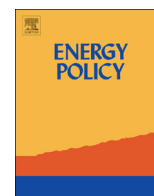




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Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Nuclear power in Australia: A comparative analysis of public opinion regarding climate change and the Fukushima disaster



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HIGHLIGHTS

- Australia-wide survey assessed opinions of nuclear power in 2010 and 2012.
- Study examined attitudes in relation to climate change and Fukushima disaster.
- Australians believe nuclear power offers a cleaner, more efficient option to coal.
- Australians are against nuclear power due to safety concerns and distrust.
- Reluctant acceptance of nuclear power is a fragile attitudinal state easily swayed.

ARTICLE INFO

Article history:

Received 9 September 2012

Received in revised form

4 September 2013

Accepted 11 September 2013

Available online 3 October 2013

Keywords:

Climate change

Public attitudes

Energy futures

ABSTRACT

A nation-wide survey was conducted in 2010 to investigate the Australian public's attitudes to nuclear power in relation to climate change and in comparison to other energy alternatives. The survey showed a majority of respondents (42%) willing to accept nuclear power if it would help tackle climate change. Following the disaster at the Fukushima Daiichi Nuclear Power Complex in Japan, an event triggered by the 11 March 2011 Tohoku earthquake and tsunami, it was expected that support for nuclear power in Australia would change. In light of this, a follow-up survey was conducted in 2012. Indeed, the post-Fukushima results show a majority of respondents (40%) were *not* willing to accept nuclear power as an option to help tackle climate change, despite the fact that most Australians still believed nuclear power to offer a cleaner, more efficient option than coal, which currently dominates the domestic production of energy. Expanding the use of renewable energy sources (71%) remains the most popular option, followed by energy-efficient technologies (58%) and behavioural change (54%). Opposition to nuclear power will continue to be an obstacle against its future development even when posed as a viable solution to climate change.

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1. Introduction

Although Australia has significant reserves of uranium and is one of the world's main exporters of the mineral, it does not itself exploit nuclear power. This is despite the country having a stable political and economic environment in addition to relatively stable geology, an important factor with respect to the location of nuclear power stations and for storing radioactive waste. Some prominent

Australian environmentalists¹ have advocated the use of nuclear energy as a low-carbon alternative to burning fossil fuels, and several countries – particularly China and India (IAEA, 2011a) – are expanding their nuclear industries with 65 nuclear power reactors under construction worldwide (IAEA, 2011b). In Australia, however, the tenor of the debate about the possibility of using nuclear power remains muted. Of the two major political parties, Labor's long-standing policy is to oppose its development, while the Liberal Party has generally supported the notion (Choose Nuclear Free, 2010).

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¹ For example, Barry Brook is a leading environmental scientist holding the Sir Hubert Wilkins Chair of Climate Change at the University of Adelaide where he is also Director of Climate Science. Professor Brook is an advocate of low-carbon energy solutions, including nuclear power, to address climate change issues. Professor Tim Flannery, chairman of the Copenhagen Climate Council and Australia's Climate Commissioner also advocated nuclear power as a possible solution for reducing Australia's carbon emissions but later changed his stance to be against nuclear power in 2007.

The absence of serious debate may arise from the political perception that there is deeply embedded opposition to nuclear power within the Australian community (Falk and Settle, 2010; Graetz and Manning, 2011). Other considerations are Australia's energy dependence on coal-fuelled power stations (Hamilton, 2001) and concerns about the safety of nuclear material (Schläpfer, 2009). Regardless of the veracity of these perceptions, there is currently little public information as to whether or not Australians are willing to embrace nuclear power as an alternative to fossil fuels. Given Australia's political commitment to reduce greenhouse gas emissions (Pielke Jr, 2011), knowing what the Australian public thinks about nuclear power as one reliable 'solution' to anthropogenic climate change is important.

To address this, we conducted an online survey in 2010 that examined the public's perspective about the acceptability of nuclear power as an option to help tackle climate change. However, since our survey was conducted, the tsunami-induced nuclear meltdown at the Fukushima Daiichi nuclear plant in Japan following the Mw 9.0 Tohoku earthquake on 11 March 2011 provoked negative reactions to nuclear power around the world. Several governments, including those in Germany, Switzerland, Italy and Japan, indicated plans to phase out nuclear power.

While researchers speculated that public support for nuclear power might lessen following a major accident (e.g. Butler et al., 2011; Pidgeon et al., 2008), this was not the case in the UK following the Fukushima disaster (Poortinga et al., in press). We therefore undertook a follow-up survey in 2012 in order to document whether or not public attitudes in Australia towards the development of a nuclear power industry had changed.

Using the 2010 and 2012 survey results, this paper:

- examines public opinions of nuclear power in the context of anthropogenic climate change,
- determines whether or not the Australian public's opinions of nuclear power changed following the issues at the Fukushima Daiichi nuclear power plant in Japan, and
- discusses public views on energy futures in Australia in relation to reducing greenhouse gas emissions.

Before describing the methods and results of the surveys, we first outline relevant aspects of the Australian energy situation, political perspectives of nuclear power and climate change, and the media, opinion polls and question framing. The paper concludes with a discussion of the survey results in relation to energy futures in Australia and what implications these might have for policy debate.

2. Energy, climate change and opinion polls in Australia

2.1. Current energy use and targets

In a government-sponsored and commissioned report, Garnaut (2008) notes that Australia's emissions-intensive electricity sector

Table 1
Per capita metric tonnes of CO₂-emissions (from The World Bank, 2013).

