Geo Factsheet

www.curriculum-press.co.uk Number 240

NUCLEAR POWER: A Global Renaissance

Introduction

Until a few years ago the future of nuclear power looked bleak with a number of countries apparently 'running down' their nuclear power stations and many other nations firmly set against the idea of introducing nuclear electricity. However, heightened fears about oil supplies, energy security and climate change have brought this controversial source of power back onto the global energy agenda. The main difficulties the nuclear industry still has to surmount are the high cost of constructing new plants, the uncertainty over the cost of nuclear power compared to other sources of energy and the shortage of nuclear skills around the world. The deciding factor will be government subsidies as an increasing number of countries decide they have no choice but to include nuclear power in their **energy mix**. Between 2000 and 2006, 20,000 megawatts of nuclear capacity came on line globally, mostly in the Far East and in January 2008 the UK government announced its plans to back a new generation of nuclear power stations.

Energy mix: the relative contribution of different energy sources to a country's energy production/consumption.

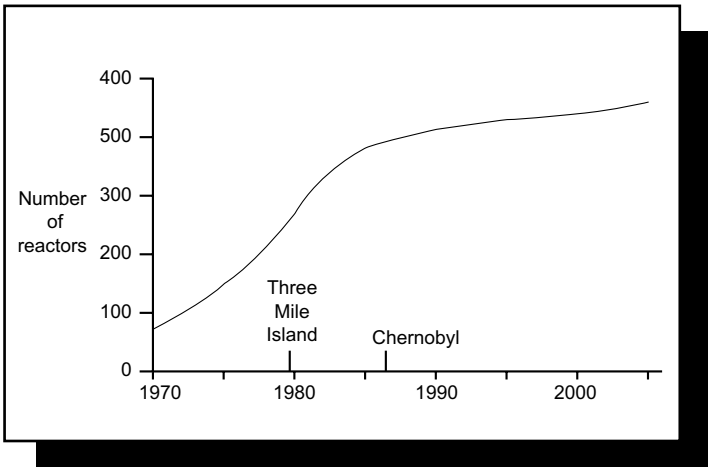
Advantages and disadvantages

No other source of energy creates such heated discussion as nuclear power. The main concerns about nuclear power are:

- **Power plant accidents**, which could release radiation into air, land and sea.
- **Radioactive waste storage/disposal:** Most concern is over the small proportion of 'high-level waste'. This is so radioactive it generates heat and corrodes all containers. It would cause death within a few days to anyone directly exposed to it. In the UK this amounts to about 0.3% of the total volume of all nuclear waste. However, it accounts for about half the total radioactivity. No country has yet implemented a long-term solution to the nuclear waste problem. The USA and Finland have plans to build waste repositories deep underground in areas of known geological stability.
- **Rogue state or terrorist use of nuclear fuel for weapons:** As the number of countries with access to nuclear technology rises, such concerns are likely to increase. An interim report published in December 2008 by the US Congressional Commission on the Strategic Posture of the United States' concluded, "it appears that we are at a 'tipping point' in nuclear proliferation. Part of the concern is that countries such as Iran which claim to be developing nuclear electricity only may well put themselves in a position to develop nuclear weapons."
- **High construction and decommissioning costs:** Recent estimates put an average price of about 5 billion euros ($6.3 billion) on a new nuclear power plant. When a nuclear plant has come to the end of its useful life, the costs of decommissioning are high.
- Because of the genuine risks associated with nuclear power and the level of security/secrecy required, it is seen by some people as less 'democratic' than other sources of power.
- The possible increase in certain types of cancer near nuclear plants. There has been much debate about this issue, but the evidence appears to be becoming more convincing.

At one time the rise of nuclear power looked unstoppable. However, a serious incident at the Three Mile Island nuclear power plant in Pennsylvania, USA, in 1979 and the much more serious Chernobyl disaster in the Ukraine in 1986 brought any growth in the industry to a virtual halt as *Fig. 1* shows. No new nuclear power plants have been ordered in the USA since then although public opinion has become more favourable in recent years as [a] Three Mile Island and Chernobyl recede into the past and [b] worries about polluting fossil fuels increase. Most of the recent nuclear power plants constructed have been in Asia.

Fig. 1 The number of nuclear power reactors worldwide.



