Public attitudes to biomass cofiring

Rohan Fernando

CCC/214 ISBN 978-92-9029-534-1

January 2013

Abstract

There is substantial interest in producing energy from renewable sources given the continuing concerns regarding climate change. One attractive renewable source for power generation is the use of biomass. Cofiring biomass is one of the simplest ways of reducing GHG emissions from coal-fired power plant. When doing so, in addition to addressing technical factors, it is important to consider public attitudes, as these shape government policies. Surveys of public attitudes to energy usually include renewable sources such as wind, solar and hydro. Bioenergy is sometimes included but cofiring seldom so. When assessing public attitudes, it is instructive to consider what information is freely available to the public. Hence information provided by major national or international organisations, either in favour or against cofiring, are described.

It is apparent that the public in most countries have little knowledge of bioenergy as a renewable energy source and most opinion polls do not even address the issue of the public's attitudes towards it. The few polls that have been conducted indicate that solar, wind and hydro are much more popular than bioenergy. Bioenergy is more popular in countries such as in Northern Europe which have extensive experience in using wood products as an energy source. Opposition to cofiring biomass in coal-fired plant is mainly on the grounds of biomass availability and sustainability. The power industry publications concentrate on the technical issues for the plant when cofiring biomass rather than availability and sustainability concerns.

Acronyms and abbreviations

CCS	carbon capture and storage
CHP	combined heat and power
EU	European Union
GHG	greenhouse gases
RO	renewable obligation

Contents

1 Introduction

Given the continuing concerns regarding climate change, there is substantial interest in producing energy from renewable sources. One attractive renewable source for power generation is the use of biomass. Bioenergy is generally regarded as being carbon neutral as the same amount of CO_2 as is released during combustion, is absorbed during feedstock growth. Cofiring biomass is one of the simplest ways of reducing net CO_2 emissions from coal-fired power plant and there have been several hundred such demonstrations worldwide over the past 20 years. In addition to addressing the technical issues of cofiring biomass at a coal-fired power plant, it is also important to consider the public attitudes to cofiring. These attitudes are a major factor in shaping government policy. The reaction of the local public to a proposed cofiring project, whether supportive or opposed, will affect the feasibility of a project. The local reaction may well be different from the attitudes of the general public. The attitudes of technical experts and the environmental lobby are also crucial in determining whether cofiring is seen as an acceptable technology to reduce carbon emissions. Many of the concerns regarding cofiring centre on sustainability issues. For example, for many years the public has been told that chopping down trees is bad for the environment, hence it may be difficult to convince them that wood can be used in a sustainable way for power production. There are particular concerns that cultivation of biomass will impair food production and increase food prices in developing nations and lead to the destruction of tropical rain forests. Attitudes to bioenergy vary from country to country. Some have more experience in managing forests and utilising wood for fuel than others. In addition to ensuring that the biomass is cultivated in a regenerative manner and does not affect food production or tropical forests, it is also necessary to consider the fossil energy involved in the agricultural production such as the use of fertiliser, the CO_2 emissions relating to the storage and transport of the feedstock and emissions relating to the construction and operation of the plant.

Biomass cofiring also entails technical issues for the power plant itself. Several Clean Coal Centre publications have described these. *Cofiring of biomass and waste* was discussed by Davidson (1999). Reports entitled *The experience of indirect cofiring of biomass and coal*, *Fuels for biomass cofiring*, *Cofiring coal with waste fuels* and *Co-gasification and indirect cofiring of coal and biomass* have been produced by Fernando (2002, 2005, 2007, 2009). This report describes current public attitudes to biomass cofiring and follows two earlier reports on public attitudes to coal-fired power plant (Fernando, 2006 and 2010). Generally only surveys undertaken by major organisations, sampling at least 1000 respondents with margins of error of a few per cent, are included in this report. Hence the methodology of the surveys is not assessed. The above reports on public attitudes to coal plant found that, after about 2006, surveys of attitudes to different energy sources did not usually even include coal, presumably as it was assumed that the public would be overwhelmingly opposed to it. Surveys of attitudes to renewable energy sources usually include wind and solar power. Bioenergy is sometimes included but cofiring is hardly ever considered. Cofiring is a niche technology which has not entered the consciousness of the public or pollsters sufficiently. Hence this report will mainly focus on attitudes to bioenergy and cofiring and only include polls which specifically include bioenergy, as opposed to renewables in general. When considering public attitudes, it is instructive to consider what information is freely available to the public on relevant topics which could influence their views. This is mainly information accessible on the web. It is impractical to try to assess all the information presented to the public on television, radio and newspapers but it is possible to describe what information is provided by major national and international organisations which are either in favour or against the cofiring of biomass in coal-fired plant. As this is what is available to the public, it is not the purpose of this report to adjudicate whether arguments in favour or against are valid. The majority of reported cofiring projects are in northern Europe and the USA and it is also mainly in these regions that the few surveys including bioenergy have been undertaken.

2 Global attitudes

Global attitudes to climate change and how to address the challenge have been reviewed by Fernando (2010) but hardly any of these polls included bioenergy. One study which did question the public from several countries worldwide on bioenergy was conducted by Reiner and others (2006). Respondents from the USA, Sweden, the UK and Japan were questioned on several aspects of climate change but mainly on their knowledge and attitudes to CCS. However, one question included attitudes to bioenergy. The surveys were conducted in 2003-04 and involved about 1000 respondents in each country. The survey informed the respondents of several technologies which have been proposed to address global warming and asked the respondents which they would use. The replies are shown in Figure 1. Solar energy, energy-efficient appliances and energy efficient cars all received 80–90% favourable ratings with virtually no one expressing negative views. Wind energy, carbon sequestration (planting trees) and the use of biomass/bioenergy were all viewed favourably by clear majorities with only relatively few stating negative opinions. In the case of bioenergy, about two-thirds thought that it should definitely or probably be used, about a quarter were uncertain and the remaining 10–15% were opposed. The least opposition was in the UK. Nuclear energy and CCS were viewed with considerably more ambivalence with comparable levels of support and opposition.

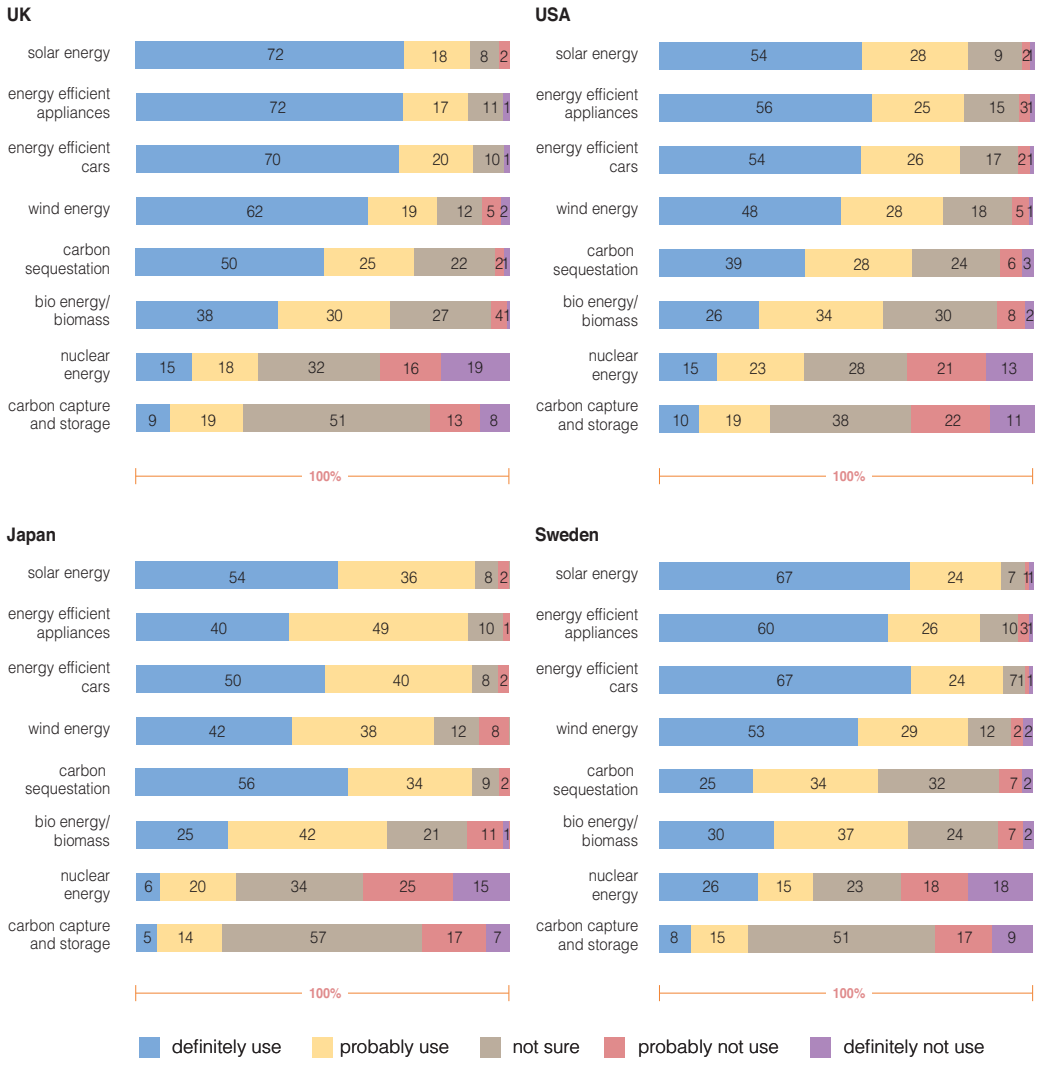

Figure 1 Attitudes to mitigation technologies to reduce global warming (Reiner and others, 2006)

3 European attitudes

The attitudes of Europeans to climate change and mitigation technologies have been reviewed by Fernando (2006) with data mainly from Eurobarometer reports. The attitudes of citizens of all the countries in the EU on a variety of subjects are regularly published in these reports. The surveys were requested by the European Commission and the European Parliament and co-ordinated by the Directorate-General for Communication of the European Commission. A Eurobarometer survey was published entitled *Energy Technologies: Knowledge, Perception, Measures* (2007) which addressed general perceptions of energy issues including knowledge and attitudes. The survey was conducted in the 25 member states and took place between May and June 2006 when 24,815 people were questioned. Given the need to change the pattern of energy consumption to reduce greenhouse gas emissions, the respondents were asked whether they were in favour or opposed to the use of different sources of energy in their countries. The results which are shown in Figure 2 show that the respondents were highly positive about the use of renewable energy: solar energy (80%), wind (71%) and hydroelectric energy (65%) with only a handful opposing. There was also positive support for ocean energy (60%) and energy from biomass (55%). The support for bioenergy, however, was significantly less than for solar, wind or hydro. Considering fossil fuels, there was a reasonable degree of support for natural gas (42%) but only a about a quarter supported oil (27%) or coal (26%). Nuclear energy had the lowest level of support (20%). The respondents were not asked about cofiring biomass in coal-fired plant. But extrapolating between the levels of support for coal and biomass would suggest that only a minority would be expected to be in favour of cofiring.

