



Nuclear power, climate change and energy security: Exploring British public attitudes

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ABSTRACT

Public attitudes towards nuclear power in the UK have historically been deeply divided, but as concern about climate change and energy security has exerted an increasing influence on British energy policy, nuclear power has been reframed as a low-carbon technology. Previous research has suggested that a significant proportion of people may 'reluctantly accept' nuclear power as a means of addressing the greater threat of climate change. Drawing on the results of a national British survey ($n=1822$), the current study found that attitudes towards nuclear remain divided, with only a minority expressing unconditional acceptance. In general, people who expressed greater concern about climate change and energy security and possessed higher environmental values were less likely to favour nuclear power. However, when nuclear power was given an explicit 'reluctant acceptance' framing – allowing people to express their dislike for nuclear power alongside their conditional support – concerns about climate change and energy security became positive predictors of support for nuclear power. These findings suggest that concern about climate change and energy security will only increase acceptance of nuclear power under limited circumstances—specifically once other (preferred) options have been exhausted.

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"We are facing the greatest energy challenge of our lifetime... (W)e need both energy security and a low carbon future... Nuclear power – as long as it can demonstrate that it can be viable without public subsidy – has a role to play in our energy mix."

(Charles Hendry, Minister for Energy, Department for Energy and Climate Change, June 2010)

1. Introduction

Climate change and the task of meeting future energy needs are two intertwined and urgent policy challenges for nations throughout the world, including the UK. As concerns about climate change and energy security have exerted an increasing influence on British energy policy, nuclear power has been reframed as a low-carbon technology. Public attitudes towards nuclear power in the UK have historically been deeply divided, with only a minority expressing unconditional support for replacing or increasing country's existing nuclear capacity. However, previous research has suggested that a significant proportion of people may 'reluctantly accept' nuclear power as a means of

addressing the greater threat of climate change (Bickerstaff et al., 2008; Pidgeon et al., 2008; Teravainen et al., 2011).

The current research seeks to further explore and refine the idea of 'reluctant acceptance' of nuclear power, and has three aims. First, to compare attitudes towards nuclear power in 2005 and 2010, in order to detect any impacts of the ongoing reframing of nuclear power as a low-carbon technology. Second, to explore the extent to which explicitly framing nuclear power as a method of addressing climate change and 'energy security' (an understudied but increasingly visible aspect of energy policy debates) increases its acceptance. And third, to investigate how environmental values, concern about climate change and concern about energy security are related to the acceptance of nuclear power.

1.1. Climate change, energy security and the reframing of nuclear power

The UK currently has the most ambitious decarbonisation targets set by any national government in the world: by 2050, the greenhouse gas emissions of the UK must be reduced by 80% (Committee on Climate Change, 2008; HM Government, 2008). It is essential for industrialised nations to commit to emissions reductions of this magnitude in order to avoid 'dangerous' climate change (Committee on Climate Change, 2009; Lorenzoni et al., 2005; New et al., 2009). However, meeting such tough targets means that the

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energy mix of the country needs to change drastically over the next four decades.

Old energy infrastructure will have to be replaced by new, low carbon technologies requiring technical innovation and a nationwide programme of installation and maintenance. In 2005, the UK became a net energy importer for the first time in 25 years (Kemp and Wexler, 2010), while North Sea oil and gas production has continued to decline. More than a third of current electricity generation capacity is due to be retired over the next two decades (Department of Trade and Industry, 2007). While in theory the deployment of renewable energy sources and aggressive energy efficiency measures could almost eliminate the need for fossil fuels altogether (see, e.g., Edenhofer et al., 2011; Kemp and Wexler, 2010), in practice there is little evidence of sufficiently ambitious policy making in this direction (Lorenzoni et al., 2008; Anderson et al., 2009; Kemp and Wexler, 2010).

The carbon emissions of burning fossil fuels may be mitigated to some extent by technological developments such as carbon capture and storage (CCS). In fact, as the number of coal-fired power stations is projected to increase in the EU in the next few decades, an assumption built into many projections is that CCS will be needed to bridge the gap between increasing fossil fuel use and decreasing CO₂ emissions—despite the fact that CCS technologies have not yet been demonstrated on a meaningful scale (Anderson et al., 2009). But regardless of the extent to which renewable technologies, energy efficiency measures or CCS technologies are able to sufficiently mitigate the emissions of carbon-based methods of providing energy, it is now widely acknowledged that the current level of dependence on fossil fuels will have to be substantially reduced. This is not only because of concerns climate change, but also because it is expected that fossil fuels – in particular oil – will become increasingly difficult to access over the next three decades (International Energy Agency, 2008).

The global nature of energy markets and an increasing reliance on energy imports means that UK energy needs are becoming contingent on international issues outside of its direct control. With global energy consumption predicted to increase substantially in the short to medium term, and serious question marks over the longevity of traditional (fossil-fuel based) energy sources, the notion of 'energy security' has become an increasingly important part of energy policy debates in the UK. Although securing energy has always been a central goal for national governments, energy security has become particularly prominent in discussions about energy policy and environmental sustainability in recent years (see, e.g., Hendry, 2010).

However, despite the ubiquity of the term 'energy security' in contemporary policy debates about climate change and energy issues, it is unclear exactly what is meant by the term (Chester, 2010). The International Energy Agency has defined it as "the uninterrupted physical availability of energy at a price which is affordable, while respecting environment concerns" (International Energy Agency, 2001), although the term has also been used to refer to increasing reliance on fossil fuel imports, fluctuating energy prices and energy supply, concerns over growing energy consumption and the political instability of oil-exporting nations (amongst other things). In a summary of international public opinion produced by the World Council on Foreign Relations (2009), concern about energy security as a 'foreign policy' issue was found to be high in countries across the world, with a significant degree of international support for measures such as energy conservation and investment in renewables to tackle energy security.

While it is not yet clear what the future UK energy mix will look like, the Renewables Obligation (Department of Energy and Climate Change, 2009a) mandates 15% of electricity to be

generated from renewable sources by 2015, and a full 30% by 2020. A recent analysis by the Committee on Climate Change reaffirmed that these targets were feasible (Committee on Climate Change, 2011). However, there is considerable uncertainty about the appropriate mix of low-carbon technologies in the short and medium-term future, and concerns have continued to be raised about under-investment and the reliability of many renewable technologies. The role that nuclear power might play in the future UK energy mix is also highly contested. In 2010, approximately 18% of UK electricity was provided by nuclear power stations (DECC, 2010). However, the planned decommissioning of all 'Magnox' and many Advanced Gas Cooled Reactors (AGR) means that, without a new generation of power plants, the contribution of nuclear energy will be reduced to around 5% or 6% of total electricity production.