The advantages of nuclear power are:

- **Zero emissions of greenhouse gases when operating.** This has become more and more important as concern about climate change has risen. Along with hydropower, nuclear electricity is the major source of 'carbon-free' energy used today.
- **Reduced reliance on imported fossil fuels.** More countries have become concerned about energy security. Energy insecurity may lead to increased geopolitical tension and the potential for conflict as consumers attempt to secure supplies. This will be most likely within a 'business as usual' framework of reliance on fossil fuels. Nuclear power is seen by a number of governments as a tried and tested way of reducing reliance on energy imports. France is a classic example of how this has been done *(Fig. 2)*.
- **Not as vulnerable to fuel price fluctuations as oil and gas.** Uranium, the fuel for nuclear plants is relatively plentiful with most major mines in politically stable countries.
- In recent years nuclear plants have demonstrated a v**ery high level of reliability and efficiency** as technology has advanced and experience has been built up.
- Nuclear technology has **spin-offs** in fields such as medicine and agriculture.

- France decided to invest in nuclear power in 1974
- About 80% of the country's electricity is generated by 59 nuclear plants
- France stopped building new reactors at the end of the 1980s
- A 2002 government report called the nuclear industry "a monster without a future"
- Areva, the French government-owned company is building the first nuclear reactors to be constructed in western Europe for nearly 20 years. The company has developed its 'third generation' reactor design. A new reprocessing technique produces less waste than in other countries.
- France is now poised to develop its nuclear expertise into a significant export. The country has the most recent and extensive experience of any country in the world of building and operating nuclear plants.

A few countries have developed **fast breeder reactor** technology. These reactors are very efficient at manufacturing plutonium fuel from their original uranium fuel load. This greatly increases energy generation but it could prove disastrous if the plutonium got in to the wrong hands as plutonium is the key ingredient for nuclear weapons. Fast breeder technology is still in the experimental stage and is not commercially available yet.

Fast-breeder reactor: a nuclear reactor in which the chain reaction is maintained mainly by fast neutrons. It is capable of producing more fissionable material than it consumes.

Global nuclear energy: present and future

Table 1 shows the situation of world nuclear electricity generation at the end of 2008. Worldwide, 439 nuclear reactors were operating in 30 countries with a total capacity of 373,676 MW. With 104 nuclear reactors with a combined capacity of 100,845 MW the USA led the way. This accounted for 27% of global capacity. The USA was followed by France [63,473 MW], Japan [47,577 MW], Russia [21,743 MW] and Germany [20,339 MW]. A total of 13 countries rely on nuclear power for at least 30% of their electricity supply. These countries are led by France [77%], Lithuania [64%], Belgium [54%] and Slovakia [54%].

Table 1 also shows that 37 nuclear reactors were under construction in December 2008, with a total capacity of 33,018 MW. These were in China [9], Russia [8], India [6], South Korea [3], Canada [2], Japan [2], Slovakia [2], Argentina [1], Finland [1], France [1], Pakistan [1] and Iran [1]. Iran is the only country on this list that does not currently generate nuclear electricity.

Table 1 World Nuclear Power Reactors: present and future.