	2009
Australia	18.4
Brazil	1.9
Canada	15.2
China	5.8
Germany	9
New Zealand	7.4
UK	7.7
USA	17.3

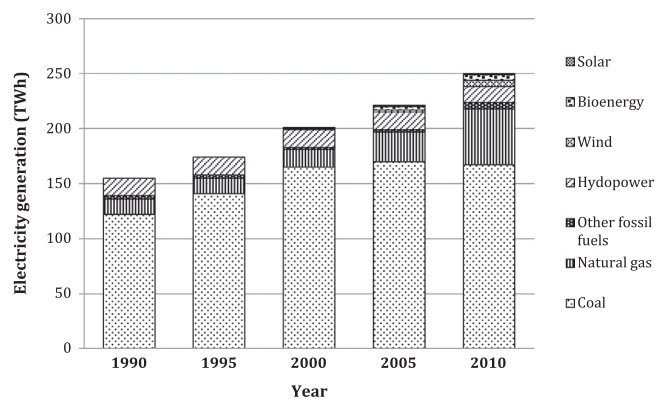


Fig. 1. Temporal evolution of the energy mix in Australian electricity production, 1990–2010 (from Stark et al., 2012).

Table 2

Australian total final energy consumption by industry, 2010–2011 (from Stark et al., 2012).

	Petajoules	Growth %	Share %
Mining	389	10.4	10.1
Manufacturing and construction	1047	0.8	27.3
Transport	1479	2.0	38.5
Commercial	308	−0.3	8.0
Residential	452	1.7	11.8
Other	165	1.7	4.3
Total	3839	2.2	100.0

is the main reason why Australia's greenhouse gas emissions per person are among the highest in the world (Table 1). In terms of carbon intensity, Australia produced 0.84 t of carbon dioxide for every \$US1000 of GDP in 2006 (Pielke Jr, 2011).

The production of energy for domestic consumption in Australia is dominated by coal, oil and gas, with only a minor component from renewable sources. As electricity generation has increased, the proportion of coal in the energy mix has more or less remained constant since 2000 (Fig. 1). During the same period, the proportion of renewables in the energy mix has increased, but it remains a small fraction. Nevertheless, renewable energy consumption in the five years to 2009 grew faster than the other three sources, increasing in absolute terms by 3.5% (Schultz and Petchey, 2010).

Transport is the biggest user of energy, followed closely by manufacturing and construction (Table 2). However, in terms of growth over this time period, mining stands out with a 10.4% increase in consumption compared to only 2.0% for transport and 0.8% for manufacturing and construction.

The most recent update to the Garnaut Climate Change Review (Garnaut, 2011) concludes that an overhaul of the electricity sector is fundamental for Australia to reduce its greenhouse emissions. A renewable energy target was introduced by the government in 2001 and expanded in 2009 with the aim of a 20% renewable share of domestic electricity supply by 2020 (ORER, 2010) and a 60% reduction in greenhouse gas emissions by 2050 compared to 1990 levels. This target is less ambitious than the ones many other developed countries have set and is below what would be needed to limit global warming to 2 °C (Meinshausen et al., 2009).

Australia's target is unlikely to be achieved, however, as to do so would require a rate of decarbonisation greater than what has been achieved by any other developed country, including France with its large-scale adoption of nuclear power, the UK with the closing of coal mines and the Japanese with an aging population (Pielke Jr, 2011). Pielke Jr (2011) argues that if Australia's energy demands were to remain at 2004 levels, with renewable energy

Table 3

Significant events related to nuclear power and anthropogenic climate change and their influence in Australian politics (from Clarke et al., 2011; Four Corners, 2005; Hamilton, 2001; Howe, 2007).

Date	Policy change, significant event, scientific progress, etc.	Australian reaction/basis
1944	Scientific advancement in nuclear research and the development of the atomic bomb led to requests from the USA and UK for uranium	Exploration of uranium begins in Australia
1953	Australian Atomic Energy Commission (AAEC) established	
1958	Australia's first nuclear reactor provided by the UK and located at Lucas Heights, NSW	
1961	Second nuclear reactor located at Lucas Heights, NSW	
1970	Australia signs the Nuclear Non-Proliferation Treaty	
1971	Commonwealth proposal for a power-generating nuclear reactor to be sited on Commonwealth territory at Jervis Bay, New South Wales cancelled	Growing anti-nuclear sentiment in Australia
1973	Australia ratifies the Nuclear Non-Proliferation Treaty	
1977	Final Ranger Enquiry report, on the implications of Australia's involvement in exporting uranium, handed to government. For the report see National Archives of Australia (2013)	First instituted in 1975, the report was regarded as reliable and independent study which recommended that Australia unilaterally apply additional stringent safeguard conditions to uranium export agreements
1979	Nuclear accident at Three Mile Island, Pennsylvania	
1986	Chernobyl nuclear disaster Russia.	AAEC changes its name to the Australian Nuclear Science and Technology Organisation (ANSTO) in 1987, and changes its role to environmental and health research
1988	Intergovernmental Panel on Climate Change (IPCC) established by the WMO and UNEP	Following this in 1989 the Federal government establishes a National Climate Change Programme
1992		The Council of Australian Governments (COAG) endorsed the National Greenhouse Response Strategy.
June 1999	Kyoto protocol begins to take effect and creates a new business environment	However, the 90s were generally defined by policy initiatives to remove restrictions on business
November 2000	<i>Lock The Gate Alliance</i> formed to oppose unchecked mining for coal seam gas	Prime Minister's Science, Engineering and Innovation Council (PMSEIC) urge the government to move from a defensive to a more positive position on climate change. The PMSEIC report argues that the Kyoto agreement is a powerful instrument for change (See Working group for PMSEIC, 1999)
2002	Japan and the European Union ratify the Kyoto Protocol	
2005	Senate pass a motion opposing nuclear power in Australia	Australian Liberal PM John Howard announces on June 5 that Australia will not ratify due to national economic interests
2006	The Australian Business Roundtable on Climate change (formed in 2004 and comprising representatives from BP Australia, Origin Energy, Insurance Australia Group and other businesses) release their report 'the Business Case for Early Action' which includes recommendations for a carbon price, innovation and investment in new green technologies and a plan to integrate adaptation into the development and planning process (e.g. building codes)	COAG agree to adopt a new national Climate Change Plan of Action and establish a group to oversee the implementation of their recommendations
2007	At the Conference of the Parties (COP) 13 th session held in Bali, scientists warn that the climate change prognosis is worse than previously predicted. Amid high levels of media attention and expectations the conference sets a road map for 'Kyoto II' to be agreed upon by COP 15, Copenhagen 2009	ABC's Four Corners TV programme on February 13 alleges a government strategy to 'gag' CSIRO scientists from releasing information on climate change science to the public
2009	COP 15, Copenhagen 2009	Newly appointed Labor PM Kevin Rudd ratifies the Kyoto Protocol. The government promises to reduce greenhouse gas emissions by 60% on 2000 levels by 2050, establish an emissions trading scheme by 2010 and set a 20% target for renewable energy by 2020
November 2010	Increasing calls from prominent MP's and industry leaders to bring nuclear power back onto the political agenda in 2011. Climate change mitigation cited as an important factor	
2009–2011		Copenhagen fails to agree to a new legal treaty. Leaders of the US and the BASIC group of countries (Brazil, South Africa, India and China) would not agree to legally binding targets
March 2011	Large tsunami causes a nuclear meltdown of reactors at the Fukushima Daiichi power complex, Fukushima, Japan	Australian government hotly debates the Emissions Trading Scheme and Carbon Tax
July 2011	Labor Coalition announces their carbon tax scheme to begin July 2012, moving towards an emissions-trading system in 2015	The carbon tax scheme instigates vigorous public and political debate
November 2011	Carbon tax legislation passed Senate	
July 2013	Newly reinstated PM Kevin Rudd announces that the move towards an emissions-trading system will occur one year earlier than previously legislated. Coming into force in 2014	A continuing and contentious issue for Labor government in coalition with the Greens. Main opposition party threatens to repeal legislation if elected
		With elections due in September 2013. The Labor party are attempting to distance themselves from the negative association of the carbon tax