Arguments emphasising the role of nuclear energy as a response to emerging concerns about climate change can be traced back several decades. A number of pro-nuclear interests began actively advocating this in West Germany long before climate change had even become a major public policy issue (see Weingart et al., 2000). Bickerstaff et al. (2008) observed that from the early 2000s onwards, industry actors, some engineers and scientists, and senior politicians in the UK have increasingly referred to nuclear power as a method of responding to climate change, using its low-carbon credentials to advocate government investment in the sector. The nuclear industry has enthusiastically contributed to the reframing of nuclear power as one element of the response to climate change and has been lobbying for its inclusion in the future low-carbon energy mix (Leake and Box, 2005). In this way the nuclear industry has attempted to position itself as providing a vehicle through which the UK can continue to generate and consume large quantities of power whilst still working towards meeting its carbon reduction targets.

The link between energy security and nuclear power is also not particularly new, in the UK as elsewhere (e.g. see Hecht, 1998). Energy security was part of the justification for the building of the world's very first commercial nuclear reactor at Calder Hall, Cumbria in 1956 (Tweena, 2006) and the decision to greatly expand the UK's Magnox programme following the Suez crisis (Welsh, 2000). A further programme of British nuclear power stations in 1979 again included energy security as a primary motivation. However, while societies have always asked questions about the security of energy supplies (whether this involves collecting firewood or designing a 25 year plan for extracting and piping natural gas), it is only relatively recently that the concept of energy security has played such a prominent role in public policy debates about energy. Spurred on by the parallel debate about climate change, energy security has become an increasingly visible component of the nuclear discourse (Teravainen et al., 2011).

Over the past decade the official position of the UK government on the role of nuclear power in the future energy mix has tended to be cautious. For example, in the key strategic *Energy White Paper*, the Department of Trade and Industry (2003) declared an intention to shift the UK energy mix towards low-carbon sources, but did not set any specific preferences for the nation's fuel mix. However, government thinking towards the end of the last decade did begin to change. In May 2007 it issued a consultation document on the role of nuclear energy in a low carbon economy, and the following year *A White Paper on Nuclear Power* (Department for Business Enterprise & Regulatory Reform, 2008), which provided a clear sign that not only did the government consider nuclear power as part of the future energy mix, but that the case for new nuclear hinged on its role in reducing carbon emissions and securing energy supplies in an increasingly volatile energy market. Recognising that a lack of public support and confidence were likely to become an issue, the UK government

also sponsored a much criticised public debate on nuclear power in the summer of 2007.

Around the same time, the nuclear industry began a complex process of registering their interest in developing sites for new nuclear build in England and Wales, and fulfilling the pre-planning application prerequisite of engaging with the public living close to the proposed sites. In 2009, the UK Department for Energy and Climate Change published a list of industry nominated sites for new nuclear build, all but two of which were located adjacent to an existing nuclear facility. The stated policy of the Conservative-Liberal Democrat coalition government that took office in May 2010 is to use price mechanisms (e.g., introducing a 'floor' price for trading permits to emit carbon on international markets) to encourage and facilitate the building of new nuclear power stations, but not to commit tax-generated revenue to this process. This is a compromise borne out of the competing ideologies of the parties comprising the coalition government. However, as we discuss in detail below, it also reflects the continuing ambivalence of public attitudes towards nuclear power.

It is perhaps more surprising, given the historical opposition of environmental campaign groups to nuclear power, to find similar arguments being made by some members of the environmental movement. The ecologist James Lovelock has publically endorsed nuclear power as a necessary means of combating climate change (Black, 2003). The prominent journalists and environmental activists George Monbiot and Mark Lynas have both advocated limited programmes of new nuclear power stations (Monbiot, 2009; Lynas, 2010). However, the position of influential non-governmental organisations such as Greenpeace and Friends of the Earth has remained one of outright opposition to new nuclear power (see, e.g., Friends of the Earth, 2004; Greenpeace, 2010), supported by projections of the Centre for Alternative Technology that there is no need for nuclear power in a 'zero-carbon' Britain (Kemp and Wexler, 2010; see also WWF International, 2011).

Bickerstaff et al. (2008) developed their arguments about the reframing of nuclear power at a time when few formal signals from the government about the future of nuclear were available. Their arguments have proven prescient, as subsequent policy developments show. What, however, is missing in many of the policy discussions is an appreciation of the potential role of public acceptability of nuclear power. This issue is important because in the past 20 years nuclear programmes around the world have stalled as a result of economic difficulties, concerns over waste disposal and major accidents, and above all a hostile public mood towards the technology (Rosa and Clarke, 1999). As Spence and Pidgeon (2009) have pointed out, many current transition proposals involving nuclear (and other innovative low-carbon technologies) make untested assumptions about public acceptability. Public support is likely to be one of the most important factors that will determine future technological pathways that the UK and other societies eventually take in the face of climate change and energy security.

1.2. Public attitudes towards climate change, energy security and energy technologies

Given the increasing frequency with which arguments about climate change, energy security, and nuclear power are being fused together by the UK government, nuclear industry lobbyists and even some environmental advocates, it is important to consider attitudes towards nuclear power in the context of attitudes towards climate change, energy security and other forms of electricity generation. Currently, very few studies have sought to focus on all of these topics simultaneously (e.g. Pidgeon et al., 2008; Spence et al., 2010a).

Public opinion about climate change has become increasingly well documented (e.g., Eurobarometer, 2006, 2007, 2008; Leiserowitz, et al., 2010; Lorenzoni and Pidgeon, 2006; Pew Research Centre, 2009; Upham et al., 2009). Awareness about climate change is very high, and a number of surveys have shown that the British, European and North American public view climate change negatively and express substantial concern about it. For example, surveys in 2005 (Poortinga et al., 2006) and 2007 (Eurobarometer, 2007) found that around 90% of British citizens were concerned about climate change. However, climate change continues to be a low priority issue for most people when contrasted with other societal issues such as the economy, education, or the threat of terrorism (Upham et al., 2009), and in recent years the level of reported concern about climate change has fallen somewhat, accompanied by an increase in the number of people expressing uncertainty about the reality of anthropogenic influence on the climate (BBC, 2010; Leiserowitz et al., 2010; Pew Research Centre, 2009; Pidgeon and Fischhoff, 2011).

