New Nuclear Power in the UK: A Strategy for Energy Security?

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Introduction

Energy security has risen up the global political agenda during the past few years. There are many reasons for this: rapid increases in oil and gas prices, heightened awareness of terrorism, the war in Iraq, and the blackouts that have hit several electricity networks.

The key threats are the price of energy and its availability. Some threats can disrupt the provision of energy to consumers and businesses (power blackouts; fuel blockades) whilst perhaps the more significant affect the price of energy (tension in Middle East; lack of UK onshore gas storage). This paper argues that much policy discussion is conducted without a clear idea of the dimensions of energy security and their relative significance, and that such an analysis is vital to a rational, mature energy policy.

The renewed interest in nuclear power as a central part of the UK's energy strategy became clear in a speech by the then Prime Minister Tony Blair. Announcing the 2006 Energy Review, Blair emphasised what he saw as the twin concerns for energy policy – climate change and energy security: 'Round the world you can sense feverish re-thinking. Energy prices have risen. Energy supply is under threat. Climate change is producing a sense of urgency' (Blair, 2005). A few sentences later, he added that the Energy Review would 'include specifically the issue of whether we facilitate the development of a new generation of nuclear power stations' (Blair, 2005).

In this paper, we provide a framework to analyse the possible role of new nuclear in enhancing security, including of course the possibility that new nuclear could increase *in*security in some cases. Within this, there are several related issues that are important in the energy security debate. These include the availability and diversity of energy sources from foreign sources (Kalicki and Goldwyn, 2005), diversity within those energy sources, international supply routes for energy sources, domestic energy infrastructures, threats due to terrorism (Yergin, 2006), and wider effects such as vulnerability to the impacts of climate change (Barnett, 2001).

This paper is organised in three parts. The first is a detailed examination of energy security, focusing on various threats to security and their potential and actual impacts. The second part considers a strategy that is often put forward to counteract these threats: diversity. The third part focuses on the extent to which new nuclear power could help mitigate these threats.

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Unpacking energy security

Energy security is frequently invoked in support of various policies and technologies. Yet we rarely hear a mature, reasoned and comprehensive debate on the nature and severity of the different sources of threat to our energy security. Here, we have sought to bring together all of the dimensions of energy security in an integrated framework. Our aim is to see the 'big picture' of energy security, and in doing so enable a more effective analysis of the role that different policies and technologies might play in addressing it.

The threats are summarised in Table 1 together with some examples, possible mitigation strategies, and a summary of nuclear power's potential role. They are grouped into the following four categories:

- Fossil fuel scarcity and external disruptions including international terrorism
- Lack of investment in infrastructure
- Technology or infrastructure failure
- Domestic (UK-based) activism or terrorism

Whilst the first of these categories is internationally oriented with an emphasis on threats that are 'external' to the UK, the other three categories focus primarily (though not exclusively) on threats from within the UK's borders. This balance is deliberate for two reasons. First, there is a need to compensate for the tendency of the security debate to focus on external threats at the expense of a complimentary examination of domestic vulnerabilities (Stern, 2004). Second, the focus of this paper is on a proposed domestic solution to some of these threats – new nuclear. In order to understand whether this would improve security, it is necessary to go beyond a rather simplistic analysis that contends that any action that reduces energy imports will automatically lead to better energy security (Performance and Innovation Unit, 2002).

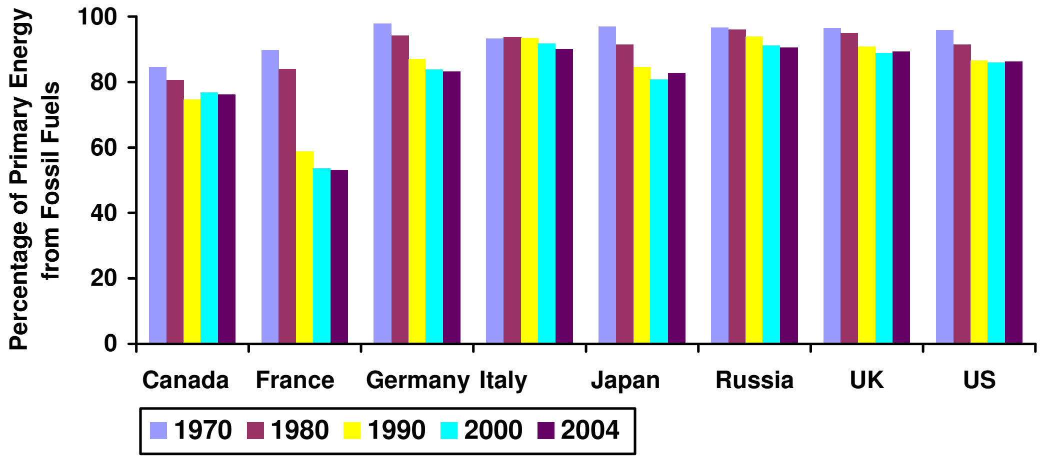
Table 1. Threats to UK energy security and their potential impacts