The detailed results for attitudes for energy from biomass for the EU 25 countries are shown in Figure 3. This shows that there was a substantial variation in degree of support. In Germany and Austria there was a substantial majority in favour and only a handful opposed whereas in Malta over twice as many were opposed as favoured biomass as an energy source. The countries in northern and central Europe were the most favourable and the Mediterranean countries most opposed. The UK and Ireland were in the sceptical fold. The reason for this variation might have been that northern and central Europe contain extensive forests and the population there were used to timber being managed for commercial use especially as a fuel. The survey also examined views on energy sources for the future. The respondents were asked what sources they thought were the three most important energy sources for their country at present and in 30 years' time. The average replies are shown in Figure 4. It is apparent that Europeans see renewable energy as the solution to their future energy needs. The chief energy sources for the future were expected to be solar, wind and nuclear. On average, although biomass was expected to increase substantially from current usage, fewer than a fifth thought that biomass would be among the three most important sources for the future. The results for individual countries are given in Table 1. Respondents from

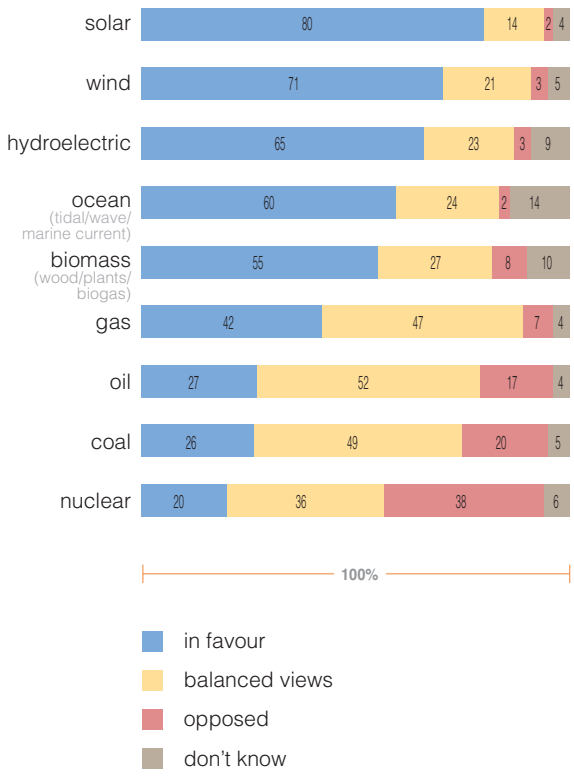

Figure 2 EU attitudes to energy sources (Eurobarometer, 2007)

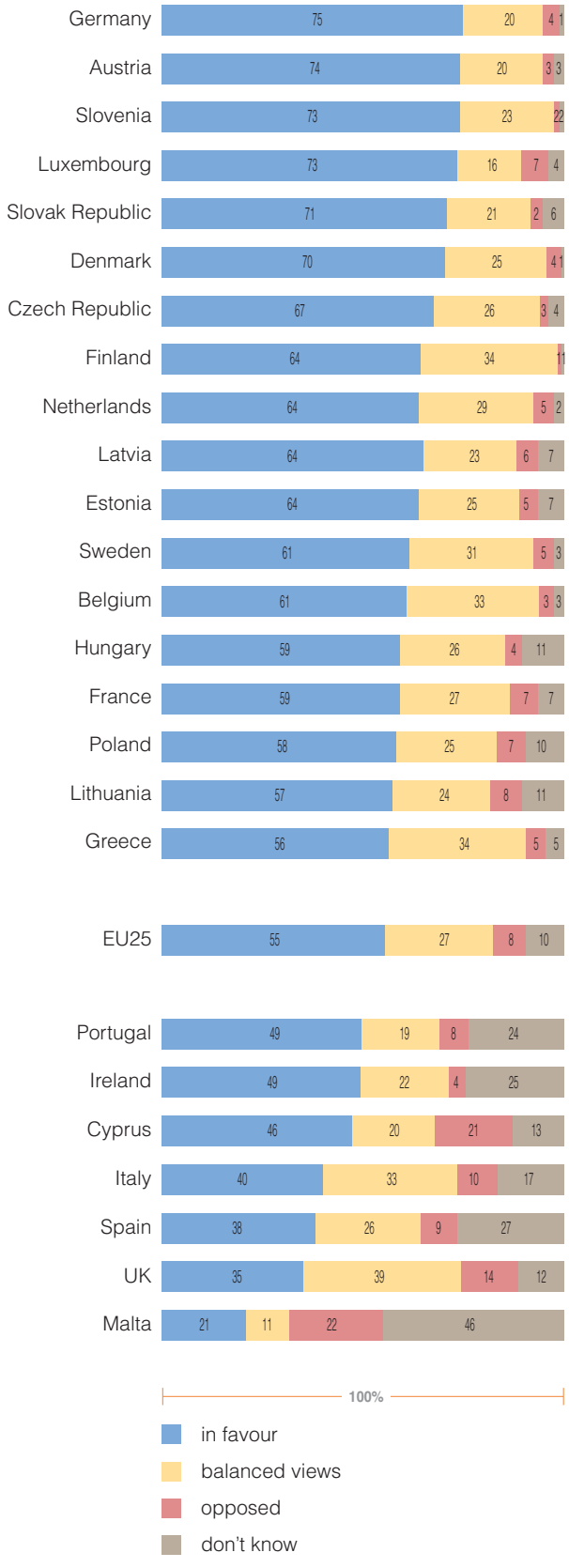

Figure 3 **EU attitudes to biomass energy** (Eurobarometer, 2007)

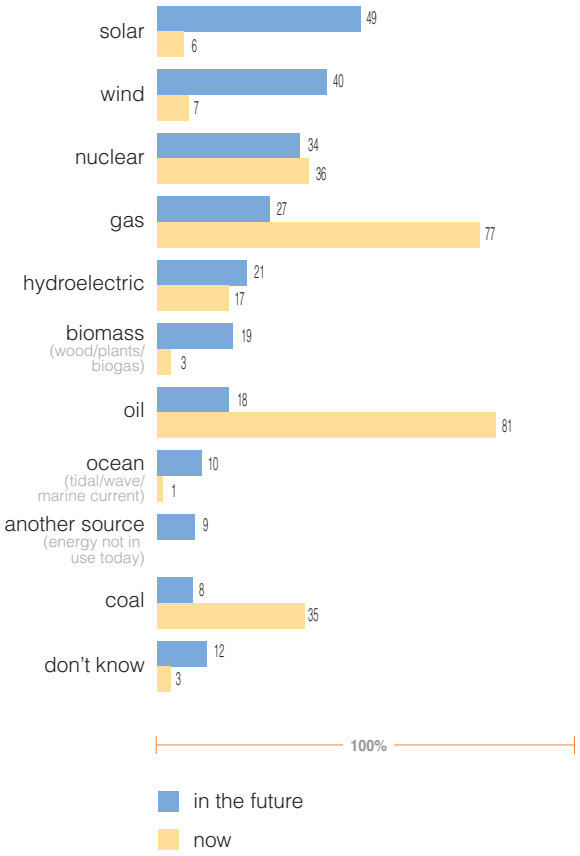

Figure 4 **EU attitudes to future energy sources** (Eurobarometer, 2007)

Scandinavian countries were the most enthusiastic that biomass would be a main energy source with nearly half of those sampled thinking so. This is only to be expected given that biomass has been used extensively in these countries as an energy source over many years. The Mediterranean countries (Malta, Cyprus, Portugal, Spain and Greece) were the least enthusiastic (Eurobarometer, 2007).

In a later survey in November 2009, the views of about a thousand respondents in each EU country on climate change were obtained. They were questioned on their attitudes to biofuels. These are liquid fuels derived from biomass which can replace petrol and diesel. Issues relating to biofuels are not identical to those affecting bioenergy but nevertheless the results give some indication on the public's attitudes to the use of biomass. The results, which are shown in Figure 5, showed that there was substantial support with the

Table 1 Attitudes to energy sources (Eurobarometer, 2007)

	Coal	Oil	Gas	Nuclear	Hydro	Biomass	Wind	Solar	Ocean	Other	DK
Belgium	4	16	35	40	19	23	59	60	10	11	1
Cz. Rep	14	16	27	58	30	24	24	40	2	13	7
Denmark	6	26	43	10	9	41	77	46	27	2	2
Germany	11	13	28	32	26	31	44	59	8	13	6
Estonia	15	17	23	31	24	25	50	28	2	14	13
Greece	7	36	77	8	28	6	38	61	3	5	1
Spain	3	20	15	14	15	3	27	37	4	2	35
France	2	13	19	55	18	24	47	64	13	11	5
Ireland	10	20	27	17	19	16	61	39	17	7	16
Italy	7	22	29	26	23	11	21	39	9	9	21
Cyprus	4	34	30	7	23	7	41	78	9	11	11
Latvia	11	31	40	20	46	28	37	23	2	3	9
Lithuania	6	30	34	38	28	13	31	28	4	14	15
Luxembourg	4	21	35	37	11	30	39	59	4	13	7
Hungary	6	11	25	47	13	24	48	57	3	7	10
Malta	6	34	22	2	5	3	49	69	16	10	15
Netherlands	4	16	30	44	13	23	64	53	16	15	2
Austria	5	12	23	26	24	36	44	53	5	11	12
Poland	21	16	26	22	11	16	38	44	5	7	16
Portugal	4	20	29	13	31	5	32	30	13	4	30
Slovenia	3	13	27	23	35	42	29	48	5	15	7
Slovakia	7	18	35	46	41	37	23	38	3	10	7
Finland	3	19	24	69	33	45	29	32	6	16	3
Sweden	2	9	10	53	56	41	48	36	12	15	1
UK	9	23	29	48	21	9	45	46	20	8	9

percentage of those agreeing with the use of biofuels approaching 80%. The support was greatest in Denmark, Cyprus and The Netherlands and least in Luxembourg and Romania (Eurobarometer, 2009). A further survey was also conducted on attitudes to biofuels and when EU respondents were asked whether the use of biofuels should be encouraged, on average 72% approved and 20% disapproved. The results for individual countries are shown in Figure 6. The greatest support was from Slovakia, Latvia and Denmark. The least support came from Malta and from some countries outside the EU, namely Turkey and Switzerland. As there were some concerns that the production of biofuels was destroying tropical rainforests, the same question was asked with the additional proviso that the biofuel was obtained sustainably. The results are shown in Figure 7. The level of support in the EU as a whole has increased to 83% with only 10% opposing. There was nearly universal support in Denmark (96%) and Finland (95%). In all countries in the EU, support was greater than 70%. The clear exception was a country outside the EU, Turkey, where only 38% supported the use of sustainable biomass. It is evident that the issue of the sustainability of the fuel makes a material