In comparison, only a handful of studies on public attitudes to energy security have been conducted. Reiner (2006) reported the findings of a national survey in the UK that asked a variety of questions about the electricity sector and energy policies. The results indicated a high degree of support for government subsidies of renewable energy technologies, but also significant support for attaining 'energy independence'. Solar and wind power are generally perceived most favourably and coal least favourably in terms of being able to deliver reliable and secure energy. Other renewables (with the exception of biomass) are usually also perceived as more secure than oil, gas and nuclear power, although the precise wording of questions makes direct comparisons difficult.

One of the subsidiary objectives of the current study, therefore, was to construct and explore analytically a reliable scale measuring beliefs about these disparate dimensions to energy security, as the lack of conceptual clarity about energy security has important implications for attempts to link it to nuclear power. Watson and Scott (2009) have argued that although the government and other actors have frequently made the case for new nuclear based on concern about energy security, many policy discussions are conducted without a clear idea of the dimensions of energy security. Correspondingly, it is not entirely clear that nuclear would necessarily enhance energy security—in particular the risks of domestic terrorism or civil unrest (Watson and Scott, 2009).

Regarding energy sources more generally, questions are routinely asked in polls and surveys, and here renewable energy generation is consistently favoured by members of the public (e.g., Greenberg, 2009; McGowan and Sauter, 2005; Pidgeon et al., 2008a; Upham et al., 2009). Typically, upwards of 80% of survey respondents report being 'very favourable' towards solar and wind energy the two best-known forms of renewable electricity generation. Fossil fuel-based methods of energy generation tend to be much less positively perceived. Pidgeon et al. (2008) found that only 39% expressed favourability towards oil, and 38% towards coal, with gas faring slightly better at 55% favourability.

The preceding analyses set out the background against which attitudes towards nuclear power must be interpreted: a high level of awareness and concern about climate change; an emerging (although as yet poorly understood) level of concern about energy security; and a clear preference in surveys for the low-carbon qualities of renewable forms of electricity generation over fossil fuel-based sources. We now provide a brief summary of the literature documenting public attitudes towards nuclear power before addressing the concept of reluctant acceptance in more detail, and introducing the aims of the current research.

1.3. Public attitudes towards nuclear power: the rise of reluctant acceptance?

Attitudes towards nuclear electricity generation have waxed and waned over the half-century that this technology has been in commercial operation. Despite initial enthusiasm in the 1950s and early 60s, the UK public has historically expressed significant levels of opposition to nuclear power, particularly following the accidents at Three Mile Island and Chernobyl (Dalquist, 2004; Eiser et al., 1990; Nelkin and Pollack, 1981; van der Pligt, 1992). Nuclear accidents have, through processes of 'social amplification' (Pidgeon et al., 2003), contributed to nuclear power becoming a highly stigmatised energy technology (Flynn, 2003). However, opposition to nuclear power appears to have decreased steadily in the UK since the early 2000s (Knight, 2005; Grove-White et al., 2006; Pidgeon et al., 2008). Research conducted by Ipsos-MORI for the Nuclear Industry Association suggests that since 2004 more people have favourable than unfavourable attitudes towards nuclear energy (Knight, 2009).

In general, though, UK opinion remains divided, and responses are highly dependent on question wording and format. Pidgeon et al. (2008) reported that nuclear power was the least preferred of all energy sources in a national UK survey conducted in 2005. Of 17 recent public opinion polls and studies reviewed by the Parliamentary Office of Science and Technology (POST, 2007), 3 showed overall 'conditional' support, 8 showed a split in public opinion, and 6 had an overall negative result, driven by a lack of confidence in arrangements for the disposal and storage of waste, concerns about decommissioning and a perceived lack of safety in nuclear power stations, and the availability of better or preferable energy solutions (also Accenture, 2008).

However, in keeping with the policy-level reframing of nuclear power as a source of low-carbon energy, recent UK polls have found that nuclear is typically considered to be an important aspect of the country's future energy mix (Pidgeon et al., 2008). A series of polls commissioned by the nuclear power provider EDF asked UK respondents whether they agreed with the statement 'Nuclear power has disadvantages but the country needs it as part of the energy balance with coal, gas and wind power'. The number of people agreeing with this statement has risen gradually from 59% in 2007 to 64% in 2010 (EDF/YouGov, 2010). In addition, a set of studies have sought to identify and describe what appears to be a highly conditional favourability towards nuclear power among the UK public (Bickerstaff et al., 2008; Pidgeon et al., 2008; Spence et al., 2010a). This 'reluctant acceptance' discourse (Bickerstaff et al., 2008) stems from public concerns about climate change mitigation and the security of supply of national energy resources, and reflects an ambivalent attitudinal position that identifies nuclear power as a potential method of addressing these twin challenges.

Bickerstaff et al. (2008) presented a mixed-methods analysis of citizen views of climate change and nuclear power, combining data from a nationally representative survey and citizen focus groups both conducted in 2002. At that particular time, the reframing of nuclear power as a solution to climate change had not been widely discussed either in UK energy policy or in the mainstream media. This enabled an analysis of the process by which participants responded to what was, for most, a novel way of framing the case for new nuclear build. Just two of the thirty-two focus group participants wholeheartedly supported the concept of climate change mitigation through new nuclear build as an acceptable and appropriate policy position. The majority of participants decided after a debate that nuclear power was the 'lesser of two evils' or 'a devil's bargain' that would bring benefits but also potentially serious consequences. These participants generally concluded that there was little or no choice in the

matter. Thus, their position of reluctant acceptance was characterised by resignation, discomfort, and frustration that nuclear power was seen to be undesirable but possibly indispensable for the foreseeable future (Bickerstaff et al., 2008 p. 159). Bickerstaff et al. concluded that a policy discourse which framed nuclear power in terms of climate change mitigation would lead people towards adopting a position of reluctant acceptance towards new nuclear power stations.