COUNTRY	Nuclear electricity generation 2007		No. of reactors operable Dec 08	No. of reactors under construction Dec 08	No. of reactors planned Dec 08	No. of reactors proposed Dec 08	Uranium required 2009 (tonnes)
	Billion kWh	%e					
Argentina	6.7	6.2	2	1	1	1	123
Armenia	2.35	43.5	1	0	0	1	51
Bangladesh	0	0	0	0	0	2	0
Belarus	0	0	0	0	2	2	0
Belgium	46	54	7	0	0	0	1011
Brazil	11.7	2.8	2	0	1	4	303
Bulgaria	13.7	32	2	0	2	0	261
Canada	88.2	14.7	18	2	3	6	1665
China	59.3	1.9	11	11	26	72	1396
Czech Republic	24.6	30.3	6	0	0	2	619
Egypt	0	0	0	0	1	1	0
Finland	22.5	29	4	1	0	1	1051
France	420.1	77	59	1	0	1	10527
Germany	133.2	26	17	0	0	0	3332
Hungary	13.9	37	4	0	0	2	271
India	15.8	2.5	17	6	10	15	978
Indonesia	0	0	0	0	2	4	0
Iran	0	0	0	1	2	1	143
Israel	0	0	0	0	0	1	0
Italy	0	0	0	0	0	10	0
Japan	267	27.5	53	2	11	1	7569
Kazakhstan	0	0	0	0	2	2	0
Korea (North)	0	0	0	0	1	0	0
Korea (South)	136.6	35.3	20	5	3	2	3109
Lithuania	9.1	64.4	1	0	0	2	225
Mexico	9.95	4.6	2	0	0	2	246
Netherlands	4.0	4.1	1	0	0	0	98
Pakistan	2.3	2.34	2	1	2	2	65
Poland	0	0	0	0	0	5	0
Romania	7.1	13	2	0	2	1	174
Russia	148	16	31	8	11	25	3365
Slovakia	14.2	54	4	2	0	1	313
Slovenia	5.4	42	1	0	0	1	141
South Africa	12.6	5.5	2	0	3	24	303
Spain	52.7	17.4	8	0	0	0	1398
Sweden	64.3	46	10	0	0	0	1418
Switzerland	26.5	43	5	0	0	3	537
Thailand	0	0	0	0	2	4	0
Turkey	0	0	0	0	2	1	0
Ukraine	87.2	48	15	0	2	20	1974
UAE	0	0	0	0	3	11	0
United Kingdom	57.5	15	19	0	0	6	2199
USA	806.6	19.4	104	0	12	20	18918
Vietnam	0	0	0	0	2	8	0
WORLD**	**2608**	**15**	**436**	**43**	**106**	**266**	**64,615**

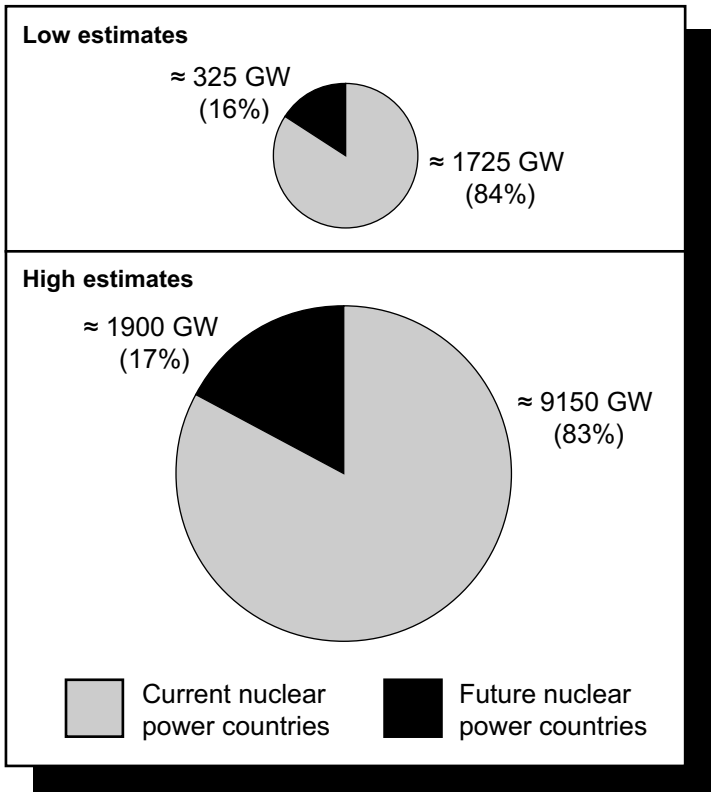
***World total includes 6 reactors operating in Taiwan.*

Source: *www.world-nuclear.org/info/reactors.htm*

However, the number of planned and proposed reactors is much greater. The number of reactors classified as planned in December 2008 was 106 with a total capacity of 117,825 MW. The largest numbers of planned reactors are in China [24], the USA [12], Russia [11], Japan [11] and India [10]. Countries on this list that do not currently generate nuclear electricity are Belarus, Egypt, Indonesia, Iran, Kazakhstan, North Korea, Thailand, Turkey, UAE and Vietnam. The planned spread of nuclear technology brings with it major political issues.

Those nuclear reactors which the World Nuclear Association classifies as 'proposed' number 270 with a combined capacity of 266,275 MW. The largest numbers are in China [76], Russia [25], South Africa [24], USA [20], Ukraine [20] and India [15]. This list includes even more countries that do not currently generate nuclear electricity.