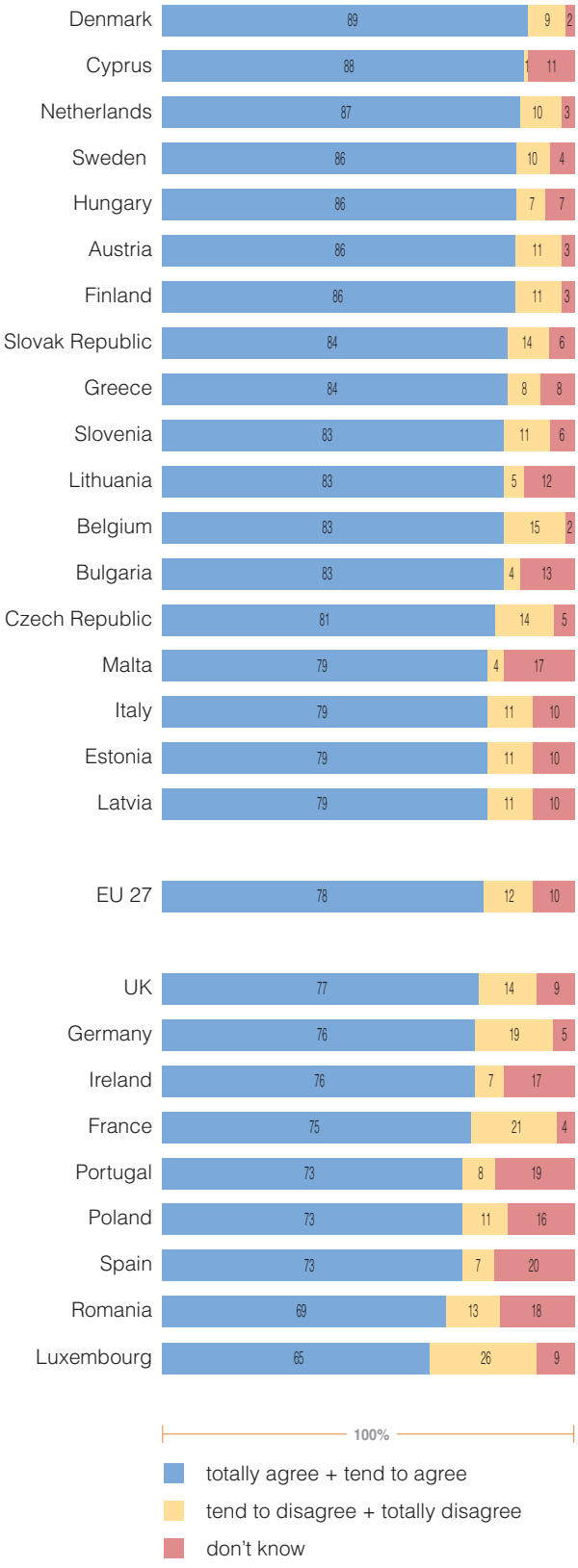

Figure 5 **EU attitudes to biofuels** (Eurobarometer, 2009)

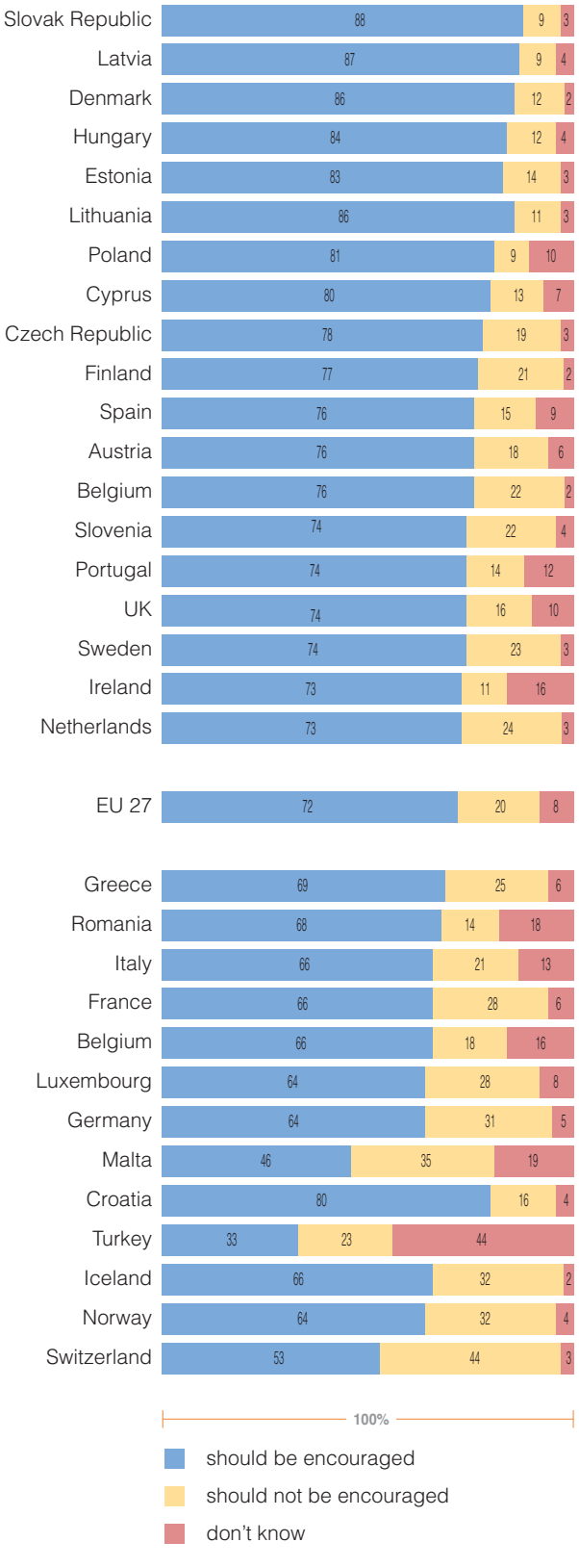

Figure 6 **EU attitudes for encouraging biofuels** (Eurobarometer, 2010)

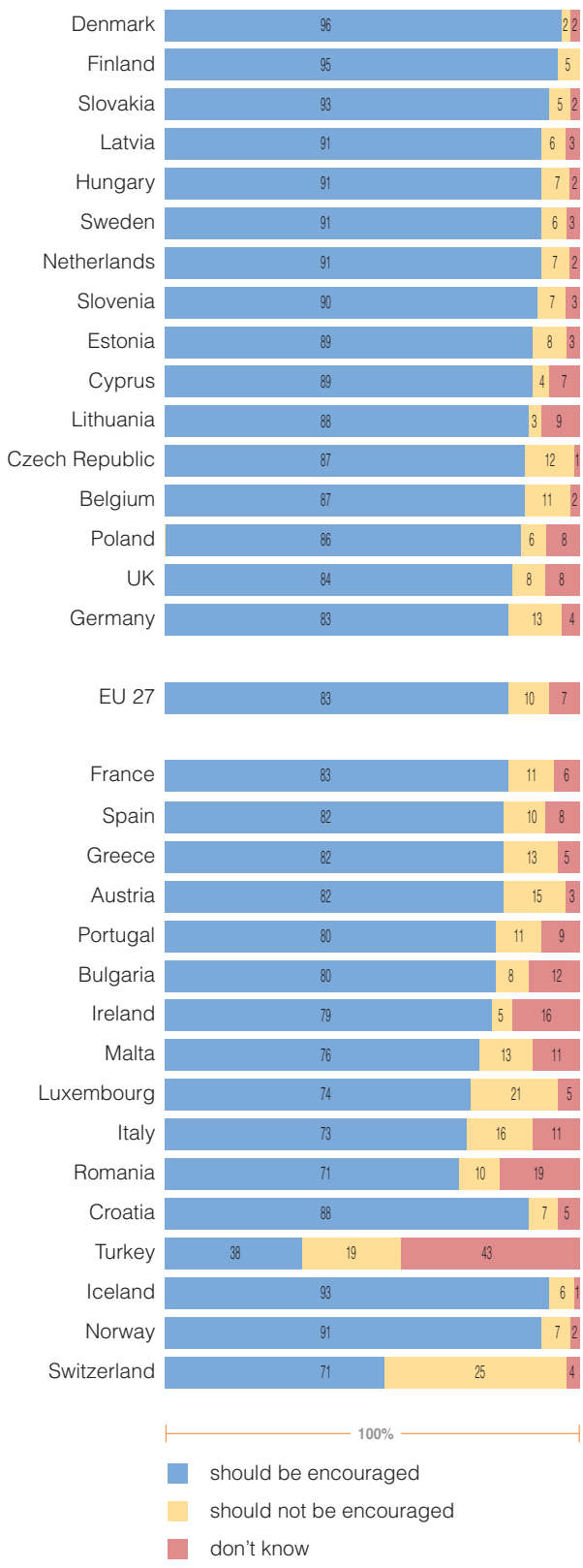

Figure 7 **EU attitudes for encouraging sustainable biofuels** (Eurobarometer, 2010)

difference to people's opinions on fuel use (Eurobarometer, 2010).