Teravainen et al. (2011) analysed documents and conducted interviews with stakeholders from Finland, France and the UK, and identified a number of dominant discourse strategies in the nuclear debate. They found that since the late 1990s, energy security and climate change have become important justifications for new nuclear power. In keeping with the findings of Bickerstaff et al. (2008), one of the strategies identified was 'necessitation'—the idea that tackling climate change and energy security was only possible if nuclear power was included in the energy mix. The 'relativisation' of nuclear risks was another important component of the nuclear discourse. Increasingly, European advocates of nuclear power were able to compare the risks of nuclear power favourably to the risks of dangerous climate change, as well as the threat of the 'lights going out' due to energy insecurity (Teravainen et al., 2011).

Further evidence of public endorsement of the reluctant acceptance attitudinal position was provided by Venables et al. (2009). People living near two long-established nuclear power stations in England (Bradwell in Essex and Oldbury in Gloucestershire) classified a series of statements about nuclear power into four broad categories: a belief that nuclear power is beneficial and safe; a sense of threat and distrust; a resignation accompanied by the belief that 'there is no point in worrying'; and finally a set of statements indicating a more ambivalent (reluctant) acceptance of the local power station. Even in such 'nuclear communities', traditionally thought of as being very positively oriented towards nuclear power, support is not always unconditional.

Other survey research has also suggested that segments of the UK public are receptive to the framing of nuclear power as a response to concerns over energy security. While Pidgeon et al. (2008) found that nuclear power was the least favoured form of electricity generation (compared to fossil fuels and renewables), favourability rose significantly when nuclear power was presented in the context of energy security, and 65% agreed that nuclear power was needed as part of the UK 'energy mix'. The study also found that people in general would prefer to attempt to tackle climate change via means other than nuclear power (i.e. through increased use of renewables or lifestyle changes), suggesting that while people may be willing to accept nuclear power if it is seen as a contributor to climate change mitigation or energy security, few would actively choose it over renewable sources of electricity production or energy efficiency.

Spence et al. (2010a) investigated the relationship between environmental and climate concerns and support for various energy options using the same nationally representative dataset as Pidgeon et al. (2008). This analysis found that a high level of concern about climate change was *not* predictive of support for nuclear power—indeed the reverse was the case, with a significant negative correlation observed between increase in concern about climate change and support for nuclear power. Spence et al. suggested that this finding reflects the philosophy of traditional environmentalist movements in maintaining a clear anti-nuclear stance while also expressing a high degree of concern about climate change. But if individuals predisposed to care about climate change do not support nuclear power, then why should the reframing of nuclear power as a solution to climate change lead to an increase in acceptance? Spence et al. argued that an increased conditional acceptance of nuclear power is contingent

on it being *explicitly* framed as a means of mitigating climate change, and that in keeping with the findings of Bickerstaff et al. (2008) and Pidgeon et al. (2008), most people are unlikely to spontaneously evaluate nuclear power in this way.

Other research has suggested that environmental concern and values relating to ‘interfering with nature’ and ‘morality’ may be of particular importance in determining attitudes to nuclear power (Sjoberg, 2000, 2004). Individuals with different values appear to attribute different levels of importance or salience to different aspects of nuclear power, in accordance with their prior beliefs (van der Pligt, 1992; Eiser et al., 1988, 1995). However, Whitfield et al. (2009) examined a range of cognitive and cultural factors that underpinned attitudes towards nuclear power and found only an indirect effect of values and general beliefs on attitudes towards nuclear power. The impact of personal values was partially mediated by the perceived risks associated with nuclear power and the level of trust in nuclear organisations.

The current research seeks to build on these findings by exploring the concept of reluctant acceptance in more depth. We consider whether attitudes towards nuclear power in Britain have changed in light of the increasing salience of climate change and energy security in national energy policies in recent years, and in what way environmental values and concern about climate change and energy security are related to attitudes to nuclear power. The study builds upon the 2005 survey of British attitudes towards climate change and nuclear power reported by Pidgeon et al. (2008), by drawing on the results of a nationally representative survey conducted in the first three months of 2010 (Spence et al., 2010b). As the two surveys contained a number of identical questions, we are able to track changes in public attitudes to nuclear power (and other energy technologies) directly over the period 2005–2010. A range of new questions were also included in the 2010 survey in order to explore attitudes to nuclear power in more detail, and in particular the concept of reluctant acceptance of nuclear power, as identified by Bickerstaff et al. (2008). The goal of the current research was therefore to answer three key questions:

- (1) Has the reframing of nuclear power impacted on British public attitudes towards nuclear power—have they changed since 2005?
- (2) To what extent does the explicit reframing of nuclear power as a method of addressing the problems of climate change and energy security lead to greater conditional or reluctant acceptance of nuclear power?
- (3) How is general environmental concern (environmental values, concern about climate change) and concern about energy security related to attitudes towards and acceptance of nuclear power?

2. The 2010 survey

2.1. Methods

A nationally representative quota sample of the UK population aged 15 years and older (i.e. England, Scotland and Wales; $n=1822$) were interviewed face-to-face in their own homes by Ipsos-MORI between 5 January and 26th March, 2010. Interviews were conducted at 315 sample points (including Scottish and Welsh oversamples) selected randomly from a stratified sample of output areas sorted by Government Office and council area. Stratified sampling works by sampling subgroups of the population independently. The UK was first broken down into usable sample points based on census output areas and these were also used to obtain representative demographic statistics for the area

(gender and age figures were based on ONS 2007 mid-year population estimates while working status was based on 2001 Census data). As some of these areas were in practice too small for sampling effectively, particularly in Scotland, those that were small were grouped together to form slightly larger areas. We then sampled from these points at random, though it was ensured that different regions and ruralities were proportionally represented within this. We also weighted the likelihood that a sample was selected based on its size, meaning that larger areas were more likely to be chosen. Within each sampled area, interviewers were asked to achieve set quotas for gender, age, and working status based on the known demographics of the local population of the area. This ensured that the achieved sample was representative of the population even at the local level. Interviewers left at least three addresses between each call and conducted a maximum of one interview per address.