Fig. 3 Pie charts – projected nuclear capacity 2100.



Source: *www.world-nuclear.org/outlook/clean_energy_need.html*

The World Nuclear Association has also produced a 'Nuclear Century Outlook'. Most nuclear projections, as those in *Table 1* extend to 2030 and assume business-as-usual behaviour. In contrast, *Fig. 3* projects to the year 2100, showing the lowest and the highest estimates. A range of important factors have been considered in arriving at these estimates. These include:

- Population projections, with the global population rising from its current 6.6 billion towards 9 billion by 2050
- The introduction of nuclear power into new nations as they see few viable alternatives to including nuclear power in their energy mix.
- The relationship between nuclear power and renewable energy technologies in meeting global clean-energy need. Major advances in renewable energy technologies could significantly reduce the demand for nuclear power. However, the World Nuclear Association sees both forms of energy as being complimentary, stating "Even with expansive growth in nuclear power, renewables will also be needed on a large scale, despite their higher cost. In this sense, nuclear and renewable are not competitors but clean-energy partners."

Even the low projection to 2100 represents more than a five-fold increase over current global nuclear capacity. The projections assume that there will be no significant problem with nuclear fuel availability. Most nuclear experts seem to concur with this view due to a combination of factors:

- New uranium discoveries
- More advanced mining techniques
- Use of uranium 'tailings' (low level waste buried at the mine site)
- A higher rate of reprocessing
- Introduction of the thorium fuel cycle, and,
- Eventually, the employment of fast breeder reactors.

The Nuclear Industry

Nuclear power is not just an important source of energy, it is an industry in its own right. The construction of a nuclear power plant requires advanced and expensive technology as well as highly skilled labour. The sharp decline in the commissioning of new nuclear plants after the accidents at Three Mile Island and Chernobyl led to a major contraction in the industry and a significant loss of skills. If the industry is to undergo the renaissance that many energy experts predict, it will have to re-skill at a relatively rapid rate.

The three companies of a significant size in the nuclear reactor construction market are:

- Areva, a French government-owned company
- Westinghouse, now a unit of Toshiba of Japan
- GE Hitachi, a recently formed joint venture.

This is a highly capital intensive industry where the cost of labour is not a major factor. Areva has forecast that demand for nuclear capacity could bring it orders for 60 reactors, or one-third of the total market, by 2020. As the UK has not built a nuclear plant for such a long time, it is likely that it will have to look to one of the companies above to construct any nuclear plants built in the future.

Nuclear Power in the UK

Fig. 4 shows the current distribution of the UK's nuclear power plants. Until mid-2005 it seemed unlikely that the UK would consider building a new generation of nuclear power plants. In fact the 2003 energy white paper described nuclear power as "an unattractive option". However, with falling North Sea energy production and concerns about possible supply disruptions on imported energy (gas), nuclear appears to be back on the agenda.

Fig. 4 current distribution of the UK's nuclear power plants.