A survey has been conducted recently in 2011 by Eurobarometer on attitudes of respondents from twelve EU countries to CCS and to energy sources. The countries included were Germany, the UK, Italy, Spain, the Netherlands, Poland, Finland, France, Greece, the Czech Republic, Bulgaria and Romania. There are EU-funded CCS projects in six countries and other CCS projects in five others. Greece was additionally chosen due to its high dependence on domestic coal. The surveys involved at least 1000 respondents from each country. The respondents were asked to what extent they were in favour or opposed to a range of energy sources in their country. The results are shown in Figure 8. More than nine in ten (94%) were in favour of solar energy with nearly seven in ten (69%) being strongly in favour. Wind energy also had substantial support with 89% in favour and 60% strongly in favour. The next most popular was hydroelectric and over eight in ten (85%) favoured its use with over half strongly in favour. Surprisingly natural gas which is not renewable was ahead of biomass, which is. Eight out of ten were in favour of natural gas. There was a significant drop in support in the case of biomass with six out of ten (60%) in favour and 26% strongly so. A relatively large proportion of 29% admitted that they did not know that biomass was an energy source. This perhaps reflects the fact that the public are uncertain whether the use of biomass is renewable. There was less support for coal but the levels of those supporting (43%) and opposing (48%) were similar which is surprising given the opposition to coal use as a cause of global warming. Nuclear energy was least popular. If it is assumed that support for biomass cofiring is intermediate between the levels of support for coal and biomass, a majority is likely to be either strongly or fairly in favour. The attitudes towards the use of biomass for individual countries are given in Table 2. It was most favoured in Finland, the Netherlands and the Czech Republic. Biomass is utilised extensively in these countries especially in Finland. The countries least favouring biomass were Spain, Italy, the UK and Greece. These results confirm the pattern of other polls in that the use of biomass is

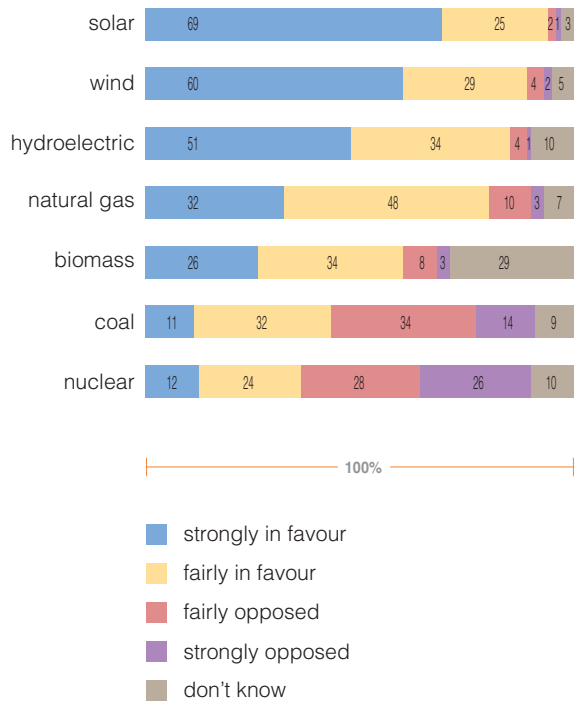

Figure 8 Recent EU attitudes to sources of energy (Eurobarometer, 2011)

generally favoured in countries in northern and central Europe and least favoured in the Mediterranean ones (Eurobarometer, 2011).

In a recent survey, Eurobarometer (2012) have addressed the views of EU citizens on their attitudes regarding EU support for increasing access to energy in the developing world. Several areas of concern were investigated but the question of most relevance for this report was their attitudes towards the sources of energy that should be prioritised. The 13,528 respondents in the 27 EU member states were given the choice of renewable energy (wind, hydro and solar), fossil energy (oil, gas and coal), biomass, no need to prioritise, other and don't know. It is interesting to note that biomass was not listed as a renewable source. The doubts expressed regarding the sustainability of bioenergy may have affected those who devised the questions. The answers are given in Table 3. There was considerable support averaging 77% for renewable energy. The support for fossil energy was 7% and nuclear 6%. The highest level of support for fossil energy was 14% from the UK. The level of support for biomass was least at 4%. The greatest support for biomass came form Slovenia (12%), Finland (10%) and Latvia (10%). These results would be troublesome for the proponents of bioenergy – firstly, as it was not considered a source of renewable energy by those who conducted the poll and secondly, as the level of support was so low, indeed even lower than for fossil fuels (Eurobarometer, 2012).

Table 2 Attitudes to biomass energy (Eurobarometer, 2011)

	Strongly in favour	Fairly in favour	Fairly opposed	Strongly opposed	Don't know	Total in favour	Total opposed
Belgium	39	25	6	2	28	64	8
Czech Republic	32	47	10	3	8	79	13
Germany	31	43	15	4	7	74	19
Greece	21	31	14	7	27	52	21
Spain	16	21	6	2	55	37	8
France	33	41	6	3	17	74	9
Italy	16	28	10	7	39	44	17
Netherlands	43	36	7	2	12	79	9
Poland	33	37	6	1	23	70	7
Romania	34	19	7	2	38	53	9
Finland	38	46	8	1	7	84	9
UK	16	30	5	2	47	46	7
EU total	26	34	8	3	29	60	11

Table 3 Attitudes to energy sources in developing world (Eurobarometer, 2012)

	Renewable (wind, hydro, solar)	Fossil (oil, gas, coal)	Nuclear	Biomass	None needs to be prioritised	Other	Don't know
EU 27	77	7	6	4	1	1	4
Belgium	78	6	3	9	1	0	3
Bulgaria	61	7	14	9	4	1	4
Czech Republic	67	10	14	4	1	1	3
Denmark	86	4	3	4	1	0	2
Germany	84	6	3	3	1	0	3
Estonia	65	7	8	5	2	1	12
Ireland	79	10	5	3	1	0	2
Greece	82	10	3	3	0	0	2
Spain	82	4	6	4	0	1	3
France	77	6	9	5	0	1	2
Italy	80	6	7	2	0	1	4
Cyprus	81	11	3	1	1	0	3
Latvia	72	9	6	9	1	1	2
Lithuania	63	11	6	10	1	2	7
Luxembourg	86	6	3	3	0	0	2
Hungary	79	9	3	5	0	0	4
Malta	86	7	0	3	0	1	3
Netherlands	83	4	3	6	1	0	3
Austria	85	3	1	9	1	1	0
Poland	73	8	11	5	0	0	3
Portugal	86	5	2	2	0	0	5
Romania	78	11	2	5	0	0	4
Slovenia	77	2	5	12	1	1	2
Slovakia	71	7	9	9	0	1	3
Finland	76	3	7	10	1	0	3
Sweden	78	4	9	4	0	1	4
UK	66	14	7	5	1	1	6

A small survey of a sample of about a hundred people interviewed by PDE (Projectbureau Duurzame Energie) did address cofiring directly. The survey first asked which technologies the respondents regarded as associated with renewable energy and the following replies were obtained: wind (60%), solar (22%), hydro (15%) and bioenergy (8%). There was clearly low awareness of bioenergy as being green. The same survey indicated that only 13% thought they were well informed about bioenergy. The survey then went on to ask which concepts associated with bioenergy the respondents considered to be green. The results are shown in Figure 9. Cofiring in coal-fired plant was least popular with half

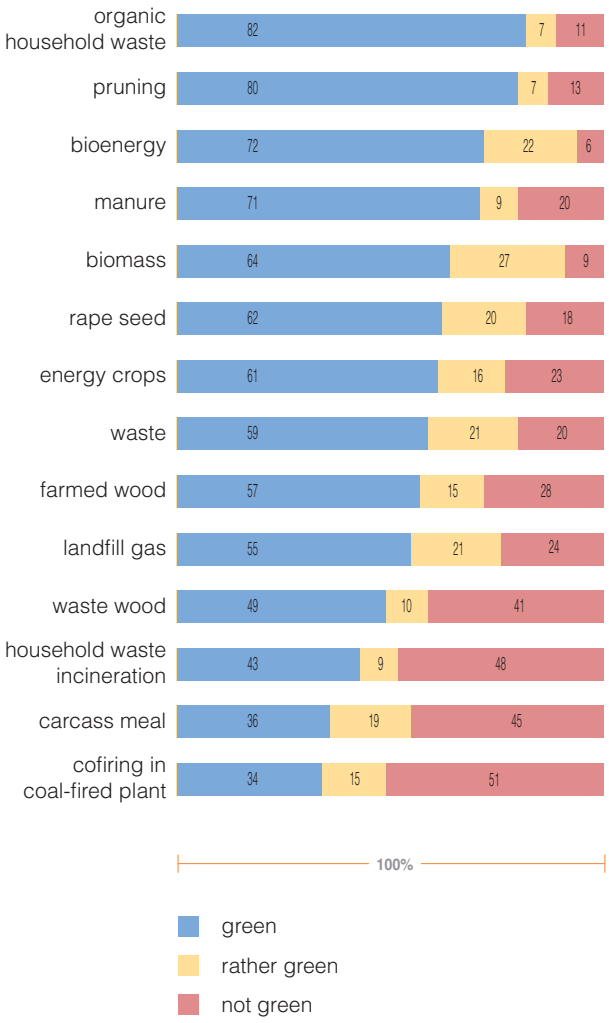

Figure 9 Dutch attitudes to bioenergy
(Rohracher and others, 2004)

the respondents regarding it as not even green and only 30% thinking so. Cofiring was even less popular than waste incineration. Too much must not be read into the results of such a small survey but given the extensive amount of biomass cofiring that takes place in the Netherlands, it is surprising that the public were not aware of its potential benefits (Rohracher and others, 2004).

The surveys of attitudes to energy sources in Europe have shown that there is considerable support for the use of renewable energy especially solar, wind and hydro. There is a moderate level of support for bioenergy and the use of natural gas. There is least support for oil, coal and nuclear. The greatest support for bioenergy was in northern and central Europe where there are extensive forests and the populace are used to timber being managed sustainably as an energy source. The least support for biomass was in Mediterranean countries. The one survey which included attitudes to cofiring in coal-fired plant yielded a very negative response.

4 UK attitudes

Several surveys have been conducted in recent years in the UK into the public's attitudes towards renewable energy. Some have included attitudes to bioenergy but none has specifically mentioned cofiring. In 2003, the Department of Trade and Industry in conjunction with their counterparts in Scotland, Wales and Northern Ireland commissioned a survey of public attitudes to renewable energy. A total of 1279 respondents were interviewed in Great Britain and Northern Ireland. Within this sample 318 were aware that they lived near a renewable energy site. These were considered as being an informed sample. To determine the initial awareness of renewable energy, respondents were asked which ways of producing electricity they knew of. The results are shown in Figure 10 which shows that a large proportion (over 75%) had heard of renewable energy and an even larger proportion (90%) among the informed sample. The source with the greatest public awareness was wind and the one with the least was biomass. Only 7% of the general public mentioned biomass spontaneously and even in the informed sample the figure mentioning biomass was 18%. The respondents who claimed to be aware of each renewable technology were then asked how much they knew about the technology and the way it is used to produce electricity. The responses which are shown in Figure 11 indicate that for solar, hydro and wind, the majority knows at least something but over three-quarters said they were not aware of biomass as an energy source. The survey then addressed the general public's overall opinion of renewable energy sources which resulted in the opinions shown in Figure 12. A substantial proportion considered solar, wind and hydro to be a good idea. The proportion favouring biomass was much smaller but was nevertheless a majority. The value for average opinion was plotted against average knowledge (Figure 13) and this demonstrates a direct correlation – the higher the knowledge of a technology, the higher the opinion of it. This may suggest that if the public were better informed about bioenergy, their opinion of it may be higher. This survey was undertaken in 2003 and as there has been more coverage of bioenergy in the media since then, it is likely that public awareness of biomass is higher today (TNS, 2003).