Given this method, samples obtained from Scotland and Wales are likely to be smaller than English samples due to their relatively smaller population sizes. We therefore obtained additional samples from these countries ($N=109$ and 185 , respectively, for Scotland and Wales), sampling in the same way, though excluding output areas that had already been chosen. This meant we gained disproportionately larger representation of these countries in our final sample in order that they were rigorously sampled and allowing us to conduct inter-country comparisons. For the analysis within this paper we therefore weighted the sample to the profile of the known UK population on the basis of gender, age, working status, social grade and ethnicity in order to more accurately represent the population.¹

Computer Assisted Personal Interviews (CAPI) were conducted by fully trained and supervised market and opinion research interviewers and took (on average) 30 min to complete. Interviewers introduced themselves as being from “Ipsos MORI, the independent research organisation carrying out a survey on behalf of Cardiff University about the environment and how our energy is supplied now and in the future”. No incentives were offered for participation. In total, the survey comprised 52 questions about climate change and energy, although here we focus on a relevant subset of those questions (for a description of all the key findings from the survey, see Spence et al., 2010b).

2.2. Measures

A range of predictor variables were included in the current analyses; socio-demographics (age, gender, voting preference, and socio-economic group), environmental values, concern about climate change and concern about energy security (a full list of the items used in the study is provided in Appendix A).

Four items (De Groot and Steg, 2008) were used to measure environmental values, which have been used extensively in previous research on public attitudes to climate change and pro-environmental behaviour (see, e.g., Poortinga et al., 2004; Slimak and Dietz, 2006; Stern, 2000; Stern and Dietz, 1994; Stern et al., 1995). Participants rated the importance of the following four items: Preventing pollution (protecting natural resources); Respecting the earth (harmony with other species); Unity with nature (fitting into nature) and Protecting the environment (preserving nature). The four environmental values correlated very highly together (Cronbach’s $\alpha=0.90$), and so a single score

¹ The findings from the overall sample of 1822 are based on a core sample of 1528, to which the additional booster samples from Scotland and Wales were added. Reported results are accurate to within $\pm 2.6\%$ (the full confidence intervals are: 1.6% at a 10% or 90% finding, 2.4% at a 30%/70% finding and 2.6% at a 50% finding).

measuring pro-environmental values was computed and used for subsequent analyses.

Concern about climate change was measured using three items: general concern about climate change, concern about the personal effects of climate change, and concern about the effects of climate change on society in general. These three items formed a highly internally consistent scale (Cronbach's $\alpha=0.83$), and so were combined for subsequent analyses.

Concern about energy security was measured using a scale comprised of six items: (1) that electricity would become unaffordable, (2) that electricity will be rationed, (3) that the UK will become too dependent on energy from other countries, (4) that terrorist attacks will cause interruptions to electricity supplies, (5) that supplies of fossil fuels (e.g. coal and gas) will run out, and (6) that there will be power cuts. The scale was intentionally designed to capture a broad range of meanings of 'energy security', as it has previously been assigned a range of interpretations (Chester, 2010). Particular care was taken with its construction. Following a literature review of the types of questions that have previously been used to measure energy security, a pilot questionnaire was trialled containing multiple questions pertaining to energy security resulting in the six items used in the final scale. The items were selected to represent several broad aspects of energy security that our preliminary research had indicated were especially important; 'dependence', 'long-term security', 'price', 'vulnerability of supply' and 'reliability'. The items used in the energy security scale were highly correlated (Cronbach's $\alpha=0.79$) and were therefore combined into a single aggregate measure of concern about energy security for subsequent analyses.

The dependent measures included in the study were comprised of three classes of measures: (1) general measures of favourability towards nuclear power (without framing) and other electricity generating technologies, (2) measures of favourability towards nuclear power with a climate change or energy security framing, and (3) an item explicitly measuring the 'reluctant acceptance' framing of nuclear power. Some of these measures were direct replications of items used in Pidgeon et al. (2008). Due to the large number of items included, the wording and response scales of the dependent variables are included in an Appendix rather than reported here (see Appendix A). In addition, precise details of all the items included in the survey can be found in Spence et al. (2010b).

3. Results and discussion

3.1. Concern about climate change, concern about energy security and endorsement of pro-environmental values

The majority (71%) of our survey respondents were either fairly or very concerned about climate change. This figure is lower than comparable findings from our 2005 study (see Pidgeon et al., 2008; Spence et al., 2010b), but is in line with trends noted in other recent surveys in the US and the UK (Leiserowitz et al., 2010; Pew Research Centre, 2009; Eurobarometer, 2009). It suggests that the level of concern about climate change in the UK is still high, with only 8% claiming that they were not at all concerned about climate change. Levels of concern about energy security were also high—perhaps surprisingly so given the lesser role (compared to climate change) that energy security has played in the national energy discourse so far. Concern was particularly high about electricity becoming unaffordable in the future (78%), the prospect of the UK becoming too dependent on other countries for energy (80%), and supplies of fossil fuels running out (78%). These results suggest that energy security is an issue

that is capable of prompting significant concern for members of the British public. However, they must also be interpreted cautiously given the relative novelty of the concept of energy security, and the lack of well-replicated scales for measuring it.

There was a high degree of endorsement of the four environmental values, with the majority rating each value as very, or extremely important. Concern about climate change correlated positively with concern about energy security (Pearson's $r=0.24$, $p<0.001$) and the environmental values scale (Pearson's $r=0.32$, $p<0.001$), while concern about energy security was also positively correlated to the environmental values scale (Pearson's $r=0.161$, $p<0.001$).

3.2. Unconditional support for nuclear power

General favourability ratings of nuclear power have not changed a great deal since 2005, both in terms of absolute level of approval and relative to other sources of generating electricity. Fig. 1 shows that 35% of the 2010 sample were either mainly or very favourable towards nuclear power as compared to 36% in 2005. On this generic favourability measure, nuclear power continues to be unconditionally favoured by a minority of the British population, remaining among the least preferred of all methods of generating electricity in both surveys (see Greenberg, 2009, for comparable data from the US).

Participants also indicated whether they felt the benefits of nuclear power outweighed the risks, or the risks outweighed the benefits. On this risk acceptability item more people felt that the benefits of nuclear power slightly or greatly outweighed the risks (38% in 2010 compared to 32% in 2005). A third item (not used in the 2005 survey) asked how they felt about nuclear power on an emotional level (affect item). These three measures of general attitudes towards nuclear power formed a highly reliable "unconditional support for nuclear power" scale (Cronbach's $\alpha=0.87$).