Root Cause	Threat/challenge	Possible Effects	Examples	Solutions	Nuclear as Solution?
Group 1. Fossil fuel scarcity and external disruptions	Fossil fuel scarcity	• High fuel prices • Economic impacts	• Current high oil price, partly due to strong demand (e.g. from China) and OPEC restrictions on supply	• Assure foreign supply (e.g. invade Iraq); switch fuel sources; pressure on OPEC	• Yes, but depends on costs • Limited by lack of nuclear relevance to heat & transport
	External disruptions to supply of fossil fuels	• Sudden price increases • Sudden economic impacts (e.g. recession)	• 1970s oil price shocks • Russian threats to cut off gas supplies to neighbours • Terrorist attacks on international pipelines	• Negotiate with suppliers; diversify sources and fuels; explore alternatives to fossil fuels; invest in storage capacity	• Yes, but depends on costs • Limited by lack of nuclear relevance to heat & transport • Nuclear slow to respond
Group 2. Lack of domestic investment in infrastructure	Insufficient capacity / storage to supply	• Exposure to price volatility • Disruptions	• Lack of UK gas storage due to Rough fire. Insufficient incentives to invest in storage	• Invest in infrastructure; adjust regulations; better strategic planning	• Yes if it adds to capacity margin, but (as with other sources) at significant cost • Limited 'load following'
Group 3. Technology or infrastructure failure	Common mode technology failures	• Price increases • Disruptions to supply of electricity / energy sources	• French blackouts due to overheating of PWRs in 2003 (most of French power from nuclear)	• Diversify type of fuel/technology used; • Adapt the technology, adjust design for future	• Depends on extent; diversity within nuclear. • French example – nuclear can be vulnerable
	One-off technology / infrastructure failure	• Price increase or disruption, depending on extent • Hazards to life/health; infrastructure damage	• Oil tanker disasters or nuclear disasters caused by technical failure; operator error	• Vigilance: standards, training, maintenance, inspection • Minimise use	• Not necessarily, given history of nuclear failures – rare but serious when they happen
	Climate change impacts	• Underperformance / failure of infrastructure • Price increases and/or disruptions	• French blackouts due to overheating nuclear plants • Threats to coastal sites? • Limits on fossil fuel use	• Water storage, shut down reactors, other cooling? • Change siting policy; invest in other technologies	• Not particularly - nuclear infrastructure can be vulnerable to overheating and sea level rise.
	Environmental and health effects of energy system	• Health or environmental impacts	• Fossil fuel air pollution • Radiation from nuclear accidents and small leaks	• Regulate; set standards; R&D; new technology • Avoid the technology	• No. Inherently hazardous technology.
Group 4. Domestic activism or terrorism	Held to ransom by in-country activists	• Price increases • Sudden disruptions	• UK fuel protests in 2000 exploited centralised distribution / just-in-time • Grangemouth pension dispute	• Capitulate and reduce fuel duties; offer other carrots; tough it out; negotiate pension scheme	• Not necessarily. Nuclear infrastructure could also be vulnerable to protest (e.g. spent fuel transport)
	Terrorism, attack on UK infrastructure	• Price increases • Sudden disruptions • Damage; loss of life	• Attack on nuclear power station, oil/gas terminals • Equivalent of 9/11 attacks	• Protect infrastructure; avoid the technology • Adjust foreign policy	• Not necessarily. Nuclear infrastructure a potential target

Group 1: Fossil fuel scarcity & external disruptions

Fossil fuels continue to play a dominant role in modern economies. Securing enough fossil fuels at affordable prices is therefore a high priority. Figure 1 illustrates the extent of fossil fuel dependency in G8 countries.

Figure 1. Percentage of Primary Energy Supply from Fossil Fuels in G8 Countries



Source: (Department of Trade and Industry, 2007c, Background Indicators Annex)

Fossil fuels continue to account for the majority of energy supplied within G8 countries since 1970. The UK is typical since its proportion of energy met by fossil fuels has only fallen marginally since 1970. This dependence means that perceived limits to their availability are a feature of many energy security discussions. The famous *Limits to Growth* book published in 1972 (Meadows, Meadows et al., 1972) predicted that oil would run out in 20 years – a prediction that clearly turned out to be wrong[2]. More recently, a number of analysts have revived these arguments with a particular focus on an imminent peak in oil production (Campbell, 2005; Bentley, Mannan et al., 2007).

Others point to flaws in the arguments of peak oil proponents – in particular by focusing on the economic nature of fossil fuel reserves (Watkins, 2006). Instead of being a fixed quantity that is steadily depleted over time, the quantity of recoverable reserves itself varies with the price of fossil fuels, and improvements in extraction technology. Hence reserves have lasted much longer than expected. Indeed, some estimates of recoverable reserves by peak oil proponents have increased over time – and the timing of the global peak has often been pushed into the future (Lynch, 1999).

Table 2 summarises data from one of the mostly widely used sources, the *BP Statistical Review of World Energy* (BP, 2007). These figures should be interpreted with care. They focus on proven reserves and provide a static picture that will change over time as a result of movements in prices, and advances in exploration and extraction technology. Table 3 provides complementary data on fossil fuel production.

[2] Warnings about limits to natural resources date back much further than this. See for example, 'An Essay on the Principles of Population' written by Thomas Malthus in 1798.