Table 4

Selected questions and results from polls canvassing public opinion on nuclear power in Australia. All questions (except the debate poll) asked the respondent: “If in favour/support – is that strongly in favour/support or partly in favour/support? If against – is that strongly against/oppose or partly against/oppose?” Those recorded as ‘neither’ refer to those responding either “don’t know” or “uncommitted”.

Reference	Date	Location	Method	Question	% for	% against	% neither
Newspoll (2006)	May 2006	Australia-wide	Phone	Currently, while there is a nuclear reactor at Lucas Heights in Sydney used for medical and scientific purposes, there are no nuclear power stations in Australia. Are you personally in favour or against nuclear power stations being built in Australia?	38	51	11
Newspoll (2007a)	December 2006	Australia-wide	Phone	Currently, while there is a nuclear reactor at Lucas Heights in Sydney used for medical and scientific purposes, there are no nuclear power stations in Australia. Are you personally in favour or against nuclear power stations being built in Australia?	35	50	15
Newspoll (2007b)	March 2007	Australia-wide	Phone	Thinking now about reducing greenhouse gas emissions to help address climate change. Are you personally in favour or against the development of a nuclear power industry in Australia, as one of a range of energy solutions to help reduce greenhouse gas emissions?	45	40	15
ACNielsen poll (Mumble, 2009)	October 2009	n/a	n/a	The introduction of nuclear power has been suggested as one means to address climate change. Do you support or oppose the Federal Government considering the introduction of nuclear power in Australia?	49	43	7

contributing 20% of supply, the country would still need the equivalent of 13 nuclear power stations by 2020 in order to decarbonise the economy by replacing coal consumption with a zero-carbon alternative. This assumes an average production per plant of 750 MW of electricity. Pielke Jr (2011) uses this nuclear power station metric as a measure of the challenge facing the country to achieve the government’s stated goal and not to advocate the nuclear option.

2.2. Political perspectives on nuclear power and climate change

According to Hamilton (2001), the politics of climate change have been more of a struggle in Australia than in other countries, with the exception of the USA, due to the uncompromising power of the fossil fuel lobby. Pielke Jr (2011) provides a summary of the political context in which Australia’s decarbonisation goals emerged. In short, the Liberal-National Coalition Government (1996–2007) refused to sign the Kyoto protocol (Table 3), something that a newly elected Labor Prime Minister was quick to address in 2007. In addition, the then Liberal Prime Minister expressed support for nuclear power in May 2006 after having legislated against it in 2005.

Discussions of developing a nuclear power industry as a measure to reduce carbon emissions emerged in the political arena again in November 2010. However, other measures, such as clean coal, carbon sequestration, carbon tax² and an emissions trading scheme³ have been more prominent within Labor discourse. Labor, with the support of the Greens Party and several independents, formed a coalition government to remain in power following the 2010 election and announced a carbon tax scheme on 10 July 2011. Although this scheme faced fierce opposition from

the Liberal and National parties, the carbon tax legislation passed both houses of federal government in November 2011 and was implemented on 1 July 2012. The move towards an emissions trading system was legislated to occur in 2015. However, in July 2013, with an election imminent, the Labor government moved to introduce the scheme one year earlier than originally planned to improve their re-election prospects.

2.3. The media, opinion polls and question framing

In Australia, Newspoll, a leading market and social research company, has carried out a number of public opinion polls regarding nuclear power. Results of such polls are published in a variety of media, including *The Australian* (Australia’s only national broadsheet newspaper), *The Age* (Melbourne’s only broadsheet) and *The Sydney Morning Herald* (Sydney’s only broadsheet). Opinion polls can be misleading, however, and Macintosh (2007) asserts that *The Australian* seriously misinterpreted Newspoll surveys by claiming that more Australians supported nuclear power in 2007 than when polled in 2006. This claim is indeed dubious, being based on answers to two different questions (Newspoll, 2007b; see Table 4 for details). When comparisons are correctly drawn from responses to the same question, it appears that slightly fewer people were in favour of nuclear power stations being built in Australia when questioned seven months after the initial survey in May 2006 (Newspoll, 2006).