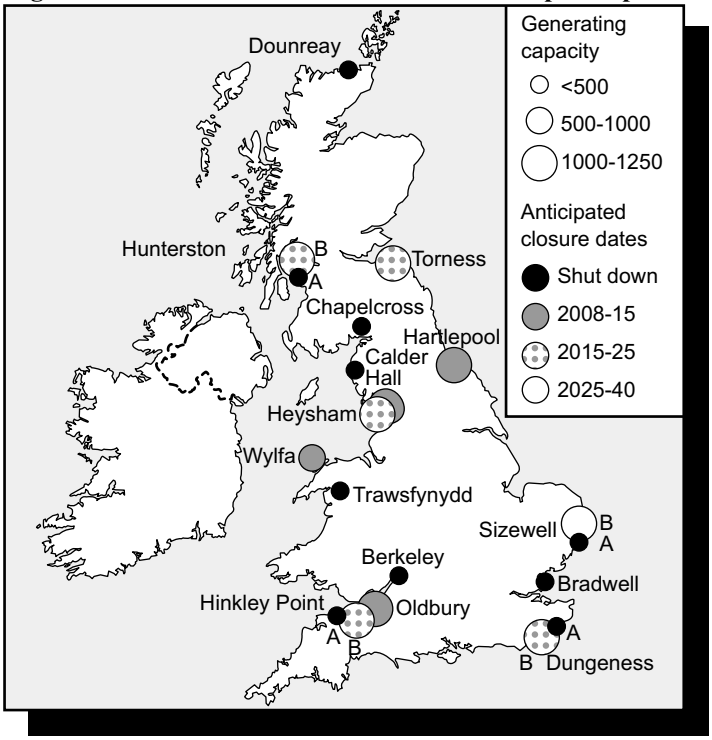


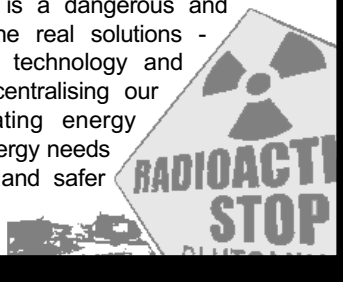
Fig. 5 Greenpeace: arguments against nuclear power.

The Government supports a new generation of nuclear power stations, arguing that we need nuclear power to tackle climate change and provide a secure future energy supply.

They're wrong; the reality is that a new generation of nuclear reactors simply won't deliver the urgent emissions cuts needed to tackle climate change. Even the most optimistic estimates suggest that a new generation of nuclear power stations will only reduce our emissions by 4% by 2024; far too late to stop global warming or address the predicted energy gap.

Instead, a new generation of reactors will create tens of thousands of tonnes of the most hazardous radioactive waste, which remains dangerous for up to a million years. It will establish new targets for terrorists, including nuclear waste trains carrying deadly cargoes along our public rail network for decades to come. It will keep the threat of a nuclear reactor accident hanging over us and risk the proliferation of weapons-grade plutonium. And it will render the public liable for the enormous cleaning up costs.

But the most imminent threat that a nuclear age poses is to the real energy solutions to climate change. Investment in nuclear energy and its infrastructure is a dangerous and expensive distraction from the real solutions - energy efficiency, renewable technology and decentralised energy. By decentralising our energy system and generating energy locally, the UK can meet its energy needs in a much cheaper, cleaner and safer way, slashing our climate change contributions.



Source: *www.greenpeace.org.uk/nuclear*

The Government is faced with the difficult decision of either allowing the industry to gradually run down as old plants have to be closed or to build new plants. A significant problem is that it takes at least ten years to plan and build a nuclear reactor. Environmental organisations such as Greenpeace *(Fig. 5)* are absolutely opposed to nuclear power. Their main objections are:

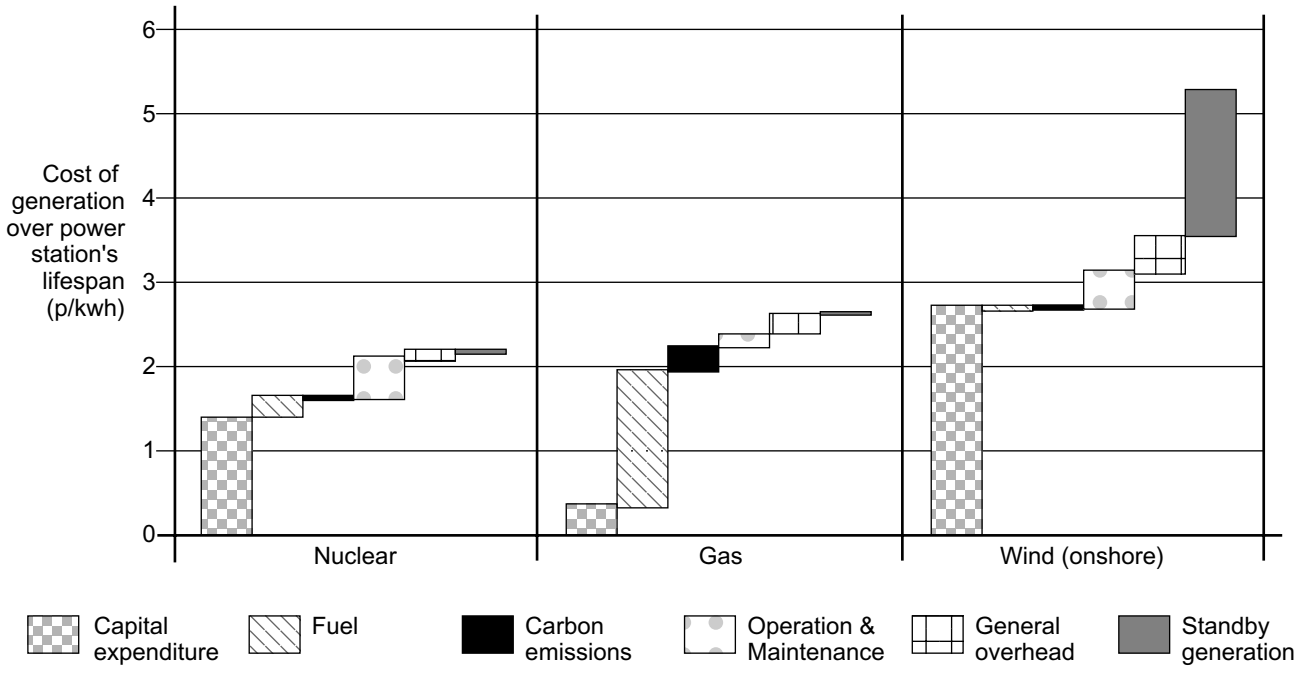
- The risk of a major accident spreading radioactivity into the atmosphere and hydrosphere
- The production of radioactive waste which will remain in a dangerous state for centuries.