Table 2. Global distribution of fossil fuel reserves in 2006

	Oil		Natural Gas		Coal	
Location of largest reserves	Saudi Arabia	22%	Russia	26%	USA	27%
	Iran	11%	Iran	16%	Russia	17%
	Iraq	9.5%	Qatar	14%	China	13%
	Kuwait	8.4%	Saudi Arabia	4%	India	10%
	UAE	8.1%	UAE	3%	Australia	9%
	Total top 5	*59%*	*Total top 5*	*63%*	*Total top 5*	*76%*
Global total reserves	**1208 bn barrels**		**181 trillion m^3**		**909 bn tonnes**	

Source: (BP, 2007)

Table 3. Global fossil fuel production in 2006

	Oil		Natural Gas		Coal	
Largest producing countries	Saudi Arabia	13%	Russia	21%	China	39%
	Russia	12%	USA	19%	USA	19%
	USA	8%	Canada	7%	India	7%
	Iran	5%	Iran	4%	Australia	7%
	China	5%	Norway	3%	Russia	5%
	Total top 5	*43%*	*Total top 5*	*54%*	*Total top 5*	*77%*
Global total production	**29.8 bn barrels**		**2.9 trillion m^3**		**6.2 bn tonnes**	
Reserves to Production Ratio	40.5 years		63 years		147 years	

Source: (BP, 2007)

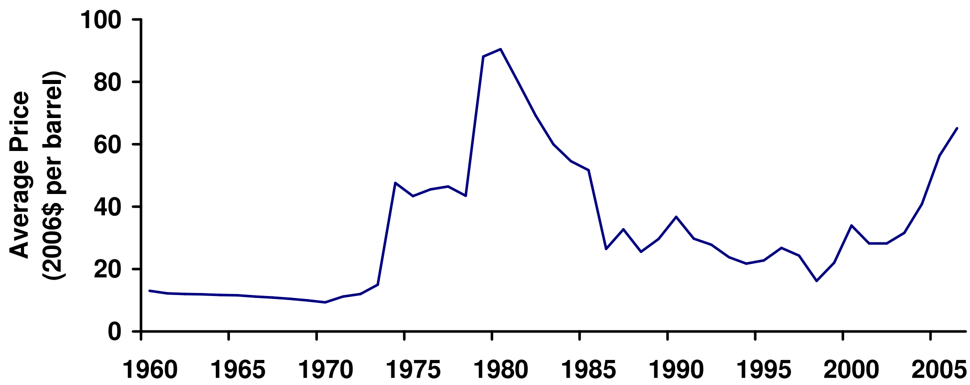
The tables illustrate why there is a focus within importing countries on the global distribution of fossil fuels. Proven reserves of oil are concentrated in the Middle East, whilst those of natural gas are mainly found in the Middle East and Russia. For political and historical reasons, there is a strong perception that this situation contributes to insecurity. The pattern of oil and gas production is more geographically diverse. Both Russia and the United States are in the top five global oil producers. The top five for natural gas includes producers from Europe and North America. However, in oil at least, Saudi Arabia has a key role as a 'swing producer' that balances changes in global supply and demand (Lynch, 2006). Coal receives much less attention than oil or natural gas in energy security debates in industrialised countries. This is because global coal reserves are estimated to be much larger and these reserves are in parts of the world that are considered to be more stable.

In addition to the risks associated with the location of fossil fuels, their transportation also raises energy security challenges. Long-distance pipelines and ships are potentially vulnerable to terrorist attacks or political interference. An example of the former type of vulnerability is the new Baku Tbilisi Ceyhan pipeline which has been built to transport oil from fields in the Caspian Sea to the Mediterranean. It is thought by some to be vulnerable to terrorist attack in parts of Georgia and Azerbaijan that it crosses (Parfitt, 2006). With respect to the latter 'political' category of vulnerability, there have been a number of disputes between Russia and neighbouring states that have affected supply through oil and gas pipelines. (Stern, 2006).

The main impact of fossil fuel availability on importing countries is through prices. Since fossil fuels are internationally traded commodities, countries that have been self sufficient for significant periods such as the UK have not been immune to price rises. Due to their importance in many economies, increases in fossil fuel prices can have a pervasive impact and can lead to upward pressure on inflation. Oil prices have tended to be the most vulnerable to rapid changes, whilst gas prices have usually followed suit. Coal prices are more independent, but can also increase at times of high oil prices due to fuel switching by consumers.

During the past 35 years, there have been a number of periods in which oil prices have risen rapidly, often as a consequence of conflicts or other political events in producer countries (see Figure 2). The oil shocks of 1973/4 and 1979 were triggered by the Yom Kippur war and the Iranian revolution respectively. A smaller rise in prices coincided with the first Gulf War in 1990 following the Iraqi invasion of Kuwait. More recently, restrictions on oil supplies due to the second Iraq war have been compounded by rapid rises in demand (particularly from China) and other factors such as heightened tensions with Iran over its alleged nuclear weapons programme. Oil prices are now higher in real terms than they have been since many records began. At the time of writing, prices are around $110 per barrel (in 2006 prices).