A regression analysis was conducted with this composite "unconditional support for nuclear power" scale as the dependent variable, and age, gender (coded as a dummy variable where female=0, male=1), social grade (included as a continuous variable), voting preferences (included as separate dummy variables for Conservative, Labour, and Liberal Democrat voting intentions), concern about climate change, concern about energy security and overall pro-environmental value scores as predictor variables. The model accounted for just under 20% of the variance in attitudes towards nuclear power, and the results are displayed in Table 1.

Men, older individuals, those in higher social classes and people with a voting preference for the Conservative party rated

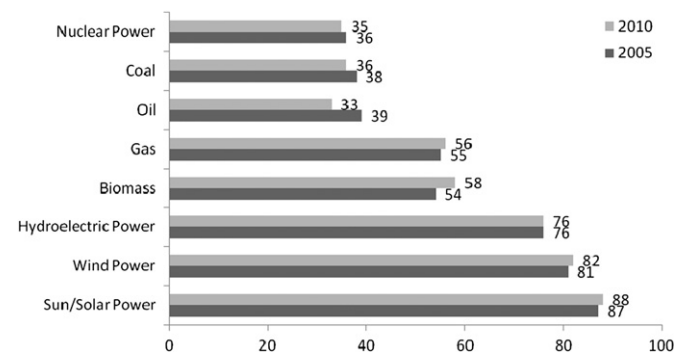


Fig. 1. Ratings of favourability towards eight different sources of electricity generation. Bars represent the percentage of respondents who stated that they were mainly favourable or very favourable towards each energy source. Results from the same question asked in 2005 (see Pidgeon et al., 2008) are included for comparison.

nuclear power more favourably. In line with Spence et al. (2010a) concern about climate change and environmental values were negatively associated with unconditional support for nuclear power. These results support Spence et al.'s assertion that a generally pro-environmental philosophy does not typically include greater support for nuclear power—at least when nuclear power is not explicitly framed as a solution to climate change or energy security. Perhaps surprisingly, concern about energy security was also negatively related to unconditional support for nuclear power.

3.3. Conditional support for nuclear power

If nuclear power is in the process of being reframed by government, industry and even some environmental advocates as a method of responding to climate change (and to a lesser extent, energy security), then what impact has this had on conditional support for nuclear power? Several questions directly linking nuclear power to climate change and energy security were included in the survey, displayed in Fig. 2, with corresponding 2005 responses where available. There is a clear pattern: when nuclear power is framed as a means of addressing climate change or energy security, support for nuclear power rises substantially in both the 2005 and 2010 data (see Fig. 2). Moreover, looking at the upper two items in Fig. 2, conditional support for nuclear as part of the energy mix (or because people believe renewables alone cannot meet our needs) has also increased since 2005. Although not shown in Fig. 2, those who strongly agree that they are willing to accept nuclear if it would help to tackle climate change also rose, from 11% in 2005 to 17% in 2010.

Table 1

Standardized regression coefficients from a linear regression analysis of unconditional support for nuclear power.

Predictor variables	Standardised coefficients
Age	0.083***
Gender	0.253***
Social grade	0.158***
Conservative voting preference	0.049
Labour voting preference	0.042
Lib Dem voting preference	−0.005
Concern about climate change	−0.147***
Concern about energy security	−0.116***
Pro-environmental value score	−0.100***
R ²	0.204***
Adjusted R ²	0.199***

*** $p < 0.001$.

The four measures of conditional support for nuclear power displayed in Fig. 2 formed a highly reliable scale (Cronbach's $\alpha = 0.88$), and so were combined for subsequent analyses. If support for nuclear power increases when it is presented as a solution to climate change and energy security, one might expect that those individuals who are concerned about these issues would be more likely to endorse conditional statements of nuclear support. However, correlational analyses did not support this conjecture. Concern about climate change was once more negatively related to conditional support for nuclear power (Pearson's $r = -0.11$, $p < 0.001$), as was concern about energy security (Pearson's $r = -0.13$, $p < 0.001$) and environmental value scores (Pearson's $r = -0.13$, $p < 0.001$). Extending the results in Spence et al. (2010a), even directly linking the notions of energy security and climate change to nuclear power did not seem to attract the support of those individuals who were generally pro-environmental in their values and beliefs.

3.4. 'Reluctant acceptance' of nuclear power

While conditional support for nuclear power was undoubtedly higher than unconditional support, responses to other questions in the survey were consistent with a negative relationship between pro-environmental beliefs and conditional acceptance of nuclear power. For example, 70% of the sample in 2010 (compared to 74% in 2005) agreed with the statement that 'We shouldn't think of nuclear power as a solution for climate change before exploring all other energy options', while 71% in 2010 (78% in 2005) agreed that 'Promoting renewable energy sources such as solar and wind power is a better way of tackling climate change than nuclear power', indicating that a means of tackling climate change, nuclear power is not generally the preferred method.

At first glance, these results are somewhat counter-intuitive—despite support for nuclear power increasing if it is framed as a response to climate change and energy security, people who expressed concern about climate change and energy security were not more likely to conditionally support nuclear power. Furthermore, even the increased conditional support of nuclear power that was observed must be interpreted against strong preferences for other energy options if they are available. If, as Bickerstaff et al. (2008) first claimed, the reframing of nuclear power as a solution to climate change plays on the trade-off between environmental and nuclear concern, then why are individuals with high levels of general pro-environmental concern not more likely to conditionally accept nuclear power?