Despite the dubious claim by *The Australian*, the March 2007 Newspoll survey provides an interesting perspective of contrasting opinions when questions are reframed. The results suggest that more people were in favour of a nuclear power industry being developed in Australia when framed alongside climate change. It is well known that the framing of questions can affect the way the public respond to them (Bruine de Bruin, 2011). For example, Corner et al. (2011) found that people are more likely to express support for nuclear power if it is presented as a possible solution to climate change. It is therefore possible that respondents in the March 2007 survey still opposed the development of a nuclear power industry, but were willing to ‘reluctantly accept’ it if it were to help tackle climate change. The label ‘Reluctant Acceptance’ was coined by Bickerstaff et al. (2008; p. 145), to describe how the public discursively re-negotiated their position on nuclear energy when it was positioned alongside climate change.

² The Carbon Tax puts a fixed price on pollution emitted. The starting price in July 2012 was \$23 per tonne of CO₂. This is paid by facilities that emit more than 25,000 tonnes of CO₂ per year. This amounts to approximately 500 organisations, however, there are knock-on indirect effects to associated industries and consumers (HIA, 2012).

³ Under an emissions trading system, the carbon price is set by the market and is expected to move in line with the carbon price in the European Union system. The government will set a pollution cap to fit with Australia’s emissions reduction target. Permits to pollute a certain amount will be provided to facilities, who will then be able to trade these permits within Australia and internationally, i.e. purchasing extra permits if needed or selling their permits at a profit if they can reduce their emissions (Australian Government, 2013).

Another example of media misinterpretation of polling results followed the release of an ACNielsen survey in 2009 (see Table 4). Media reports entitled: “Australians warm to nuclear power” (*The Age*: Munro and Strong, 2009) and “More Aussies back nuclear power: poll” (Ninemsn, 2009) ensued. Once again these claims are dubious as they are based on a comparison of responses to earlier polls and different questions with the ACNielsen Research Director, John Stirton, quoted as saying:

It is important to understand two things about this question [see Table 4 for question asked in ACNielsen poll 2009]. First, it was deliberately asked in the context of addressing climate change. Second, it asked whether voters felt the government should consider nuclear power, not introduce it. Even in this context, nuclear power failed to achieve support from a majority of voters and a significant minority (43%) remain opposed (Mumble, 2009).

Stehlik (2010) highlights the discrepancies associated with comparing different opinion polls: [p]oll results that exist in the public domain are unsuitable for meta-analysis as the questions [in successive polls] are never the same and are therefore difficult to compare and contrast. To avoid the problems outlined above, we asked the same questions in both the 2010 and 2012 surveys.

3. Methods

An online questionnaire offered the most appropriate and effective mode of delivery as the Australian population is spread over a vast area, and 79% of Australians actively use the internet and have internet access at home (ABS, 2011). According to an ACNielsen report (2010) the online community is becoming increasingly reflective of the general Australian population with internet usage increasing among lower income earners and older age groups.

An online sampling company, specialising in online data collection – Survey Sampling International (SSI) – was enlisted to host the questionnaire. Respondents were recruited via email invitation from SSI's proprietary panels and online community. Respondents were selected at random from the panels to ensure maximum diversity of the sampling frame. The surveys were administered from 9 to 14 April 2010 (pre-Fukushima) and 3 to 8 February 2012 (post-Fukushima), with a total of 1085 and 1101 successful completions⁴, respectively. Survey samples were chosen independently of one another. Sample sizes were chosen to ensure a sample error of at most plus or minus 3 percentage points at the 95% confidence level. The survey specifically targeted people aged 18 years and over in both rural and city areas in all states of Australia. Hard quotas, in terms of gender, age and geographical location (Table 5), were used based on national representative proportions according to the 2006 Australian Bureau of Statistic census data. The survey remained open until quotas for gender and geographical location had been met.

To allow for an international perspective, most questions in our survey were based on those used in recent UK questionnaires (Poortinga et al., 2006; Spence et al., 2010). A total of 40 closed questions were included in the 2010 survey, which covered the following topics:

- Respondent demographics.
- Overall opinions about various energy sources for producing electricity.

Table 5

Respondent demographics. All data are given as a percentage. Some variables do not add to 100% due to rounding.

	2010	2012
Gender:		
• Female	54.0	53.8
• Male	46.0	46.2
Age:		
• 18–34	32.9	30.2
• 35–54	46.5	47.5
• 55+	20.6	22.1
Geographical location:		
• Australian Capital Territory	2.1	2.0
• New South Wales	32.4	32.8
• Northern Territory	1.1	0.9
• Queensland	19.4	20.0
• South Australia	7.6	8.1
• Tasmania	1.3	1.3
• Victoria	25.0	24.7
• Western Australia	11.2	10.3

- Opinions on the use of coal and nuclear power to generate electricity.
- Opinions on climate change.
- Opinions on the use of various energy sources to help combat climate change.

In order to avoid leading respondents, the first questions about energy sources were not posed in the context of climate change. However, following the examples provided in the UK questionnaires, consequent questions examined whether or not respondents were willing to accept nuclear power as a possible solution to climate change.

The same questions from 2010 were used in the 2012 questionnaire to enable comparisons and identify changes in public opinion. However, additional questions were added at the end of the 2012 survey. The first was a direct question asking respondents how their support for nuclear power had changed, if at all, following the nuclear meltdown at Fukushima. A second question was added in response to the new carbon tax legislation which was to be implemented on 1 July 2012, as it was considered that it would have direct impacts on energy futures in Australia (Siriwardana et al., 2011). In both surveys, respondents were given the option of “other, please specify” in some instances to avoid limiting responses. Electronic copies of the questionnaires are available from the lead author on request.