Figure 2. Average oil price (1960-2006)



Source: (BP, 2007)

Looking back at these periods of turmoil, it is interesting to note that supplies of fossil fuels are rarely 'cut off' by external conflicts. As Michael Lynch observes, the main damage to importing countries (and some exporting countries too) is due to the economic impact of rapidly rising prices (Lynch, 1999). These impacts can be severe, and have contributed to recessions in many countries in the past. Whilst Lynch concedes that some shortages have arisen during price shocks, for example in petrol stations in the 1970s, he argues that these have occurred because of poorly managed responses.

Group 2: Lack of domestic investment in infrastructure

National infrastructures to generate and supply energy to customers can also be vulnerable to insecurity. Indeed, some analysts have argued that external threats attract a disproportionate amount of attention in energy security debates. The Energy Review conducted by the UK government's Cabinet Office noted in 2002 that:

> [I]mports are regarded as inherently more unreliable than domestic sources. However, as in other markets, energy imports allow us to access more diverse, and cheaper, resources, than if energy sources were produced solely at home. Experience with coal in the 1970s and 1980s, and the fuel protests of 2000 suggest that the equation of "domestic" and "secure" does not always apply. Imports of energy are not necessarily less secure than domestic sources. (Performance and Innovation Unit, 2002: 57)

The UK's national energy system includes a large amount of infrastructure including power plants, electricity and gas networks, facilities to import fossil fuels (e.g. LNG terminals) and pipeline networks in the UK's waters offshore. This energy infrastructure also includes all of the buildings, appliances, machinery and vehicles that uses energy (Patterson, 2007).

There are many potential challenges to the security of this infrastructure. Prominent in UK energy policy debates is the extent to which there has been sufficient investment in these assets – and whether under-investment has increased vulnerability to supply disruptions and/or undesirable increases in prices. Both the 2003 Energy White paper and the 2006 Energy Review included investigations of the incentives for investment in areas such as power plant capacity and gas storage (e.g. NERA, 2002b; Oxera, 2007).

The vulnerabilities that under-investment could contribute to are best illustrated through examples. One of the most serious was the fire in the UK's largest gas storage facility – Rough – in February 2006. This fire meant that 70-80% of the UK's gas storage capacity was unavailable and led to a rapid increase in UK gas prices. These increased much further than prices elsewhere in Europe despite the interconnector linking the UK and the continent. Jonathan Stern argues that a lack of UK incentives has meant that commercial companies have not invested in sufficient strategic storage (Stern, 2006). Had the Rough fire occurred at the time of that winter's peak demand, the consequences would have been more severe. Due to the lack of alternative supplies and cold weather across Europe, this might have required disconnections of some domestic customers to balance the system.

Another example of UK gas system vulnerability was more recent. In June 2006, an oil tanker dragged its anchor into one of the biggest pipelines bringing gas from UK fields to shore (Conway, 2007). The 'CATS' pipeline, which supplies around 8% of the UK's gas demand, was damaged and put out of action for 2-3 months. Unusually for the summer, this caused the price of gas to spike to levels normally associated with winter. Again, some questioned whether timely investment in additional infrastructure would have partly mitigated the economic impact of such short-term events (Stern, 2007).

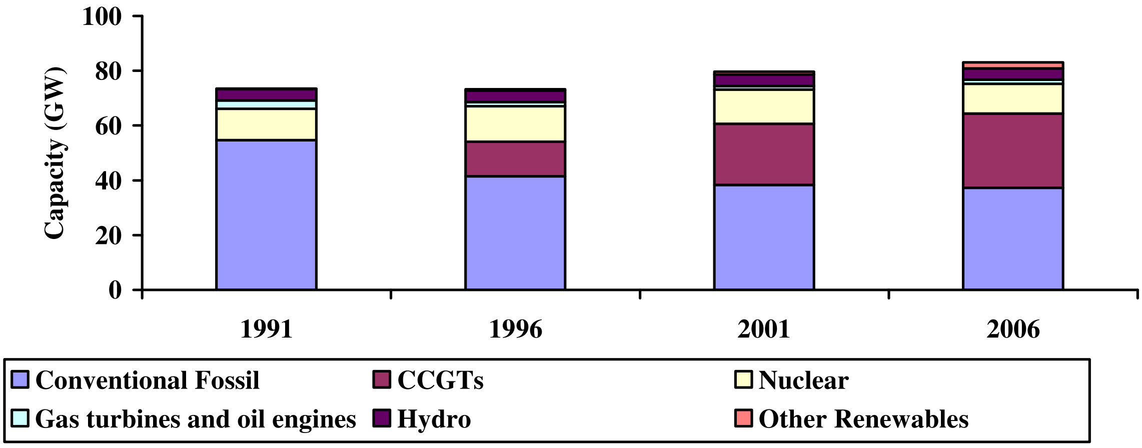
Incidences of energy insecurity due to domestic under-investment are not confined to natural gas infrastructure. In summer 2003, a series of power blackouts occurred in Europe and North America. These blackouts did not have a common cause. However, a lack of infrastructure investment was a clear contributing factor in the US blackouts, and also exacerbated the power system failure in continental Europe (Watson, 2003; Ofgem, 2004).

Perhaps the most high profile threat to energy security caused by under-investment in the UK is a hypothetical one. In the past few years, there have been increasing predictions by some commentators of a looming 'energy gap' due to a lack of investment in power generation capacity (e.g. Black, 2005). This capacity will be required to replace a number of mainly coal and nuclear plants that will be retired over the next few years. The 2007 Energy White Paper estimates that the UK will need to construct 30-35GW of new capacity in the next two decades (Department of Trade and Industry, 2007b).