A closer reading of the original articulation of reluctant acceptance in Bickerstaff et al. (2008) suggests an answer to this

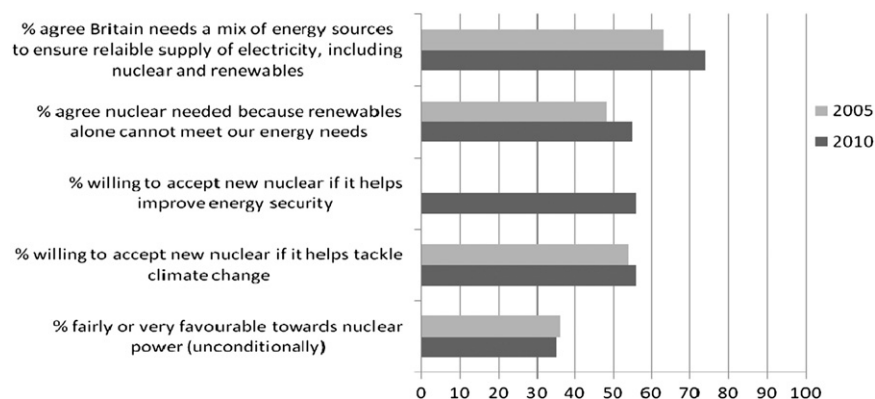


Fig. 2. Conditional and unconditional support for nuclear power in the 2010 survey, with corresponding data from 2005 where this is available.

question. While focus group participants exhibited a shift towards acceptance of nuclear power when it was framed as a solution to climate change, this pragmatic position was accompanied by serious reservations about both nuclear power, and the either/or framing of the climate change vs. nuclear power choice. Correspondingly, one final item was included in the current survey that allowed participants to make explicit any negative feelings for nuclear power, whilst also (reluctantly) accepting its utility in responding to the challenges of climate change and energy security. 57% agreed or strongly agreed with this statement: 'I don't really like the idea of nuclear power, but I reluctantly accept that we will need it to help combat climate change and energy security in the UK' (14% were unsure, and the remainder of the sample either disagreed or strongly disagreed). This shows a similar level of absolute agreement to the other statements expressing conditional support shown in Fig. 2.

However, correlational analyses revealed a *reversal* in the relationship between this explicit reluctant acceptance item and concerns about climate change and energy security. Reluctant acceptance was significantly positively correlated with concern about climate change (Pearson's $r=0.05$, $p<0.05$) and concern about energy security (Pearson's $r=0.08$, $p<0.01$). Although small in absolute size, these positive correlations diverge in a consistent manner from the pattern shown in the other dependent measures used here, as well as from the results reported in Spence et al. (2010a)—individuals who were more concerned about climate change or energy security were more likely to exhibit reluctant acceptance of nuclear power. Pro-environmental value scores exhibited a non-significant relationship with the reluctant acceptance item, however, suggesting that even with a reluctant acceptance framing, people with a strong pro-environmental philosophy may still be cautious in their endorsement of nuclear power.

4. General discussion and conclusion

The current research sought to investigate whether – in response to being reframed as a low-carbon energy technology – public attitudes towards nuclear power in the UK have changed since 2005. In particular, we explored the notion of 'reluctant acceptance' (Bickerstaff et al., 2008) and its relationship with measures of concern about climate change, environmental values, and concern about energy security. Our results suggest that attitudes towards nuclear power have shifted in a *somewhat* more favourable direction since 2005, although not consistently across all indicators. That being said, the British public remain relatively divided and uncertain over nuclear power, something which has to be interpreted against the backdrop of repeated attempts by the nuclear industry, the UK government, and even some environmentalists to re-conceptualise nuclear power as a desirable part of the future energy mix.

More importantly, the results paint a much more detailed picture of the attitudinal position of reluctant acceptance than has previously been possible. Using three classes of measures of attitudes towards nuclear power, we compared *unconditional* support for nuclear power, *conditional* support for nuclear power (in the context of climate change or energy security), and the *reluctant acceptance* of nuclear power (as a 'necessary evil' to solve climate change and energy security issues). Our results provide the first direct evidence of how measures of environmental concern and concern about energy security relate to people's unconditional, conditional and reluctant acceptance of nuclear power.

As we had expected, environmental values and concern about climate change were negatively related to unconditional acceptance of nuclear power, while the general favourability of nuclear power remained low. Perhaps surprisingly, concerns about energy security

were also negatively related to unconditional acceptance. Again, as expected, conditional support for nuclear power – as a method of tackling climate change or addressing energy security – was much higher than unconditional support for nuclear power. However, neither concern about climate change, concern about energy security, or environmental values were positive predictors of conditional acceptance of nuclear power. In fact, (and extending the results of Spence et al., 2010a) endorsement of pro-environmental values tended to be negatively related to support for nuclear power, even when it was directly framed as a solution to climate change and energy security.

However, when nuclear power was given an explicit 'reluctant acceptance' framing, these relationships were reversed and individuals with higher levels of concern about climate change and energy security became more likely to endorse it. Interestingly, even when framed explicitly in terms of reluctant acceptance, general pro-environmental values still did not positively predict support for nuclear. Hence, only when people were allowed to express their unease about nuclear power – that is, their *reluctant* acceptance – did concern about climate change and energy security increase support for nuclear power. For individuals who endorsed pro-environmental concerns, the notion of conditional acceptance of nuclear power seemed to hinge on it being an attitudinal position where they could also explicitly express a sense of unease. This novel finding has important implications for both our theoretical understanding of 'reluctant acceptance', and the likely impact of the ongoing reframing of nuclear power.

From a theoretical perspective, our results are the first to systematically examine with a large representative sample of the British public how reluctant acceptance differs from unconditional and conditional acceptance of nuclear power. The reluctant acceptance stance was originally characterised by Bickerstaff et al. (2008) as one of resignation, discomfort, and frustration that because of the threat posed by climate change, nuclear power would be a necessary part of the energy mix. While subsequent research has further confirmed the existence and prevalence of reluctant acceptance as a distinctive point of view (Venables et al., 2009), explaining it has proven somewhat more difficult.

Pidgeon et al. (2008) argued that there remains an essential ambivalence to public beliefs about nuclear power: something which reflects both the earlier history of public controversy surrounding the industry combined with the genuine complexity of the issues involved today. The different framings that can be placed on the question of long-term energy policy are also undoubtedly one of the reasons why seemingly contradictory responses are elicited by different questions within the same survey. Over the past 10 years risk the perception literature has also begun to explore models which characterise individual's perceptions and decisions as a product of both their affective feelings and more analytic reasoning strategies (Lowenstein et al., 2001; Slovic et al., 2002). The reluctant acceptance position appears to bring to the surface a particularly severe tension between intuitive affective responses to nuclear power (deep-seated worries, feelings, and negative images; Slovic, 2000) and the more analytic cognitive processes grounded in contemporary framings of the issue. Neither reasoning strategy is 'correct' in any absolute sense: rather, as authors such as Lowenstein, Slovic and colleagues point out, each forms a necessary component for people to make effective decisions about uncertain risks. Clearly then, more research on the relationship between affective responses, analytic discourses and reasoning, and ambivalence about energy technologies is warranted, as is work exploring other potential predictor variables of energy preferences such as underlying cultural predispositions (Kahan et al., 2010) or trust in regulation (Poortinga and Pidgeon, 2003; Whitfield et al., 2009).