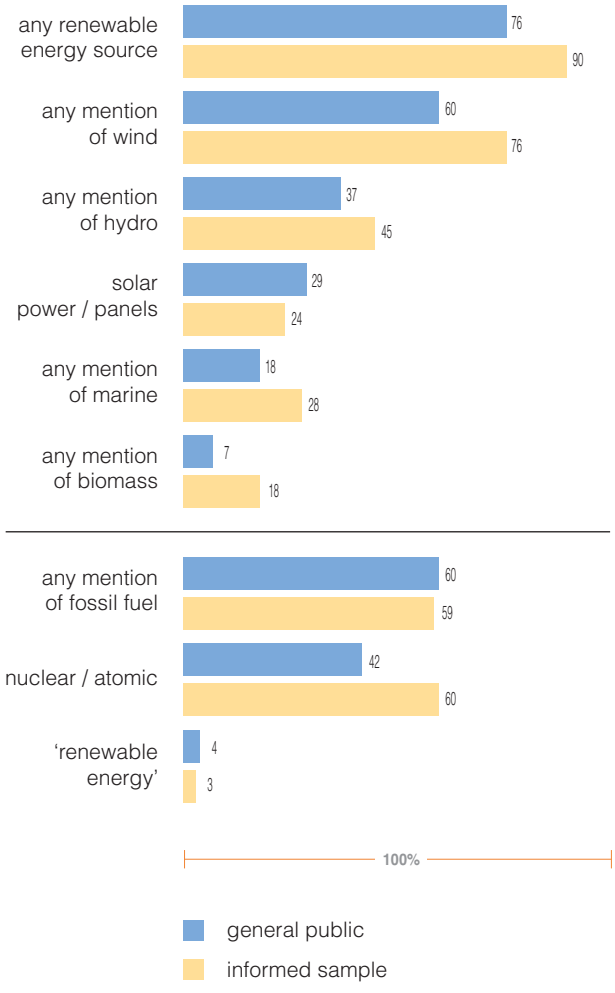

Figure 10 UK awareness of energy sources (TNS, 2003)

A more recent opinion survey was conducted in 2010 of the UK public's attitudes towards climate change and the future of energy production. The survey was conducted by Ipsos MORI and 1822 face-to-face interviews were conducted with the public in England, Scotland and Wales between 6 January and 26 March 2010. A similar survey had been conducted in 2005. The respondents were asked how favourably or unfavourably were their opinions of particular sources of energy for electricity production. The results for both 2010 and 2005 are given in Table 4. The results show that solar, wind and hydroelectric power had substantial levels of support in both 2005 and 2010. Approaching 90% of respondents considered solar power either very

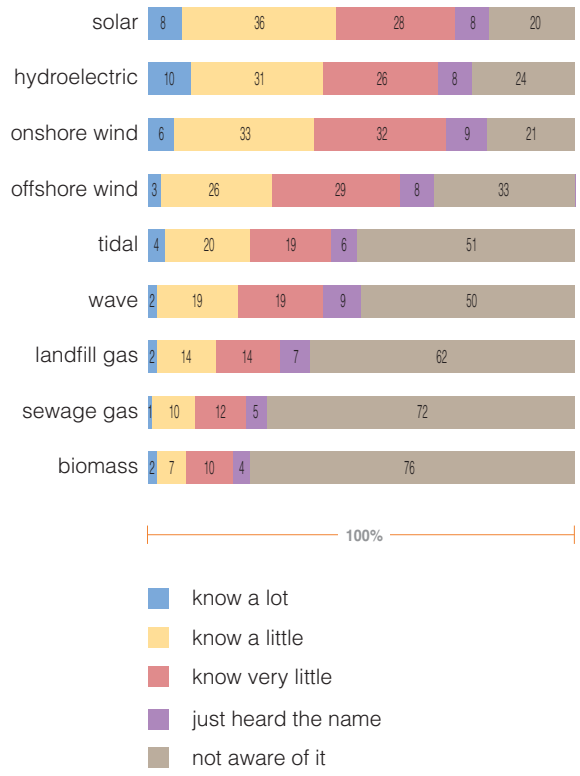

Figure 11 UK knowledge of energy sources (TNS, 2003)

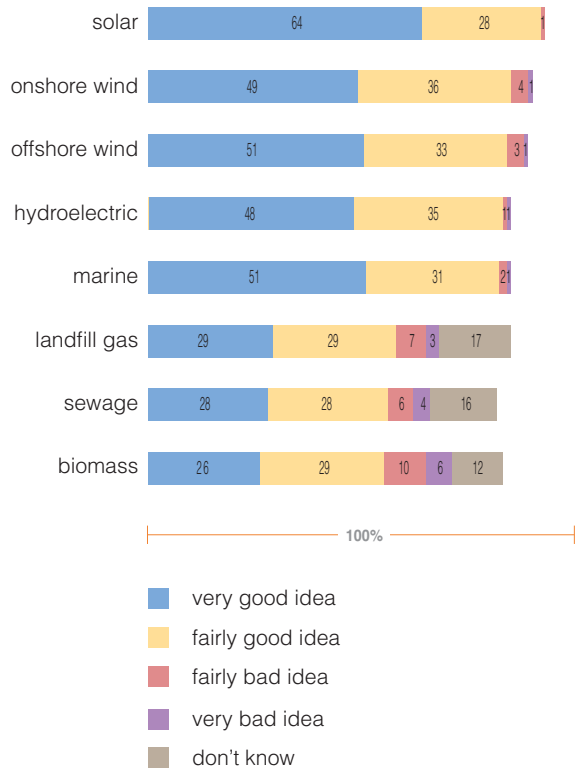

Figure 12 UK opinions on energy sources (TNS, 2003)

favourably or mainly favourably. The support for wind power exceeded 80% and that for hydro power was close to 80%. The proportion viewing these sources unfavourably was less than 10%. Bioenergy and gas power were the next most popular choices. Bioenergy was favoured by 58% of the respondents in 2010 which was somewhat greater than 54% who supported it in 2005. The level of support for gas was very similar at 55–56% in the two polls. The proportions viewing these two sources unfavourably were significantly different. In the case of bioenergy 15 % considered the energy sources unfavourably in 2010 and 8% in 2005. In the case of gas the respective figures were 22% and 18%. The proportions of respondents who had never heard of biomass, which were 7% and 10%, were very much higher than for the other energy sources. Coal and oil were the least popular sources of energy with the proportions favouring and disfavouring in the 30–40% range. It is evident that bioenergy was significantly less supported than the other renewable energy sources such as solar, wind and hydro. The level of support for bioenergy was similar to natural gas but it had a lower proportion opposing it. There was a significant proportion of the respondents who had never heard of bioenergy and this may suggest that if more information about bioenergy were given to the public, the level of support might increase (Spence and others, 2010).

Another 2005 survey also asked the respondents which sources of energy they thought would make a substantial contribution to reliable and secure supplies of electricity for Britain in the future. The results are given in Table 5. Substantial majorities thought that solar (78%), wind (78%) and hydro (69%) would make a substantial contribution. Only 10% or less thought these sources would not make a substantial contribution. About half of those sampled thought that gas (50%) and nuclear (48%) would do so. In the case of bioenergy, 43% thought it would make a contribution, 16% thought it would not but a surprisingly large 19% had never heard of bioenergy or had no opinion of it. A smaller proportion of 39% thought oil would make a contribution and coal was the least favoured with only 33% thinking it would make a contribution. The results demonstrated that a

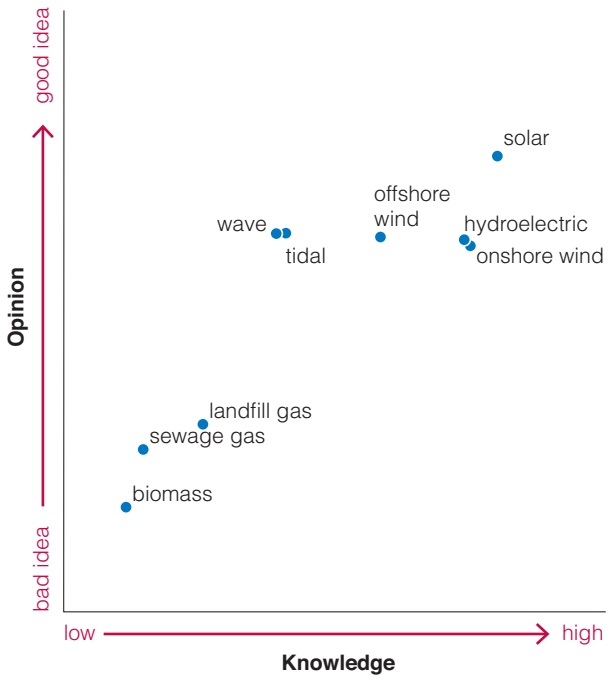

Figure 13 Correlation of knowledge and opinions of energy sources (TNS, 2003)

substantially greater proportion of the respondents thought that solar, wind and hydropower would constitute Britain's energy sources for the future rather than biomass. A significantly greater proportion considered that nuclear and gas would be part of the energy mix than bioenergy. This survey also confirmed the lack of awareness of biomass amongst the public (Poortinga and others, 2006). Similar results were obtained in a survey conducted by MORI for the Nuclear Industry Association. A representative sample of 2035 adults was questioned in November 2005 on their attitudes to nuclear energy and related issues. One question was 'Which of these energy sources do you think can do most to help ensure we have reliable and secure supplies of energy in the future'. The results obtained were: wind (54%), solar (52%), nuclear (33%), wave (32%), gas (23%), biomass (11%), oil (10%) and coal (8%). Wind and solar are clearly most favoured. Nuclear and wave were next most popular with similar levels of support. Natural gas was next with reasonable support. The least popular with similar levels of support in descending order were biomass, oil and coal. Energy from biomass is far less popular than wind, solar, nuclear and wave, significantly less popular than gas and only slightly more popular than oil and coal (MORI, 2005).