However, this prediction of a gap in electricity supply is not supported by evidence of any disruption to supply or increases in prices due to scarcity. Despite its shortcomings in providing sufficient signals for new investment (NERA, 2002a), the UK electricity market has delivered a large amount of new investment since the early 1990s. Most important, over

25GW of new gas-fired capacity has been constructed during this period (Watson, 2004). Figure 3 illustrates this.

Figure 3: Changes in UK Electricity Capacity (1991-2006)



Source: Digest of UK Energy Statistics (Various years).

In addition, there has been some investment – albeit slow – in renewable electricity. Looking forward, the evidence suggests that further new gas-fired plant will be built in the absence of incentives on private investors to build plants based on other technologies, including nuclear[3]. Whilst in the past, new gas-fired plant has had the positive side effect of reducing UK carbon emissions, these reductions may not continue indefinitely. Therefore, perhaps the main issue is not the adequacy of incentives for investment *per se*, but the adequacy of incentives for plant of the right kind (i.e. with low or zero carbon emissions).

Group 3: Technology and infrastructure failures

This group includes technical failures of infrastructure and failures due to the impacts of extreme weather, some of which may be attributed to climate change. Some types of failure – even if they are isolated – can have serious security implications, at least for local populations. As the third part of this paper notes, this has been particularly true of nuclear power in the past. Accidents such as those at Three Mile Island and Chernobyl have had international implications.

Many technical failures are much less serious than these high profile examples. They are a feature of all large infrastructure systems and are usually absorbed due to 'redundancy' – spare capacity in the system. But if they become widespread in a prominent part of the system infrastructure, the consequences of such failures can be more serious. One example is the class failures that affected the new generation of power generation gas turbines in the 1990s (Bergek, Tell et al., 2008). As a result of rapid innovation to make gas turbine power plants more efficient, a series of reliability problems affected all of the major manufacturers. Because of the size of these turbines, they could not be tested in the factory – but had to be tested in the field. It was only after some time that the problems emerged.

For most countries that have gas-fired generation as part of their electricity systems, these problems affected one or two plants – so could be absorbed so that enough capacity could be made available to meet demand. However, the UK's 'dash for gas' was in full swing at the

[3] See for example, the regular Power Station Tracker in Platts' *Power UK* journal.

time. UK utilities were keen to be amongst the early adopters of more efficient plant, and were therefore affected more than most. In winter 1995/96, the capacity margin of the UK electricity system fell to an alarmingly low level due to a combination of gas turbine problems and unexpected outages at two nuclear stations (Watson, 1998).

Examples of weather impacts on a particular type of infrastructure include the problems with France's nuclear plants in summer 2003 due to intense heat (Gentleman, 2003). Many of these plants were unable to operate at their design capacity due to a lack of cooling water – some were shut down entirely. This was a contributing factor in the blackout that affected a large part of continental Europe at that time.

Other examples include the threat to a key substation due to the floods in the west of England in 2008. If it had failed, this would have cut off water and electricity supplies to 250,000 people. They also include the effect of hurricanes such as Katrina on offshore oil and gas facilities in the Gulf of Mexico. Whilst particular weather events cannot be completely ascribed to climate change, the scientific consensus is that extreme events such as hurricanes and intensive rainfall will increase over the coming Century (IPCC, 2007). This, in turn, will mean that energy infrastructures such as power plants, platforms and buildings will need to be designed or adapted to withstand greater extremes than in the past. As Daniel Yergin notes, 'the offshore oil industry has long built facilities to withstand a "hundred-year storm" -- but nobody anticipated that two such devastating storms would strike the energy complex in the Gulf of Mexico within a matter of weeks' (Yergin, 2006).

Group 4: Domestic activism and terrorism

This group of threats to energy security includes the possibility that terrorist groups will sabotage key parts of the energy infrastructure such as pipelines and power plants. As noted previously under the first group of threats, terrorist threats are international in nature. According to Daniel Yergin, 'Al Qaeda has threatened to attack … [the world's] critical infrastructure -- of which energy is among the most crucial elements. The world will increasingly depend on new sources of supply from places where security systems are still being developed, such as the oil and natural gas fields offshore of West Africa and in the Caspian Sea' (Yergin, 2006). As events on both sides of the Atlantic in recent years have shown, terrorism is an important threat within OECD countries such as the UK. Infrastructures such as LNG terminals and nuclear power plants are potential targets.

This group also covers blockades or strikes due to industrial disputes or civil disobedience. Threats of this kind are often underplayed. Yet in the last quarter of a century, some of the most significant threats to UK energy security have taken this form. The most recent example has been the 2008 Grangemouth strike, where a dispute over pensions caused a two-day shutdown followed by a lengthy start-up process to get the refinery back up to full working capacity. This affected supplies of petrol in Scotland and Northern England (Carrell, 2008), leading to some rationing and the need to bring in fuel by tanker. This dispute also meant that the pipeline from the Forties oil field had to be shut down – with the knock-on effect that production on many oil platforms was suspended.

