costs would be significant (see Figure 7.4).

Unless there is a steep reduction in nuclear energy capital costs, a significant and sustained rise in fossil fuel costs or political decisions to internalise some of the external costs associated with fossil fuels, private sector investment in new nuclear power plants may be lacking. Until then, decisions to build new nuclear power plants are likely to be significantly influenced by public policy factors, such as security of supply. Whether and how these governmental concerns may be addressed in competitive markets is an open question and outside the purview of the private sector.

Figure 7.4: Effect of carbon tax on levelised generation cost in different countries (10% discount rate)



Source: NEA. *Nuclear Energy and the Kyoto Protocol* (Paris: OECD, 2002).

Table 7.2
External costs for electricity production in the European Union (Euro cents/kWh)

Coal and lignite	1.8 - 15.0
Oil	2.6 - 10.9
Gas	0.5 - 3.5
Hydro	0.04 - 0.7
Photovoltaic	0.1 - 0.3
Biomass (includes peat)	0.1 - 5.2
Wind	0.05 - 0.25
Nuclear	0.3 - 0.7

Source: European Commission, *ExternE – Externalities of Energy*, Vol. 10: National Implementation (Luxembourg: EC, 1999), p. 6.

For further information

See the references listed below provided in the "For Further Information" section for more in-depth information on:

- The economics of the nuclear fuel cycle, see 7.1.
- An in-depth analysis of the cost of generating electricity by the various technologies in current use, including nuclear, see 7.2.
- Additional information on the economics of nuclear energy, see 7.2, 7.3 and 7.4.
- Nuclear energy in competitive electricity markets, see 7.3 through 7.5.
- External costs of generating energy, see 7.6 through 7.8.