In policy terms, the results of the current research suggest that even the direct reframing of nuclear power as a response to climate change or energy security is unlikely to readily mesh with strong pro-environmental philosophies and values that many people endorse. At the very minimum it will cue a tension for many people between their affective and analytic response to the issue – in effect serving as a communication housing a deeply mixed set of messages. This also cautions us against the idea of using any simplistic notion of public consultation or engagement around nuclear energy as a means of garnering public consent for new power stations. The conceptual space occupied by the reluctant acceptance position may be fairly narrow, only becoming triggered when people are given the opportunity to simultaneously express their (ambivalent or reluctant) support alongside a continuing dislike for nuclear power. Public engagement and energy policy decision making must therefore recognise and work with these contradictions, rather than seeking to impose a single or definitive framing of the issues under consideration (as some have argued the 2007 UK nuclear public dialogue attempted to do). As the window of opportunity for addressing climate change and energy security grows ever smaller, and global greenhouse gas emissions continue to rise, is it critical that such engagement is taken forward in as open and flexible a way as possible.

At a basic policy level, our results suggest that much apparent public support for nuclear power remains fragile, with underlying concerns never far from the surface of awareness (see also Rosa and Clarke, 1999; Pidgeon et al., 2008). As a postscript to our analysis, at the point of finalising this paper in early 2011 the world witnessed the catastrophic earthquake and tsunami damage to the Fukushima nuclear power plant in Japan. Those events, it is now becoming clear, have been second only to Chernobyl in terms of their on-site damage, the loss of safety systems, and amount of radiation released. Only further empirical work will show us the longer-term impacts of these events on perceptions in the UK and elsewhere. However, drawing upon the theoretical work of the anthropologist Masco (2006) on the ‘nuclear uncanny’, whereby its long-standing associations with world-making and destroying powers sets nuclear apart from other technological systems, Parkhill et al. (2010) demonstrated how the extraordinary nature of nuclear technology results in certain external events, such as accidents or incidents at distant locations, holding the power to cue significant latent concerns and anxiety amongst people. While much is currently made of the issue of the technological resilience of energy systems, energy policy might therefore also consider the conditions for attaining ‘social resilience’. A policy locking a country or economy into new nuclear power as a key component of its decarbonised future would always run the risk of a potentially fatal loss of public support in the face of nuclear accidents such as at Fukushima, or a terrorist event at a civilian nuclear facility anywhere in the world. Similarly, as Teravainen et al. (2011) have remarked, the recent decline in citizens’ belief in the anthropogenic nature of climate change may actually weaken the carbon-reduction argument for nuclear power and emphasise that of energy security instead. Accordingly, decisions about future energy supply cannot be easily divorced from the interests, values and perceptions of the people and communities which energy systems are ultimately meant to benefit and serve.

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Appendix A. Items included in the current analysis (for full list of items from the 2010 survey see Spence et al., 2010)

Socio-demographic items

Age group: 15–17;18–24;25–34;35–44;45–54;55–64;65–74;75+

Gender: Male_Female

Social grade (estimated by interviewer on basis of main household income): A;B;C1;C2;D;E

Voting preference: Conservative;Labour;Liberal Democrat;Green Party;UK Independence Party;British National Party;Scottish Nationalist;Welsh Nationalist;Democratic Party;Other;Would not vote;Undecided;Refused_

Concern about climate change (3 items)

How concerned, if at all, are you about climate change, sometimes referred to as ‘global warming’?

Considering any potential effects of climate change which there might be on you personally, how concerned, if at all, are you about climate change?

Considering any potential effects of climate change that there might be on society in general, how concerned, if at all, are you about climate change?

Not at all concerned
Not very concerned
Fairly concerned
Very concerned
Don’t know
No opinion

Concern about energy security

How concerned, if at all, are you that in the future:

Electricity will become unaffordable?

Electricity will be rationed?

The UK will become too dependent on energy from other countries?

Terrorist attacks will cause interruptions to electricity supplies?

Supplies of fossil fuels (e.g. coal and gas) will run out?

There will be power cuts?

Not at all concerned
Not very concerned
Fairly concerned
Very concerned
Don’t know
No opinion

Environmental values

Preventing pollution: protecting natural resources

Respecting the earth: harmony with other species

Unity with nature: fitting into nature

Protecting the environment: preserving nature

Not at all important
Not very important

Fairly important
Very important
Extremely important
Don't know

Neither favourable nor unfavourable
Mainly favourable
Very favourable
Never heard of it
No opinion
Don't know

Unconditional attitudes towards nuclear

From what you know or have heard about using nuclear power for generating electricity in Britain, on balance, which of these statements, if any, most closely reflects your own opinion?

The benefits of nuclear power far outweigh the risks
The benefits of nuclear power slightly outweigh the risks
The benefits and risks of nuclear power are about the same
The risks of nuclear power slightly outweigh the benefits
The risks of nuclear power far outweigh the benefits

On a purely emotional level, how do you personally feel about nuclear power?

Very positive
Fairly positive
Neither positive nor negative
Fairly negative
Very negative
No opinion
Don't know

Conditional attitudes towards nuclear & 'reluctant acceptance'

I am willing to accept the building of new nuclear power stations if it would help to tackle climate change

We need nuclear power because renewable energy sources alone are not able to meet our electricity needs

Britain needs a mix of energy sources to ensure a reliable supply of electricity, including nuclear power and renewable energy sources

I am willing to accept the building of new nuclear power stations if it would help to improve energy security (i.e. a reliable supply of affordable energy)

I don't really like the idea of nuclear power, but I reluctantly accept that we will need it to help combat climate change and improve energy security (i.e. a reliable source of affordable energy) in the UK.

Strongly agree
Tend to agree
Neither agree nor disagree
Tend to disagree
Strongly disagree
No opinion
Don't know

Favourability of energy sources

How favourable or unfavourable are your overall opinions or impressions of the following energy sources for producing electricity currently?

Biomass_Coal_Gas_Hydroelectric power_Nuclear power_Oil_Sun/Solar_Wind

Very favourable
Mainly Favourable

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