Going further back, the Miners' strike of 1984/85 had serious knock-on effects on the electricity industry. Despite some advance planning by the then State-owned power company which built up coal stocks at power stations, the longevity of the strike put the electricity system in serious difficulty. The power industry had only planned for a six month strike. A depletion of their coal stocks and secondary picketing meant that emergency measures were required (Ledger and Sallis, 1995). These included a switch to oil burning in some power stations and the bribing of some workers to move coal stocks to where they were needed.

Similarly the fuel protests of 2001 disrupted the distribution of petrol and led to panic buying by many motorists (Public Safety Canada, 2005). The protestors – mainly farmers and lorry drivers - were able to exploit the vulnerabilities in the centralised 'just in time' delivery systems of the oil companies. Blockading just a few oil distribution depots and refineries led to the closure of 50% of the UK's petrol stations within just five days.

Security and diversity

Given these four groups of threats to energy security, our view is that the government has put forward only a partial analysis of energy security in its recent policy statements – particularly the 2007 consultation on new nuclear power (Department of Trade and Industry, 2007a). This emphasises those dimensions that have had small impacts on UK energy security in recent years (i.e. lack of generation capacity and energy imports), yet it downplays or overlooks those dimensions that have had real impacts on prices and/or availability (i.e. domestic disputes and underinvestment in onshore gas networks and storage). Although the pattern of future threats may differ from those of the immediate past, the case for a fuller analysis still stands.

Putting this to one side, the question still remains: can new nuclear address the security threats that the UK is likely to face? Before analysing this with respect to the four categories of security threat summarised above, it is useful to examine one of the most important strategies that is put forward by governments to strengthen energy security – diversity (e.g. Department of Trade and Industry, 2007b: 5)

Energy security strategies often emphasise a combination of national and international actions. For example, the communiqués from recent G8 summits in St Petersburg (2006) and Heiligendamm (2007)[4] focus on strengthening transparency in international energy markets and on investment in indigenous energy options (nuclear, renewables and efficiency) to reduce import dependency. Within both of these categories, diversity was put forward as an important principle.

Whilst maximising diversity sounds like an inherently good idea, it also merits close analysis. Diversity is a system property rather than a property of one particular technology such as wind or nuclear. This challenges the seemingly obvious conclusion that adding an energy technology into the mix will enhance diversity, as we will seek to show now.

Firstly, diversity has several dimensions that could have different impacts on energy security.. Diverse routes for imported fuels (e.g. oil and gas) and diverse sources of energy (e.g. solar and biomass heating as well as gas heating) are both said to be good for security. But diversity is about more than just having a lot of different options in an energy system.

Stirling has identified three distinct sub-properties of diversity: variety, balance and disparity (Stirling, 2007). Variety is a simple measure of the number of different options that are supported or deployed within the portfolio. Balance refers to share that these different options have within the portfolio. For example, an electricity system in which one option accounts for 60% of annual output and four further options account for 10% each is likely to be less

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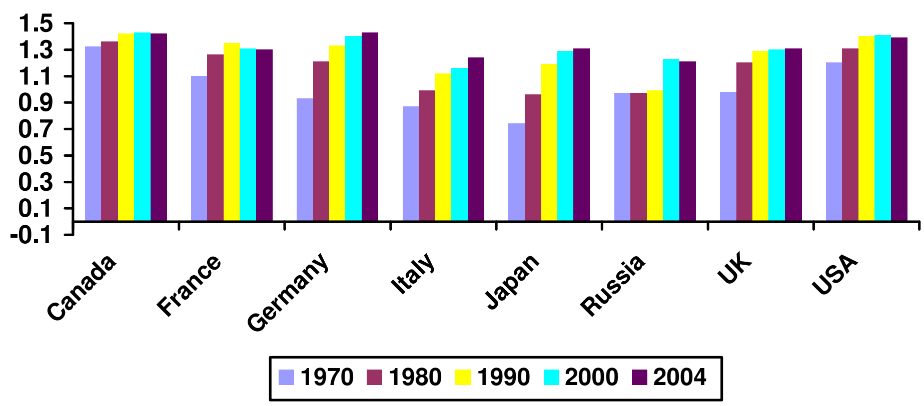
[4] See summaries at: http://www.g8.utoronto.ca/summit/index.htm .

diverse than a portfolio of five options that generate 20% of annual electricity each. Finally, disparity captures the extent to which constituent options are different from each other. A portfolio that includes ten lower-carbon coal technologies be less diverse than a portfolio that encompasses ten renewables technologies. This is because the 'renewable' category includes many more disparate options.

Another consideration is that constituent technologies within a portfolio will not be deployed in isolation from each other. Some analyses imply that technologies and measures are purely additive (Socolow, 2005). However, technological options are deployed within a common energy system, so some interaction between options is to be expected. The phenomenon of technological 'lock-in' (Unruh, 2000) is important here. Technologies that do not fundamentally challenge the technical and institutional architecture of the energy system may be easier to deploy – and may dominate a portfolio if the implications are not thought through.

The main way in which the UK government measures energy diversity is through the Shannon-Weiner index. Figure 4 shows a comparison of Shannon-Weiner diversity of primary energy supply in G8 countries 1970-2004 (Department of Trade and Industry, 2007c). In most cases, the trend has been towards increasing diversity. In the UK, this has occurred due to the increasing proportion of gas in the national energy mix. The exception is France in which the dominance of nuclear power has reduced diversity slightly.