A one-sided z-test for comparing proportions was used to test for statistically significant differences between the 2010 and 2012 survey results. We considered a $p < 0.001$ as indicating a highly significant difference, and $0.001 < p < 0.05$ a significant difference.

The following section documents the Australian public's opinion of nuclear power and climate change as reflected in our survey results.

4. Results

4.1. Opinions on various energy sources for producing electricity in Australia

Table 6 shows that, both in 2010 and 2012, the Australian public had the most positive opinions or impressions of renewable energy technologies, followed by gas and biomass. Fossil fuels and nuclear were by far the least favoured energy sources for the production of electricity. There were some significant differences between the 2010 and 2012 results, with more Australians

⁴ “Flat-liners” (respondents who tick the exact same box the whole way through the questionnaire) and “speeders” (respondents who complete the questionnaire in less time possible to accurately read and complete it) are not considered to have successfully completed the survey, and were therefore removed from the dataset.

Table 6

Respondents' opinions of the energy sources: biomass, coal, gas, hydroelectric power, nuclear power, oil, sun/solar and wind power in terms of very or mainly favourable (favourable), neither favourable nor unfavourable (neither), very or mainly unfavourable (unfavourable) and never heard of it, no opinion/don't know (don't know). All data are given as a percentage of total responses.

	Favourable		Neither		Unfavourable		Don't know	
	2010	2012	2010	2012	2010	2012	2010	2012
Biomass	40.6	40.1	28.7	28.6	18.0	13.5	12.8	17.7
Coal	22.6	27.3	30.9	28.5	40.9	39.3	5.6	4.9
Gas	50.7	49.7	30.5	28.0	14.7	18.4	4.1	3.9
Hydro	70.7	71.1	17.0	15.1	6.0	8.3	6.4	5.6
Nuclear	30.9	26.9	22.6	18.6	41.0	50.1	5.6	4.4
Oil	19.2	22.0	32.8	28.9	42.4	44.5	5.6	4.7
Sun/solar	88.9	84.8	5.9	7.5	2.8	5.5	2.4	2.2
Wind	80.1	78.1	11.3	10.4	4.6	8.6	4.0	3.0

Table 7

Respondents' concurrence (i.e. strongly or tend to agree) of generating electricity from coal and nuclear power in terms of the following statements. All data are given as a percentage.

	Coal		Nuclear	
	2010	2012	2010	2012
Causes air pollution?	70.2	79.2	21.6	29.5
Causes climate change?	49.7	54.7	23.5	28.3
Creates dangerous waste?	36.8	45.0	70.2	81.9
Is a hazard to human health?	46.9	48.7	52.8	68.8
Is cheap?	40.8	51.0	24.9	30.6
Is clean?	10.0	10.6	33.5	32.2
Is beneficial for communities living nearby?	30.4	28.1	18.9	17.2
Is beneficial for the economy?	41.3	46.5	38.2	37.1
Is inefficient?	32.0	30.7	11.8	13.9
Is reliable?	55.4	58.1	39.2	36.3
Is safe?	35.3	37.0	23.3	19.8
Spoils the landscape?	55.0	52.7	36.4	36.0

indicating a favourable opinion of coal ($p=0.0048$) and more unfavourable opinion of nuclear power in 2012 ($p < 0.0001$, highly significant). Although there was a significant decrease in favourable views of nuclear power ($p=0.0178$), this swing is mostly related to the fact that fewer people were neither favourably nor unfavourably disposed towards nuclear power after Fukushima; in other words, there was a significant decrease from 2010 to 2012 of people who were ambivalent towards nuclear power ($p=0.0093$), implying that the disaster was likely a catalyst for forming stronger opinions about nuclear power.

The results also show public opinions of renewable energy sources have changed with a highly significant increase in unfavourable views of sun/solar ($p=0.0006$) and wind ($p=0.0001$). Nevertheless, the decrease in support for renewable energy sources comes from a very high baseline and sun/solar, wind and hydropower are still the most favourable energy sources for producing electricity. No questions were asked about the feasibility of these sources ever being able to replace coal, in terms of cost per unit of electricity.

4.2. Opinions on the use of coal and nuclear power

Respondents were asked to what extent they agreed or disagreed with a series of statements in relation to coal and nuclear power as energy sources (Table 7). The results show a highly significant increase ($p < 0.0001$) in the proportion of people who believe that coal and nuclear power cause air pollution and create dangerous waste. In the 2012 survey, more people were of the opinion that nuclear power was hazardous to human health

Table 8

Respondents' opinions of nuclear power.

	2010	2012
From what you know or have heard about using nuclear power for generating electricity in Australia, on balance, which of these statements, if any, most closely reflects your own opinion?		
• The benefits of nuclear power far outweigh the risks	20.1	16.7
• The benefits of nuclear power slightly outweigh the risks	13.6	13.5
• The benefits and risks of nuclear power are about the same	12.4	13.0
• The risks of nuclear power slightly outweigh the benefits	10.7	9.2
• The risks of nuclear power far outweigh the benefits	23.9	32.8
• None of these / no opinion / don't know	19.3	14.8
Which, if any, of the following statements most closely describes your own opinion about nuclear power discussion in Australia today?		
• Overall, I support nuclear power	29.0	24.4
• Overall, I oppose nuclear power	31.7	41.4
• I am not sure whether I support or oppose nuclear power	30.4	25.6
• I don't care what happens with nuclear power	1.8	1.6
• None of these/no opinion/don't know	8.1	7.9

($p < 0.0001$) and that coal ($p < 0.0001$) and nuclear power ($p=0.0012$) were cheap, than in 2010.