Another survey was conducted around this time of attitudes in the UK towards energy and the environment. It was initiated by the Laboratory for Energy and the Environment at the Massachusetts Institute of Technology in conjunction with the Judge Institute of Management at the University of Cambridge. The survey was conducted by YouGov and involved 1056 participants. The respondents were given a series of technologies to mitigate global warming and asked which they would use. The results are given in Table 6. These show that the use of energy efficient appliances, solar and wind

Table 4 UK attitudes towards energy sources (Spence and others, 2010)

	Very favourable	Mainly favourable	Neutral	Mainly unfavourable	Very unfavourable	Never heard of it	Don't know
Biomass	24 (18)	34 (36)	19 (17)	9 (6)	5 (2)	7 (10)	3 (9)
Coal	9 (7)	27 (31)	19 (24)	30 (25)	13 (8)	–	2 (3)
Gas	14 (10)	42 (45)	20 (21)	18 (14)	4 (4)	–	2 (3)
Hydro	39 (36)	37 (40)	13 (11)	3 (2)	1 (1)	5 (3)	3 (7)
Nuclear	10 (9)	24 (27)	20 (22)	21 (20)	20 (17)	1 (1)	3 (6)
Oil	5 (6)	27 (33)	26 (22)	28 (25)	10 (8)	1	2 (4)
Solar	56 (55)	32 (32)	6 (6)	3 (2)	1 (1)	–	1 (2)
Wind	49 (50)	33 (31)	9 (8)	5 (5)	3 (2)	1	1 (2)

Figures are from 2010 and (2005)

Table 5 UK attitudes toward future energy sources (Poortinga and others, 2006)

	Strongly agree, %	Tend to agree, %	Neutral, %	Tend to disagree, %	Strongly disagree, %	Never heard of it, %	Don't know, %
Biomass	11	32	20	13	3	8	11
Coal	6	27	18	35	9	0	4
Gas	8	42	18	24	4	0	4
Hydro	25	44	13	7	1	2	6
Nuclear	13	35	20	17	9	–	5
Oil	6	33	20	29	7	–	4
Solar	40	38	9	7	1	0	3
Wind	41	37	8	8	2	–	3

Table 6 UK attitudes towards technologies to combat global warming (Curry and others, 2005)

	Definitely use, %	Probably use, %	Possibly not use, %	Definitely not use, %	Not use, %
Bioenergy	39	29	4	0	27
Carbon sequestration	51	24	2	1	22
Carbon capture and storage	10	19	14	7	50
Iron fertilisation	8	12	16	11	52
Energy efficient appliances	72	18	0	0	10
Energy efficient cars	71	19	0	0	9
Nuclear energy	16	17	15	19	33
Solar energy	72	17	2	1	8
Wind energy	62	19	5	2	12

power have substantial levels of support with only a small percentage opposing. Carbon sequestration, which is the use of trees to absorb carbon and the use of bioenergy also had a large measure of support with the former supported by 75% and the latter by 68%. Both these technologies also had only small percentages opposing. However, about a quarter of those sampled were unsure of these two technologies. Nuclear energy was far less popular with about a third supporting and opposing. The most unpopular technologies were iron fertilisation of oceans and carbon capture and storage (Curry and others, 2005).

Whitmarsh and others (2011) have assessed public attitudes, understanding and engagement in relation to low-carbon energy in the UK by reviewing academic and non-academic literature. They considered large-scale wind energy, bioenergy and biofuels, tidal and wave energy, geothermal energy, micro-generation and energy from waste. In the case of bioenergy and biofuels they concluded that bioenergy remained one of the least familiar renewable energy technologies to the UK public, despite biomass combustion being an ancient technology, but awareness was increasing. About half the UK had positive views of bioenergy but this level of support was among the lowest in Europe. They also described reactions of the public to local bioenergy projects. For example, Upham and Shackley

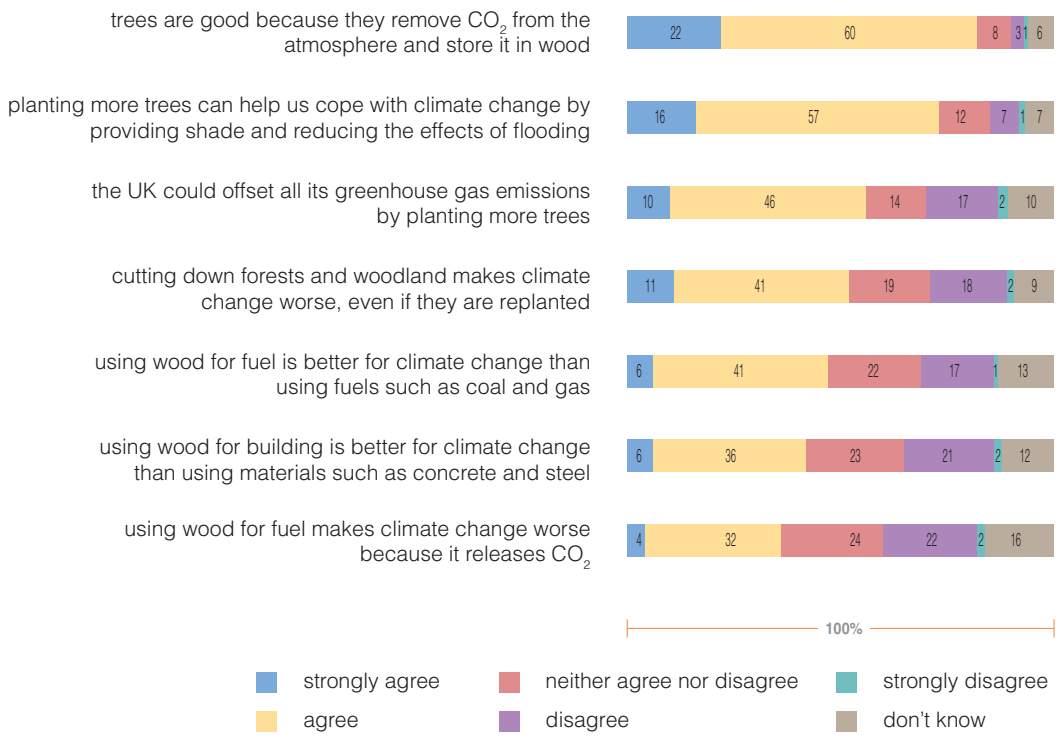

Figure 14 UK public opinions of forestry (Forestry Commission, 2011)

(2007) found very negative attitudes to the siting of a large-scale biomass gasifier in Devon, UK. Local residents living close to the proposed plant expressed a wide range of objections including lorry traffic congestion, air pollution, the credibility of the developer, odour and the appearance of the plant. Further concerns related to fuel waste, technological reliability, landscape changes and the effect on house prices. Some did consider that the development afforded benefits such as economic development, employment and reduction of greenhouse gases. A follow-up survey (Upham, 2009) showed that the level of concern remained high up to the final withdrawal of the planning application and the number of people viewing benefits of the project decreased substantially after planning permission was refused. These findings show that there is great potential for local opposition to the siting of relatively large bioenergy plant. The local view is that there is little to gain for the community but much to lose. Furthermore, trust in developers and district councils has been found to be low regarding such developments.

In an earlier survey, Upham and others (2007) reviewed the published literature on public perceptions of bioenergy in the UK. They concluded that the public had a lower level of familiarity with, and understanding of, bioenergy compared with wind and solar technologies. The public has a tendency to doubt its environmental sustainability and to associate it with incineration, which has frequently been a target for public opposition. The study of individual bioenergy projects suggested that public concerns relate to haulage traffic, waste emissions from the plant and its physical intrusion and appearance. In sensitive landscapes, there may be concerns about the appearance and ecological impacts of the energy crops. There may be doubts about the carbon balance of bioenergy, particularly where transport distances are perceived to be substantial. There is more support where the biomass is cultivated for local small-to-medium thermal or CHP projects than for centralised electricity generation. Bioenergy developments are more controversial when they are relatively large in scale and when the affected public are neither involved at an early stage nor direct recipients of any associated benefits. Conversely, where the affected public has some influence over the proposed development, where there would be substantial local benefits or where the development is of a small or moderate scale, opposition is less likely.

Table 7 UK attitudes to future sources of electricity (Populus, 2011)

	Level of support, %
Solar	25
Wind	20
Nuclear	19
Tidal/Wave	15
Hydro	8
Gas	4
Geothermal	3
Oil	2
Biomass	2
Coal	2
Other	1

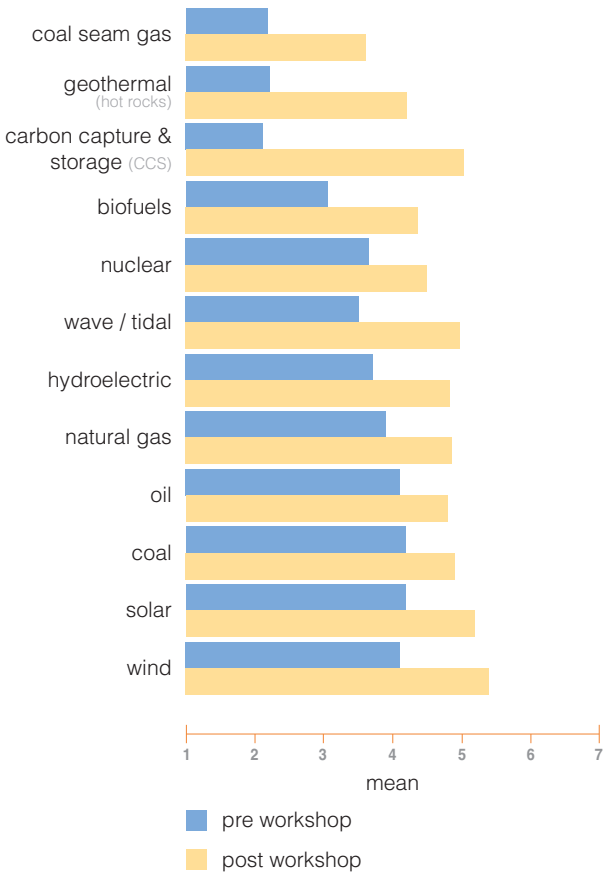

Figure 15 Scottish knowledge of energy sources (Howell and others, 2012)

The forestry commission in the UK has investigated public attitudes towards the effect of climate change on forestry and the use of wood from forests for energy production. The survey interviewed 2068 members of the public. The respondents were presented with several statements about the impact of climate change on forestry and the responses are given in Figure 14. A slight majority (52%) thought that cutting down forests and woodland makes climate change worse, even if they are replanted. Only 20% disagreed with this statement. Given such views, it is not surprising that the public are equivocal about bioenergy. Indeed, not even a majority (47%) thought that using wood for fuel is better for climate change than using fuels such as coal and gas. A relatively high 22% were uncertain and 18% disagreed with the proposition. Over a third (37%) thought that using wood for fuel makes climate change worse because it releases carbon dioxide. Only 24% thought that using wood for fuel was better for climate change. A majority (56%) were in favour of carbon sequestration namely that the UK could offset its greenhouse gas emissions by planting more trees. The UK public clearly are not convinced that wood fuel can be produced in a sustainable manner to produce a fuel that can reduce net greenhouse gas emissions (Forestry Commission, 2011).

The lack of confidence among the British public regarding biomass as a potential source of renewable energy has been confirmed by the results of a poll conducted by Populus for the British Science Festival in 2011. The survey questioned 2050 people between 26 and 29 August. The main purpose of the survey was to determine the public's acceptance of nuclear power but the respondents were initially asked about their attitudes towards several sources of energy including biomass. In reply to the question 'Which of the following would you like the UK to invest the most in for our electricity needs' the answers in Table 7 were obtained. Significant levels of support were given for solar (25%), wind (20%), nuclear (19%) and tidal (15%). The level of support for biomass was 2%, on a par with oil and coal and half the support for gas (Populus, 2011).