Figure 4: Shannon-Weiner diversity of primary energy in G8 countries (1970-2004)



Source: (Department of Trade and Industry, 2007c).

One advantage of the Shannon-Weiner index is that it places additional weight on fuels that contribute a relatively small amount to the current fuel mix. The government argues that this property is important because it reflects options for future fuel switching. However, its drawback – at least as applied by the UK government to the energy mix – is that it just focuses on six primary fuels. It does not include diversity within energy sources – e.g. the range of sources of natural gas the UK is expected to be importing over the next few years (see further discussion later). Furthermore, the index does not capture the disparity of different energy options in a national mix – something that other more complex indices achieve (Stirling, 2007).

Can new nuclear enhance security?

An assessment of the likely impact of a new programme of nuclear power on UK energy security needs to analyse its ability to address each of the four groups of security threat that we have outlined. In the following discussion, a distinction is made between the replacement of the UK's current nuclear fleet and an expanded programme that would result in a larger role for nuclear power. The latter strategy has been increasingly mentioned in recent debates, including in speeches by the Secretary of State for Business, John Hutton MP (2008).

For many of the threats, the extent to which nuclear power and other potential mitigation strategies are attractive will depend partly on costs. There is often a trade off between the level of security that is achieved through these strategies and the amount of money that is required for this (NERA, 2002b). In common with some other options, the costs of new nuclear power are subject to great uncertainties. For nuclear, however, there is a history of cost escalation that makes this uncertainty particularly acute (MacKerron, 1992).

Threat 1: Fossil fuel scarcity & external disruptions

The extent to which nuclear power can mitigate threats due to scarcity and external disruptions depends first on whether there is evidence for impending fossil fuel scarcity. At present, it is not possible to verify the claims of those who predict limits to availability. As we have already noted, there are many skeptics of the 'peak oil' argument. Whilst the supply of fossil fuels is clearly not infinite, environmental limits due to climate change could be more important than peak oil in curbing fossil fuel use. What may be more important in this context is the impact of new nuclear on the UK economy's exposure to the economic effects of fossil-fuel price volatility. A substantial programme would help to some extent - though it must be borne in mind that many other options (renewables and demand reduction) could also help.

The usefulness of nuclear power as an option to reduce these threats also depends on the counter-factual scenario – i.e. would the alternative investments to new nuclear power be more likely to expose the UK to these largely external threats. As this paper has already argued, the most likely investment option for large-scale power generation is gas. In addition, there are also a significant number of plans for new coal plants, and renewables will also continue to expand due to the Renewables Obligation. Furthermore, a serious programme of demand reduction through routes such as the Supplier Obligation could reduce the need for new supply.

One of the key arguments that is made by Ministers is that new nuclear will lessen UK dependence on imports, specifically imports of Russian gas (e.g. Blair, 2005). However, projections by Oxera for the 2007 Energy White Paper show that the UK's gas supplies will in fact be sourced from a variety of locations and through a range of transit routes (Oxera, 2007). In the period to 2020 these projections foresee some continuation of supplies from the UK continental shelf, an increase in piped gas from Norway, LNG imports from countries such as Qatar and supplies from continental Europe via interconnectors. Only the last of these includes Russian gas. It could be argued therefore that gas supplies could get more secure, not less, since supply origins and routes will become more diverse.

Furthermore, we believe that the narrative of a 'Russian gas threat' is also oversold because much of the UK's gas is not used for power generation at all. This sector accounts for around

30% of UK gas demand[5]. The rest is used for industrial processes and domestic heating. Therefore the argument that nuclear can significantly replace gas does not stand up to scrutiny unless the intention is to increase to a much larger nuclear fleet to replace gas fired power *and* generate electricity for home heating, industry and so on. This 'replace and expand' strategy may have some supporters, but is rarely discussed as a serious option. Any such strategy would have significant implications for other dimensions of security.

Threat 2: Lack of domestic investment in infrastructure

In principle, the construction of new nuclear power stations could help to replace the power generation capacity that is due to retire over the next two decades. However, due to long lead times, nuclear power would be one of the slowest ways to bring new capacity on line. The 2007 Energy White Paper clearly illustrates this with an expectation that only one nuclear plant (at most) is likely to be operational by 2020. By contrast, gas-fired capacity, many renewable electricity sources and demand reduction measures can be implemented more quickly. In addition to this, plans for the implementation of demonstration plants with carbon capture and storage (CCS) foresee a shorter timescale for operation than is the case for nuclear power. For this option, there are of course significant technical and economic risks which mean that it would be unwise to rely on plants with CCS to perform at normal commercial levels of reliability for some time.

The prospect of an expanded nuclear contribution in the UK raises another related issue. Critics of renewable energy often cite the intermittency of technologies such as wind power as evidence that such technologies have a limited role to play. This evidence is disputed, and the potential impacts of intermittency are often exaggerated (UKERC, 2006). What is often overlooked by these critics is that other options such as nuclear power can also impose constraints on system operation. Since nuclear power stations cannot easily be switched on and off, they are good at providing 'base load' power but relatively poor at responding to short-term peaks in demand.