When all the UK's current nuclear power plants close (without waste from newer nuclear plants) it is estimated that 36,590 cubic metres of intermediate and high level waste will have accumulated. This is enough to fill fourteen Olympic-sized swimming pools. Such waste is stored above ground in steel canisters enclosed by concrete. Most of the UK's low-level waste is stored in sealed concrete vaults in Drigg, Cumbria. It currently holds 960,000 cubic metres of waste. This is equivalent to 384 Olympic-sized swimming pools. Some low-level waste is considered safe enough to be placed into hazardous waste landfill sites.

The proponents of nuclear power argue that it is the only way that the UK can avoid electricity shortages and meet its climate change obligations at a reasonable cost. A recent report by the investment bank UBS calculated that nuclear electricity is cheaper than gas as long as oil is above $28 a barrel (natural gas prices are closely linked to the price of oil). There is considerable variation in estimates of the cost of nuclear power for the UK. The Royal Academy of Engineers figures shown in *Fig. 6* are some of the most optimistic.

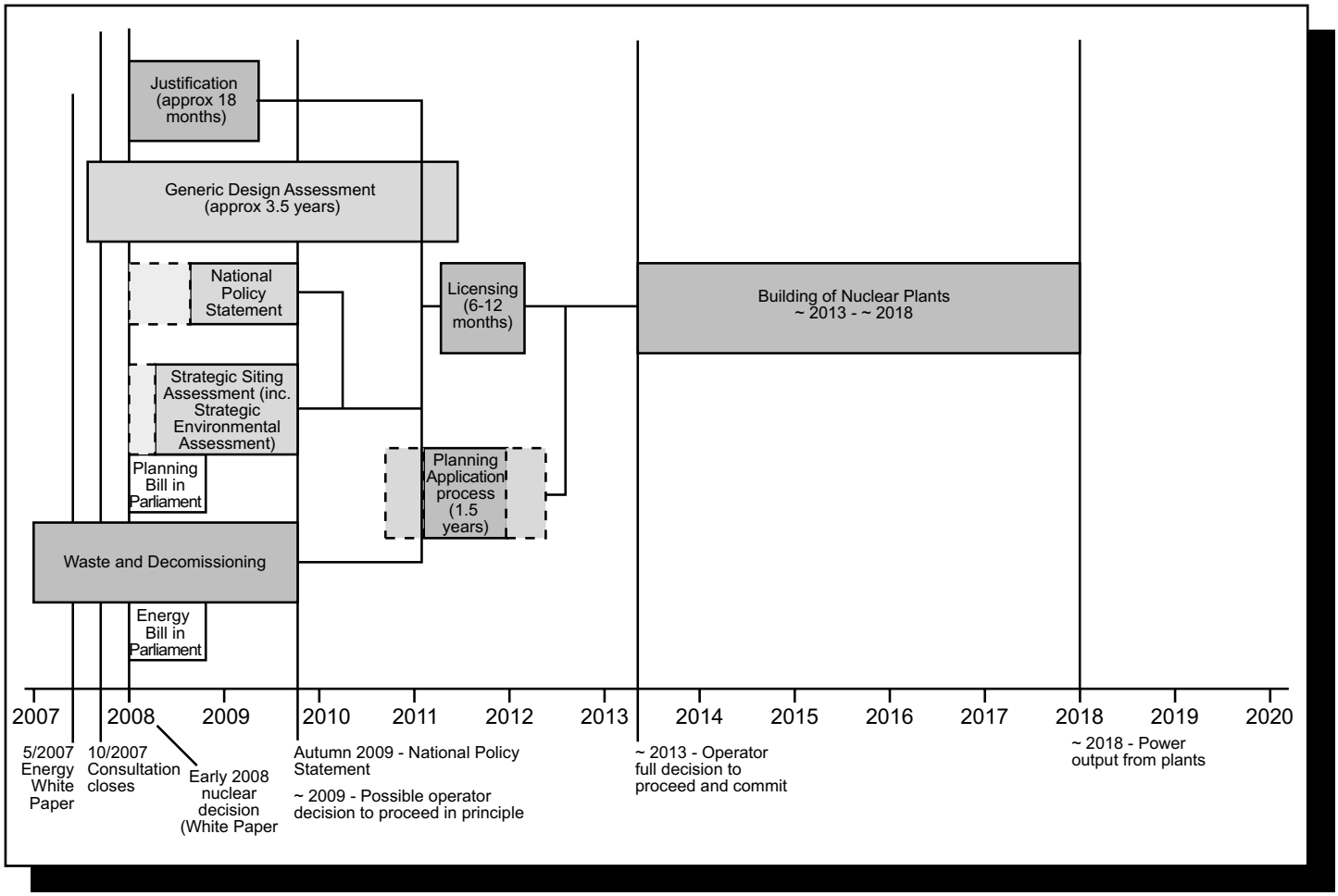
Without the construction of new power plants, the share of nuclear generated electricity will decline from 23% in 2005 to 7% by 2020. Nine of the country's twelve nuclear plants are due to be closed in the next ten years. All but one will be phased out by 2030.