In September 2011 a workshop was held in Edinburgh, Scotland to investigate Scottish citizens'

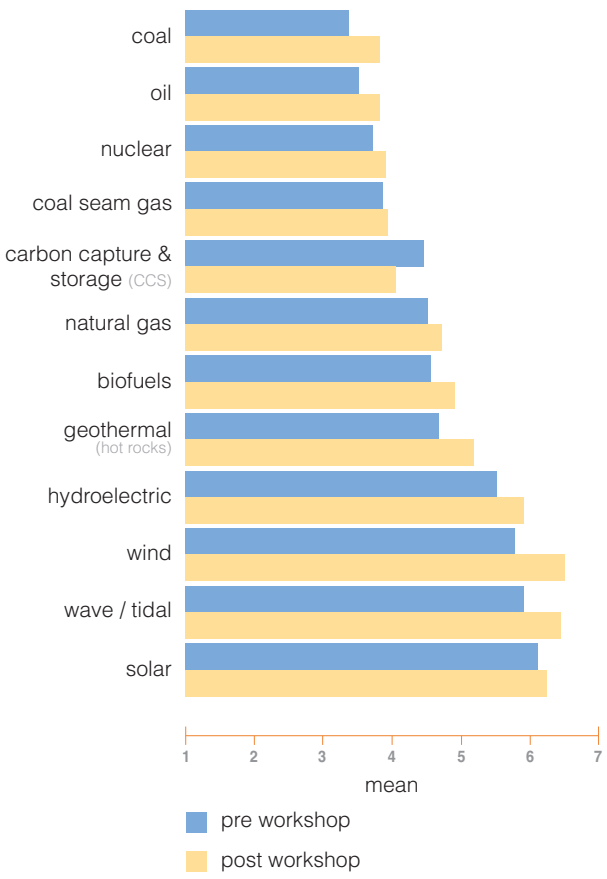

Figure 16 Scottish attitudes towards energy sources (Howell and others, 2012)

perspectives on climate change and low carbon technologies. Though the focus was on CCS, the respondents were also asked about bioenergy. The workshop consisted of 99 participants recruited to form a representative sample of the local population. At the start, middle and end of the workshop the participants completed a questionnaire on their knowledge and attitudes towards climate change and energy technologies. During the workshop, two Scottish experts presented objective and unbiased information about the issues. They were asked to rate their knowledge of the technologies both before and after the workshop and the replies are shown in Figure 15. The participants' self-rated, initial, knowledge was highest for solar, wind, coal, oil and natural gas. In the range no knowledge (1), moderate knowledge (4) and high knowledge (7), the value for bioenergy was 3.02 (pre) and 4.36 (post). The level of knowledge of bioenergy was relatively low before the workshop but increased significantly during it. The respondents were also asked about their attitudes toward the energy sources. These varied widely, as shown in Figure 16, with the most favoured being solar, wind and tidal and the least favoured being coal and oil. The support for bioenergy was intermediate between geothermal and natural gas. The proportion of participants supporting bioenergy increased from 41% to 67%, while the proportion that was unsure decreased from 44% to 20%. The participants clearly became more favourably disposed towards the technology following the limited expert information provided during the workshop (Howell and others, 2012).

The opinion surveys in the UK have mirrored those in Europe and shown that renewable sources such as solar, wind and hydro have substantial levels of support. There is moderate support for bioenergy which is either slightly more or slightly less than for natural gas with the least favoured technologies being coal, oil and nuclear. Some surveys have indicated a low level of knowledge of biomass as an energy source and some scepticism as to whether bioenergy can be sustainable. Opposition to bioenergy projects from the local population is greater for larger-scale projects and is generally because of local factors. Opposition can be reduced by involving the public at an early stage and making them aware of local benefits.

5 US attitudes

Biomass cofiring is a proven technology in the USA. Several power plants have commercially cofired biomass for several years and there have been many demonstration projects at others. There were many successful field trials at utility installations in the late 1980s and through the 1990s. Currently cofiring is limited to a few dozen plant, many of which use waste biomass from industrial and agricultural production facilities to generate power for these facilities, rather than for other customers. Neither bioenergy nor cofiring is sufficiently in the public consciousness to be included in major opinion surveys on energy sources. One of the few opinion surveys in the USA which included bioenergy was that conducted by MIT (Massachusetts Institute of Technology) and the University of Cambridge (UK) in 2003 on American attitudes towards climate change mitigation. The survey questioned 1205 people representing the general population. The respondents were asked whether they were familiar with the specific technologies and energy sources which have been proposed to address climate change. The responses in Table 8 were obtained. Only 10% of those sampled were familiar with the terms bioenergy/biomass which was considerably lower than the majorities who were familiar with more efficient cars, solar energy and nuclear energy. About half of those sampled were familiar with wind, more efficient appliances and hydrogen cars. There was even less awareness of carbon capture and storage, carbon sequestration and iron fertilisation. Later in the survey the respondents were given several technologies to address global

Table 8 US Public familiarity with energy sources (Curry, 2004)

	Heard of or read about, %
More efficient cars	70
Solar	64
Nuclear	54
Wind	50
Energy efficient appliances	49
Hydrogen cars	48
Bioenergy	10
Carbon capture and storage	4
Carbon sequestration	3
Iron fertilisation	2
None of these	17

Table 9 US public technology preferences (Curry, 2004)

	Definitely/probably use, %	Definitely/probably not use, %	Not sure, %
Solar	82	3	15
Energy efficient appliances	81	4	15
Energy efficient cars	81	4	16
Wind	76	6	18
Carbon sequestration	67	9	24
Bioenergy	59	10	30
Nuclear	38	34	28
Carbon capture and storage	29	33	38
Iron fertilisation	20	36	44

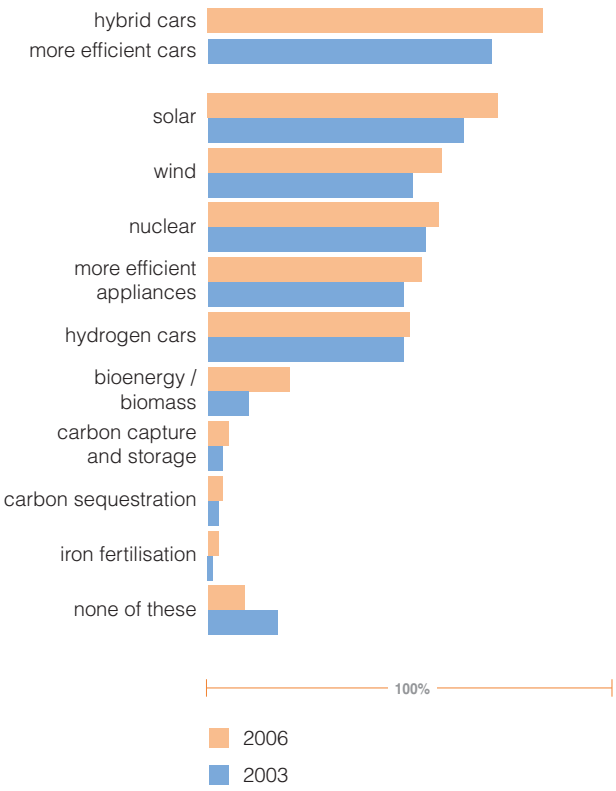

Figure 17 US public knowledge of CO_2 removal technologies (Curry and others, 2007)

warming and they were asked which they would use. The results are given in Table 9. In answer to this question, nearly 60% said they would definitely or probably use bioenergy and only 10% said they would not. A relatively high 30% were not sure. This level of support is surprising given that in the earlier question only 10% said they were familiar with bioenergy. It is possible that the greater extent of support was as the term bioenergy was explained for this question. The support for bioenergy was slightly less than for carbon sequestration and substantially less than for solar, energy efficiency and wind. Bioenergy was, however, more popular than nuclear, CCS and iron fertilisation (Curry, 2004). The same group surveyed public attitudes towards climate change and climate change mitigation technologies in the USA in 2006. In this survey responses from 1236 panellists representative of the general population were obtained. The responses to the question whether they had heard of the various technologies to combat climate change are shown in Figure 17. This figure also compares the answers from the earlier survey. The public's awareness of all technologies increased between 2003 and 2006. In the case of bioenergy, the proportion who had read or heard about the technology increased from 10% to 20% over this period. However, the public's awareness of bioenergy remained considerably lower than for hybrid cars, solar, wind or nuclear. Unfortunately, the later survey did not question the respondents as to whether they would use these technologies (Curry and others, 2007).

A more detailed survey has been conducted of public perceptions of using woody biomass as a renewable energy source (Monroe and others, 2007; Plate and others, 2010). A postal survey was conducted in Alachua County, Gainesville, Florida, which is a promising and suitable county for wood-to-energy facilities as the area has a growing energy demand and ample wood resources. The survey was conducted in September 2006 and 298 responses were received. Though the possibility of a wood-fuelled power plant had been under discussion since 2003, only 18% were aware of these discussions. When asked about their knowledge of converting wood to electricity, less than 5% considered themselves to be 'knowledgeable' and over half (54.5%) admitted that they were 'not at all knowledgeable' about the topic. Regarding their feelings about the power plant, 31.6% expressed negative or highly negative feelings and 27.1% expressed positive or highly positive feelings. Nearly half (42.1%) were neutral. When asked to articulate their feelings, more were curious, interested and sceptical than fearful. The survey also sought opinions on potential sources of wood and a large majority (71%) were supportive of using waste wood. A smaller majority (61%) were supportive of using energy crops. Their concerns in decreasing order of importance were loss of wood, air pollution, cost, traffic, competition for wood and noise. The possible benefits that were identified, again in decreasing order of importance, were using waste wood, maintaining local forests, reducing greenhouse gases, local economy, jobs and market for wood. The respondents shared some common misconceptions. They overestimated the potential for solar energy to meet the rising demand for energy. Nearly half (44%) considered that solar energy was a feasible choice compared with only 18% having any confidence in wood, despite solar energy's lack of competitiveness. They also overestimated the capacity of future (as yet unidentified) technological advances to meet US energy

Table 10 Comparison of wood with other fuels (Plate and others, 2010)

	Coal, %	Natural gas, %
Wood is better	18.8	11.6
About the same	30.7	24.2
Wood is worse	6.5	23.1

needs. There were also misconceptions regarding the sustainability of bioenergy. The respondents understood that burning fossil fuels represents a source of atmospheric CO_2. They did not realise that using wood provides a CO_2 sink if the forest growth rate is high enough to match the harvesting rate. When comparing wood with coal and natural gas, only a small fraction of respondents seemed to understand the advantages wood has in the context of climate change as shown in Table 10. A small minority in the case of coal and a significant minority in the case of gas thought that wood was worse. The degree of public trust in those proposing and opposing bioenergy developments also affects the level of public support. The results of this survey indicated that those sampled had more trust in local foresters and environmental NGOs than in private industry and chamber of commerce. The community showed a relatively high interest in participating in wood-to-energy developments with a majority thinking both that the community should be influential in a proposed project and interested in participating in the decision-making process.