In theory, nuclear power could also reduce the need for gas infrastructure reinforcement if it were deployed under a 'replace and expand' scenario over the medium to long term. However, it is unlikely that even this level of investment would replace the use of gas or oil within the UK energy system. Therefore, measures to strengthen other infrastructures such as the capacity for gas storage would still be required.

Threat 3: Technology or infrastructure failure

The reliability of nuclear power plants has improved in many countries in recent years. Availability figures are now comparable with those of fossil fuel power generation technologies. Safety concerns have also receded now that time has passed since the Chernobyl accident. The presence of a diverse mix of technologies in an electricity system that have a high level of technological disparity is a good way of guarding against generic failures in one or more technologies. Therefore, if new nuclear were to simply replace existing capacity, the threat to security from a generic failure would be lower than if a 'replace and expand' strategy were followed. The experience of France in summer 2003 shows that an electricity system dominated by nuclear technology can be vulnerable to technical underperformance and a consequent inability to meet demand. But this could also be true of fossil fuel plants – whether powered by coal or gas – and renewable technologies too.

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[5] See DBERR statistics on 'Supply and Consumption of Natural Gas and Colliery Methane' at http://www.dti.gov.uk/energy/statistics/source/gas/page18525.html

There are three further potential problems. First the new plants would use new reactor designs that bring with them uncertainty and risk of underperformance and failure. Second, whilst nuclear safety has improved, nuclear accidents have far reaching consequences and are more serious than those from failures of all other energy technologies. The risk of such accidents cannot therefore be ignored. Third, nuclear would be of no assistance in the event of non-electricity infrastructure failures such as the impact of extreme weather on offshore oil installations. Again, the picture could be different if a 'replace and expand' strategy were followed in which nuclear-generated electricity or hydrogen made a significant impact on the transport sector. But this would then increase security risks from generic technical failures.

A further issue is worth briefly mentioning within this category of risk. The threat to electricity security is not only due to a lack of timely investment, but is also due to operational risks that could prevent the electricity system from supplying consumers at a given point in time. Analysis we conducted with colleagues from the Tyndall Centre for Climate Change Research illustrates this point. This research tested the four original scenarios for a 60% reduction in UK carbon emissions developed by the Royal Commission on Environmental Pollution in 2000. Two of these scenarios included nuclear power (or fossil with carbon capture) and the other two did not. A security analysis of all scenarios for a typical year showed that those without nuclear power were able to balance supply and demand for more half hourly periods than those with nuclear power (Watson, Strbac et al., 2004).

Threat 4: Domestic activism and terrorism

Nuclear power plants have been discussed as potential terrorist targets – as have other parts of energy infrastructure such as gas pipelines and LNG terminals. Such risks need to be taken seriously. The potential consequences of an attack on a nuclear plant are more serious than attacks on other forms of infrastructure. To some extent, resistance to such attacks can be incorporated into reactor designs but, as with energy security more generally, there is a trade off between reducing risk and increasing cost.

Historically speaking, nuclear power has been less vulnerable to industrial disputes than coal. However, this does not mean that nuclear is immune to civil disruption. In the future, there could be industrial disputes or campaigns by activists that are similar to those that disrupted 'nuclear trains' in Germany a few years ago. Given the successful High Court challenge by environmental NGO Greenpeace to the government's support of nuclear power, it is possible that actions to disrupt new construction will follow.

Another important point to note is that a programme of new nuclear power plants cannot directly reduce the vulnerability of other fuel distribution infrastructure to such disruptions. Again, it might be possible for nuclear power to have a significant impact but only in the very long term under a 'replace and expand' scenario.

Conclusions

This paper has shown that a new nuclear power programme may be able to help reduce some specific energy security risks. These include some impact on the share of fossil fuels in the UK energy mix, thereby reducing the exposure of the UK economy to rapid increases in fossil fuel prices. They also include a contribution to technological disparity in an electricity system in which nuclear power retains a modest share alongside a wide range of other options. The impact on these risks (and many others) would be modest under a pure 'replacement' scenario for new nuclear. A more ambitious 'replace and expand' programme of investment could reduce some risks further, but such a programme could also exacerbate other risks – such as that of a common-mode failure where all power stations of a particular type develop the same problem.

However, despite these possible security benefits, overall we are not convinced that there is a strong security case for new nuclear, especially if the costs and risks of strategies that include new nuclear are considered alongside those of strategies that do not. A systematic analysis of these has not been carried out by government to support its case. Instead, there has been a partial analysis of some risks but a neglect of others. The evidence shows that nuclear power may *not* be able to mitigate some of the neglected risks such as domestic terrorism and civil unrest, and underinvestment in gas infrastructure.

Within the risks that are mentioned by government, there has been a particular focus on the expectation that the UK will import significant quantities of natural gas. This has been cited as a particular 'security problem' but without a clear rationale. The evidence so far is that the diversity of sources and supply routes for natural gas are expected to *increase* over the next decade. Furthermore, the argument that new nuclear power can solve this 'problem' does not stand up to scrutiny.

In conclusion, the government needs to present a much more convincing case for the security-enhancing benefits of nuclear power before favouring this option to meet the UK's security and climate goals.

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