Fig. 6 The costs of nuclear power compared to gas and wind power (excluding decommissioning and waste disposal).



Source: *Royal Academy of Engineers*

Fig. 7 Possible timescale for new nuclear power plants in the UK.



Source: *'Meeting the energy challenge' - a White Paper on nuclear power, January 2008*

In the government's White Paper on Nuclear Power, January 2008, the Prime Minister stated "Nuclear power is a tried and tested technology. It has provided the UK with secure supplies of safe, low-carbon electricity for half a century. New nuclear power stations will be better designed and more efficient than those they will replace. More than ever before, nuclear power has a key role to play as part of the UK's energy mix. I am confident that nuclear power can and will make a real contribution to meeting our commitments to limit damaging climate change". *Fig. 7* shows the likely timescale involved in Britain's second era of nuclear power.

Nuclear Fusion

Nuclear electricity is currently produced through the process of nuclear **fission**. The eventual objective is to master nuclear **fusion**, which is the way the sun's energy is generated. However, despite over 50 years of research it is thought that the harnessing of fusion technology to produce electricity on a commercial scale is at least 30 years away. The big advantages would be [a] inherent safety [b] no long-lived radioactive waste [c] plentiful supplies of the basic fuel sources, deuterium and lithium.

Conclusion

The next four or five years will be crucial to the future of nuclear energy with many countries making final decisions to extend or begin their nuclear electricity capability. There are big economic questions to be addressed, with considerable debate about the real and total costs of nuclear energy. However, the non-economic questions are every bit as important. Many governments have become increasingly worried about their countries energy security, now and in the future. In such circumstances cost becomes less important than it would otherwise be. In addition, in many countries public concerns over nuclear safely are deeply entrenched. There has not been a significant nuclear accident since Chernobyl over 20 years ago. However, should one occur it could have a devastating impact on the future of the nuclear industry. The nuclear energy issue is likely to be a major political battleground in some countries.

Useful Websites

- *www.world-nuclear.org* – World Nuclear Association
- *www.greenpeace.org* – Greenpeace
- *iaea.org* – International Atomic Energy Agency
- *nei.org* – Nuclear Energy Institute

Acknowledgements
This Factsheet was researched by Paul Guinness who works at Kings College Wimbledon.

ISSN 1351-5136