Table 8 highlights a highly significant ($p < 0.0001$) increase in the proportion of people between 2010 and 2012 who agree with the statements: *The risks of nuclear power far outweigh the benefits* and *Overall, I oppose nuclear power*.

Table A.1 in the Appendix presents a breakdown of the responses in Table 8 by gender. A greater proportion of female than male respondents believed that the risks of nuclear power far outweigh the benefits ($p < 0.0001$). Both gender groups, however, showed a highly significant increase in response to that statement ($p < 0.0001$) between 2010 and 2012. Similarly, there is a highly significant increase among both genders in the proportion that overall oppose nuclear power from 2010 to 2012 ($p < 0.0001$ in both cases), alongside a highly significant decrease in the proportion of males who overall support nuclear power ($p < 0.0001$).

Older respondents showed significantly larger overall support for nuclear power than younger respondents ($p < 0.0001$) (Table A.2). Older respondents (55+ years) believed that the benefits of nuclear power far outweighed the risks in 2010, although this position had changed in 2012. Among all age groups, opposition to nuclear power increased significantly from 2010 to 2012 ($p < 0.0001$ in all cases).

The following questions asked respondents to indicate to what extent they agreed or disagreed with a series of statements about nuclear power regulation (Table 9). In 2012, a significantly greater proportion of respondents ($p < 0.0001$) disagreed with the statements: *There are a lot of good things about nuclear power* and *I feel confident that the Australian Government will adequately regulate the nuclear power industry to ensure public safety*. There was a

Table 9
Respondents' extent of agreement to the following statements in terms of strongly or tend to agree (agree), strongly or tend to disagree (disagree) and neither agree nor disagree, no opinion/don't know (no opinion). All data are given as a percentage.

	Agree		Disagree		No opinion	
	2010	2012	2010	2012	2010	2012
There are a lot of good things about nuclear power	38.0	40.3	23.3	30.9	38.6	28.8
I need more information to form a clear opinion about nuclear power	58.5	49.0	19.5	25.4	22.0	25.7
I feel confident that the Australian government will adequately regulate the nuclear power industry to ensure public safety	40.7	34.4	31.1	40.0	28.2	25.6
I don't trust the nuclear industry to run nuclear power stations safely	40.2	50.0	23.3	20.1	36.4	30.0

Table 10
Respondents' concerns and opinions about climate change.

	2010	2012
How concerned, if at all, are you about climate change, sometimes referred to as global warming?		
• Fairly / very concerned	69.2	62.5
• Not at all / not very concerned	27.3	33.4
• No opinion / don't know	3.5	4.2
Do you personally think the world's climate is changing, or not?		
• Yes	74.0	73.1
• No	15.4	19.0
• No opinion / don't know	10.6	7.9
Thinking about the causes of climate change, which, if any, of the following best describes your opinion?		
• Climate change is mainly / entirely caused by natural processes	17.9	19.8
• Climate change is partly caused by natural processes and partly caused by human activity	41.4	39.0
• Climate change is mainly / entirely caused by human activity	30.7	30.3
• I think there is no such thing as climate change	3.9	5.6
• Don't know / no opinion / other	6.0	5.3
From what you know or have heard, which three, if any, of these ways would best tackle climate change?		
• Continue to use fossil fuels (such as gas and coal) but with capture and storage of carbon dioxide that is produced	9.2	11.3
• Expand the use of energy efficient technologies	60.0	58.5
• Expand the use of nuclear power	20.0	17.4
• Expand the use of renewable energy sources (such as solar and wind power)	75.1	70.7
• Change people's behaviour so that they reduce their energy consumption	58.0	53.9
• Reduce energy consumption through regulation and taxes	8.8	9.4

highly significant increase ($p < 0.0001$) in the proportion of people who agreed with the statement *I don't trust the nuclear industry to run nuclear power stations safely*. This was also the case for the proportion of people who agreed with the statement *I need more information to form a clear opinion about nuclear power*. These results all indicate a substantial cooling in enthusiasm for nuclear power in Australia between 2010 and 2012.

4.3. Opinions on climate change and the use of various energy sources to help combat climate change

In order to gain a broader understanding of people's opinions of nuclear power as an energy solution to help tackle climate change, questions were asked to glean information specifically about respondents' perception of climate change (Table 10). The results suggest that while the majority of respondents (73.1% in 2012) think the world's climate is changing, there was a highly significant decrease ($p=0.0004$) in the proportion of people who were fairly or very concerned about climate change. The increase ($p=0.0114$) in the proportion of people who do not think the world's climate is changing was also highly significant. These results indicate a waning in interest in the climate change debate.

There was also a significant decrease from 2010 to 2012 ($p=0.0091$) in the proportion of people who thought expanding the use of renewable energy sources was one of the best ways to tackle climate change. Nonetheless, expanding the use of renewable energy sources (70.7%) remained the most popular option to

tackle climate change among Australians, followed by energy-efficient technologies (58.0%) and behaviour change (53.9%).

Table A.3 in the Appendix presents a breakdown of the responses in Table 10 by gender. A highly significantly greater proportion of females than males were fairly or very concerned about climate change ($p < 0.0001$), but this proportion had decreased highly significantly for both males and females by 2012 ($p < 0.0001$). Older Australians are less concerned about climate change than younger people (Table A.4), and the proportion of older respondents who are not at all or not very concerned about climate change increased from 2010 to 2012 (highly significant difference in the 35–54 age group ($p < 0.0001$) and significant difference in the 55+ age group ($p < 0.1$)).

A breakdown by gender (Table A.5) and age (Table A.6) of the responses in ways to tackle climate change is given in the Appendix. There was a significant decrease from 2010 to 2012 in the proportion of males ($p=0.0022$) and females ($p < 0.05$), and a decrease across all age groups who thought expanding the use of renewable energy sources was one of the best ways to tackle climate change – with a highly significant decrease for 18–34 age group ($p < 0.0001$) and significant decrease for the 55+ age group ($p < 0.05$). A significant decrease of males ($p < 0.05$) and highly significant decrease within the 55+ age group ($p < 0.0001$) was recorded from 2010 to 2012 among those who thought that expanding the use of nuclear power was one of the best ways to tackle climate change. Nevertheless, expanding the use of renewable energy sources remained the most popular option among Australians of all ages and both genders.

Table 11

Respondents' extent of agreement to the following statements in terms of strongly or tend to agree (agree), strongly or tend to disagree (disagree) and neither agree nor disagree, no opinion/don't know (no opinion). All data are given as a percentage.

	Agree		Disagree		No opinion	
	2010	2012	2010	2012	2010	2012
I am willing to accept the building of nuclear power stations if it would help to tackle climate change	42.0	34.4	30.5	40.1	27.5	25.5
Promoting renewable energy sources, such as solar and wind power, is a better way of tackling climate change than nuclear power	73.9	75.9	6.1	6.5	20.0	17.5

Table 12

Public opinion of nuclear power following the Fukushima disaster and new legislation for a carbon tax.

	2012
In relation to the nuclear power incident following the earthquake and tsunami in Japan in March 2011, which of the following best represents your support for the development of a nuclear power industry in Australia?	
• My support for nuclear power lessened following the Fukushima disaster	23.9
• I still <i>do not</i> support nuclear power following the Fukushima disaster	51.5
• I still support nuclear power following the Fukushima disaster	23.2
• My support for nuclear power increased following the Fukushima disaster	1.5
The Australian parliament has passed legislation for a carbon tax. Are you personally in favour or against a carbon tax for Australia?	
• Partly/strongly in favour	29.5
• Uncommitted	17.3
• Partly/strongly against	53.3

Respondents were asked to express their views of nuclear power in relation to climate change, and the results show a highly significant difference in responses between 2010 and 2012 (Table 11). That is, a smaller proportion of people were willing to accept nuclear power in 2012 if it would help tackle climate change ($p=0.0001$). Table A.7 in the Appendix presents a breakdown of views of nuclear power in relation to climate change by gender. The results show that among both males and females there is a highly significant decrease in the proportion of people who are willing to accept nuclear power if it would help tackle climate change ($p < 0.0001$) from 2010 to 2012.

Finally, the 2012 survey revealed that less than a quarter of respondents indicated that their support for nuclear power had decreased following the Fukushima disaster (Table 12). It should be noted that the result of 51.5% for those that *still do not support nuclear power* is greater than the response received in Table 8, of those who overall oppose nuclear power (41.4%), as the result in Table 12 may include those who are undecided about nuclear power. This result was consistent across both genders, although there was a tendency (not significant) for a greater reduction in support for nuclear power among younger respondents. There was significant opposition to the imposition of a carbon tax for Australia (over 53.0% of respondents, males and females) with opposition increasing with age, from 46.8% for the 18–34 age group, to 53.5% for the 35–54 age group, and to 61.6% for the 55+ age group ($p < 0.0001$).

5. Discussion and implications for policy debate

This study sought to assess public opinion with respect to nuclear power in the context of climate change and document whether or not the nuclear meltdown at the Fukushima Daiichi power plant in Japan changed these views. To achieve this, online questionnaires were administered in March 2010 and February

2012. The comparative analysis reveals that fewer Australians in 2012 viewed nuclear power as a satisfactory option for electricity production than in 2010. Moreover, fewer Australians in 2012 were willing to accept the building of nuclear power stations, even if this would help tackle climate change. Although they believed nuclear power offered a cleaner, more efficient option than coal, an increased proportion (42.0% of respondents, up from 34.6% two years earlier) believed that the risks of nuclear power outweighed the benefits.

The demographic analysis of the results shows that more women than men believe the risks of nuclear power far outweigh the benefits, support the development of renewable energies and are fairly or greatly concerned about climate change. Older Australians are more likely to support nuclear power and are less concerned about climate change than younger people. These results are supported by other research which has shown that more Australian men support nuclear power than women and more respondents in the 55+ age group support nuclear power than those in the 18–54 year age groups (Stehlik, 2010). Further research has found that women have greater knowledge and concern about climate change (McCright, 2010) and in general, women perceive risks to be higher than men (Bord and O'Connor, 1997; Flynn et al., 1994; Leiserowitz, 2006; Slovic, 1999; Weber, 2006).

When nuclear power was framed as an option to help reduce Australia's carbon emissions, our 2010 survey and earlier surveys by Newspoll and ACNielsen (see Table 4) showed that respondents were more accepting of the technology. Post-Fukushima, however, fewer were willing to accept the building of nuclear power installations, even if this would help reduce greenhouse gas emissions. This reduction was consistent across both genders. Moreover, post-Fukushima significantly fewer males and older Australians (55+ age group) thought that expanding the use of nuclear power was one of the best ways to tackle climate change. It seems likely that attitudes towards nuclear power prior to the Fukushima disaster were softening in the absence of recent visible accidents but that this acceptance was 'fragile' and easily swayed by new and negative information. Prior to Fukushima, some viewed climate change as a greater risk than nuclear power. Post-Fukushima, nuclear power was no longer considered as a safe and viable option for tackling climate change. And as Slovic (1999; p. 698) concluded...*distrust, once initiated, tends to reinforce and perpetuate distrust...* with negative, trust-destroying events creating a more prominent and credible impression than positive events.

If results from our 2010 survey are compared to those from a similar survey undertaken in the UK in 2010 (Spence et al., 2010), Australians were less likely to accept nuclear power as an option for mitigating the effects of climate change (34.4% in Australia versus 56.4% in the UK). This may be due to the UK already having an established nuclear industry and an influential pro-nuclear lobby who reframed the argument to obtain more social acceptance of nuclear power (e.g. Baigorria et al., 2012), attitudes which have remained true following one of the greatest nuclear accidents in history (Poortinga et al., in press). Wittneben (2012) proposes

that this result relates to the intensity of media reports, with the British press adopting a more subtle approach by not labelling the Fukushima meltdown a catastrophe. Similarly, [Butler et al. \(2011\)](#) highlight the importance of how the media interprets certain events within broad frames (e.g. pronuclear narratives use progress and energy independence frames) in order to fit with wider cultural ideas. On the other hand, [Poortinga et al. \(in press\)](#) suggest that the British public may not believe that a similar accident could occur in the UK or that in the absence of radiation-related fatalities many believe that nuclear technology is safe. In contrast, with the absence of an established nuclear industry and an influential pro-nuclear lobby in Australia, opposition to nuclear power within the Australian community prevails.

Some argue (e.g. [Brook, 2010](#)) that Australia's distrust in nuclear power will make it more vulnerable to the impacts of climate change with respect to the country's reliance on fossil fuels. With a changing climate, unprecedented extreme weather and climate events may result ([IPCC, 2012](#)). Australia has recently experienced a number of severe recent natural disasters including: drought, bushfire, flood, tropical cyclone and heatwaves. One of the most acute Australian droughts on record began at the close of the 20th century and ended in late 2009, although it was not declared officially over until 2012. The impacts to agricultural and rural communities were disastrous, and urban populations faced extended water restrictions. As a result of the drought, the Australian government paid over \$4.5 billion AUD in exceptional circumstances assistance between 2001 and 2010 ([Heberger, 2011](#)). In 2009, 173 deaths resulted from the Black Saturday Victorian bushfires ([Crompton et al., 2010](#)) and between 424 and 454 excess deaths were recorded during the preceding southern Australian heatwave ([Haynes et al., 2010](#)). Nevertheless, there is currently no evidence to suggest that the incidence or intensity of these disasters is attributable to climate change ([Bouwer, 2011](#); [Crompton et al., 2012](#); [IPCC, 2012](#)). Similarly, [Nicholls \(2011\)](#) concluded that the 2010/11 heavy rains and floods in eastern Australia were caused by a natural fluctuation of the climate system. However, the recent extreme events have dramatically personalised current and future risks.

Despite these events and although the results show nearly three-quarters of Australians believe the world's climate is changing, Australians are becoming less concerned about it. The 2012 survey found Australians more favourably disposed to coal as an energy source than two years earlier. [O'Connor et al. \(2002\)](#) revealed that Americans were willing to adopt measures that reduce emissions as long as mitigation policies did not cost jobs, weaken the economy, or cause personal harm. This is consistent with the observation by [Pielke Jr \(2011\)](#) who argues that given a conflict between policies promoting economic growth and those restricting carbon dioxide, economic growth will win every time. In other words, people will not voluntarily accept a reduction in living standards to reduce future warming and new technological solutions will be needed to resolve the dilemma.

In Australia, as the world's largest exporter of coal ([World Coal Association, 2012](#)), the continued mining of coal ensures job security for many and growth of the economy. The Australian coal industry employs over 150,000 people – 40,000 who are directly involved in mining activities and 120,000 who are indirectly associated through the retail and services sector ([Australian Coal Association, 2013](#)). The wages associated with the coal industry paid over the 2010–2011 financial year amount to just under \$10 billion AUD, this includes \$4.4 billion paid to employees and \$5 billion paid to contractors and sub-contractors ([Australian Coal Association, 2013](#)). This is important in light of a recent survey which showed Australians are most worried about their career, achievements and future in terms of general needs ([Centre for Emotional Health, 2012](#)).

[Garnaut \(2011\)](#) claims that despite Australia's current high reliance on coal-fired electricity, it also has an abundance of alternative opportunities, including gas, wind, solar and high grade uranium oxide ...at costs that are absolutely low by international standards (p. 51). Although renewable energy use is expanding, it also faces harsh opposition and it is questionable whether or not it can ever support the baseload energy needs of Australia. A move to nuclear energy will certainly require significant economic investment, as indeed will further growth in the renewable sector. Whether or not Australia adopts a nuclear or renewable energy future, or a combination of both, the country faces an enormous challenge to reach the proposed emission reduction targets of 60% by 2050 ([Pielke Jr, 2011](#)).

The surveys described here cannot explain what influences people's perceptions in relation to nuclear power, whether they are mostly related to a distrust in government or the industry, concerns about the safe permanent management of radioactive waste or simply, dread of the unfamiliar. Furthermore, we cannot determine the effect the media has on people's perceptions of the development of a nuclear power industry in Australia. Future research should focus on seeking this information through qualitative methods such as focus groups and interviews with reference to gender and age differences. Also, our survey has not considered Indigenous Australian's views on the use of nuclear power: considering that uranium mining and nuclear waste storage facilities are either located on or are planned for traditional lands, it would be essential to extend this analysis to include their attitudes.

Despite the shortcomings of the surveys, we conclude that more Australians oppose nuclear power (2010: 31.7%; 2012: 41.4%) than support it (2010: 29.0%; 2012: 24.4%). Given the low level of public discussion on nuclear issues in Australia, it is possible that many of the responses are conditioned by instinctive rather than informed reactions to the technology. Regardless of whether this is indeed the case, this negative perception will continue to be a major obstacle against future development of a nuclear power industry in Australia even when it is advanced as a partial solution to global climate change.

Acknowledgements

All respondents are thanked for the time and effort taken to complete the survey. Two anonymous reviewers are also thanked for their insightful comments and suggestions, which improved this manuscript from the original.

Appendix A. Supplementary Materials

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.enpol.2013.09.047>.

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