Overall, the survey showed that there was a lack of knowledge about energy in general and using wood for energy in particular. Public education and outreach were regarded as essential prior to meaningful discussions about a project. The outreach effort should provide basic information from trusted sources, additional technical information about options and choices in comparison and in context, opportunities for questions and discussion and should allow a variety of perceptions to be voiced without judgment. Anecdotal evidence suggests that people who are initially fearful of wood for energy believe that the practice will destroy forests. If they are presented with data on timber harvest rates and wood production rates, these concerns can be assuaged (Monroe and others, 2007; Plate and others, 2010).

Dwivedi and Alavalapati (2009) analysed the perceptions of four stakeholder groups towards forest biomass-based bioenergy developments in the southern USA. The groups were NGOs, government, industry and academia. The method of analysis was the SWOT (Strength, Weakness, Opportunities, Threats) framework with AHP (Analytical Hierarchy Process). The questionnaire was administered to about 10–20 members of each of the four stakeholder groups and the responses in each group were combined to obtain the geometric mean. On average, the overall perception of bioenergy by all the groups was characterised by strengths (35%) and opportunities (30%) followed by weaknesses (22%) and threats (13%). The three strength factors given the highest preference by all groups were: promotes energy security, sufficient forest biomass availability and less or no competition with food production. It was noted that the factor 'reduces greenhouse emissions' was not a high priority for any of the groups. Regarding weaknesses, all the groups gave highest priority to 'conversion technologies are still under trial'. All the groups recognised government support as one among their top preferences within the opportunity category. Overall, all the stakeholders were in favour of forest biomass-based bioenergy development in the southern USA.

Biomass cofiring activity in coal-fired plant is limited currently in the USA and neither cofiring nor bioenergy are considered to be sufficiently important to be included in the many opinion surveys conducted in the USA on the public's attitudes to energy sources. The few that have included bioenergy have indicated that support for bioenergy was considerably less than for solar, hydro and wind. There is also a lack of knowledge about bioenergy and doubts about its sustainability.

6 Organisations sceptical of biomass cofiring

This chapter describes information freely available to the public from organisations sceptical of biomass cofiring.

6.1 Greenpeace

Greenpeace have campaigned for a cleaner environment for many decades and they believe that bioenergy can be part of the solution to combat climate change. However, it is not a silver bullet for unsustainable energy usage and must be used in conjunction with other measures to reduce energy consumption and increase energy efficiency. They support the use of biomass produced in a sustainable way for decentralised stationary heat and electricity generation such as cogeneration and biogas. They have suggested certain criteria, applicable globally, against which bioenergy projects should be assessed. The bioenergy production technologies must be analysed from a complete life cycle perspective to ensure that:

(i) Bioenergy is used in conjunction with other measures to reduce GHG (greenhouse gas) emissions such as reducing energy consumption and increasing energy efficiency.
(ii) The energy balance of a project must be substantially positive. Namely the end product must generate considerably more energy than is required for its production. The project must have a GHG balance of at least 60% and the calculation must include the whole production chain.
(iii) Bioenergy maximises the reduction of GHG emissions in a way that is effective in combating climate change.
(iv) The biomass from natural ecosystems is sustainably harvested. It must be sourced in an environmentally responsible and socially just manner.
(v) Social conflicts should be avoided, in particular, those caused by trade. Production and use of bioenergy should not widen social inequalities, especially between the developed and developing countries. Local needs must take priority over global trade.
(vi) The biomass must be cultivated within the framework of sustainable agriculture.

Greenpeace have a sustainable agriculture framework for the cultivation of bioenergy crops. This requires that the biomass production must not cause direct or indirect destruction of ecosystems. Crops and plantations for bioenergy must promote biodiversity. It must not impair food security or sovereignty. Bioenergy technologies must not release genetically engineered organisms to the environment. Biomass cultivation must minimise the use of agrochemicals such as synthetic fertilisers, pesticides and herbicides. It should not introduce invasive species and it must promote water conservation and soil fertility.

The use of biomass such as firewood and dung is a traditional source of energy in developing nations and is not the focus of Greenpeace's attention. Greenpeace accept that the use of ligno-celluosic or oil-rich biomass to generate electricity or heat in industrial countries is more efficient than the production of biofuels and achieves significant greenhouse gas reductions. The main issue with these projects is the availability of the raw material. Wood pellets are already becoming a major source of biomass in Europe and North America. This could lead to unsustainable wood production and the conversion of forests into plantations if sustainable criteria are not introduced quickly. At present Greenpeace do not consider that sufficient standards are in place to ensure that palm oil producers are not contributing to GHG emissions from deforestation or peatland clearance. Greenpeace are opposed to the incineration of municipal waste to produce energy (Richert, 2008; Cotter and Tirado, 2006).

Greenpeace are particularly concerned about the opening of public forests for large-scale extraction of forest biomass for energy production in Canada. They have produced a report *Fuelling a Biomess* in which they claim that burning trees for energy will harm people, the climate and forests. They accept

that specific sources of biomass for energy can be beneficial for the environment but only following strong environmental guidelines. In the case of forest biomass, processing residues from sawmills, pulp and paper plants and discarded wood products are the only feedstocks that should be used for energy production. The present trend to source directly from natural forests is not justified. In Canada, traditionally mill and pulp plant leftovers have been burnt for heat or electricity production. However, the current slump in the forest industry sector has resulted in a sharp decline in mill residue production. In an attempt to diversify the forest industry portfolio, many Canadian provinces are implementing new biomass sourcing policies in public forests. This switch from wood-manufacturing based energy production represents a drastic shift in the way forests are used in Canada, and is rapidly evolving into a destructive, industrial-scale practice. In 2010, Canada was the fourth largest wood pellet producer after the USA, Germany and Sweden and the second largest exporter. Exports to Europe have increased by 700% in less than eight years. This bioenergy boom continues even though Life Cycle analyses have demonstrated that 40% of the pellets' energy is expended during transformation and transportation before reaching cofiring or biomass only plant in Europe.

The report also states that woody biomass is key to maintaining soil fertility, forest productivity and biodiversity. Forest ecologists and environmentalists have demonstrated the key role forests play in regulating hydrological cycles, preserving diversity and sequestering carbon. They challenge the key assertion that burning biomass is good for the environment because it is carbon neutral. In fact, burning wood emits considerable quantities of CO_2. In the USA, some biomass facilities have been shown to emit up to 150% more CO_2 than they would if burning coal and up to 400% more CO_2 than if burning natural gas. Even CHP plant where biomass-generated heat replaces coal, the carbon emissions can be 200% greater than electricity and heat produced from natural gas. Governments and biomass advocates argue that burning wood is 'carbon neutral' because trees will grow back and eventually recapture the CO_2 emitted during combustion. This fails to account for CO_2 emissions from forest bioenergy production. Furthermore the 'carbon neutral' assumption contains an accounting error as it takes many decades and even centuries before forests regenerate and recapture the CO_2 that is released immediately upon combustion. The unintended emissions from harvesting forest biomass, which can result from erosion and accelerated decomposition, further deplete forest carbon stocks while nutrient and carbon loss slows regeneration. Normally, carbon in forest biomass stays intact within the forests for decades, even when decomposing. Much of it is recycled in the soil, enabling the next generation of trees to better capture carbon from the atmosphere while the rest is released very slowly. It should also be noted that large amounts of energy are needed to extract, transform, dry and transport the biomass, thus adding to the overall climate footprint of woody bioenergy.

Boreal forests, which cover over half of Canada's land area, already play an invaluable role in minimising climate change by capturing and storing considerable quantities of carbon. Biomass extracted from this carbon storehouse is one of the worst possible biomass feedstocks. The low productivity and slow regrowth of boreal forests result from the cold climate and long periods of snow cover. Black spruce, for example, takes 70–125 years to grow to harvestable levels. The boreal forest carbon stock can take up to 200 years to rebalance after disturbance. The boreal forests in Canada are one of the largest terrestrial carbon stocks in the world and most of the carbon is stored in its sensitive soil. Boreal forests have a low decomposition rate and traditional logging has already reduced their acreage as most of the harvesting takes place in intact forest landscapes. Extracting biomass from these forests, either through collection of woody debris left after logging or the removal of standing trees will deplete forest carbon stocks and dramatically accelerate CO_2 emissions when burnt. These carbon stocks would have otherwise remained in the forest for centuries instead of being released immediately.

Greenpeace further contends that burning wood in industrial boilers emits on average four times more CO than coal. Biomass combustion emits ten times more fine particles than natural gas, up to four times more than oil and twice as much as coal. Even though sulphur emissions from biomass are lower than coal, they are still a hundred times higher than natural gas. Large biomass boilers are also known to release heavy metals including lead, mercury, manganese and cadmium and other toxic

components such as dioxins and furans. If Canada is to reach the OECD 15% of electricity production from biomass target by 2020, this would require the burning of more than 147 million cubic metres of wood. This would exceed the total harvested for traditional logging in 2008. Switching existing coal plant to biomass or cofiring biomass in coal-fired plant should be discouraged. Further subsidies for bioenergy may divert support for more suitable energy alternatives such as efficiency programmes, wind, solar and geothermal. They do not regard burning forests for electricity production as a credible solution to climate change.

Greenpeace are urging both the Canadian Federal and Provincial governments to protect forests, particularly those with large carbon stocks, low growth rates and intact areas of the boreal forest, rather than seeking energy from them. Full and independent life cycle analyses of bioenergy projects must be undertaken to avoid underestimating carbon accounting. CO_2 emissions must be tracked every year to ensure that real short-term climate impacts and long-term benefits are properly assessed. The local use of woody biomass must take priority over exports. Standing trees should not be cut for energy as they provide much better carbon storage and capture options alive. Finally, rotations between logging operations should be lengthened to ensure full forest regrowth and carbon capture.

In conclusion, Greenpeace acknowledge that bioenergy can play a part in combating climate change if such projects meet certain criteria. But they refute the claim that biomass is infinitely available and represents one of the best alternatives to fossil fuels. They suggest that, given the limited amount of forest biomass that can be used sustainably and effectively to provide low-carbon energy, governments need to scale up other energy options like energy conservation, wind, solar and geothermal energy. In the particular case of Canada, forest bioenergy and the bioeconomy will not save the failing Canadian forest sector. Biomass production is a low value-added, risky business in today's market. It depends heavily on government subsidies, while offering few opportunities for forest communities (Mainville, 2011).

6.2 Friends of the Earth

Friends of the Earth (FoE) accept bioenergy has a role to play in reducing greenhouse gas emissions but only if it is done in a way that protects wildlife, people's livelihoods and guarantees emissions cuts. They support the use of locally sourced woody biomass or energy crops which result in significant reductions in net CO_2 while not impacting negatively on biodiversity, air, water and soil quality. There must be mandatory safeguards to ensure that only sustainable sourcing occurs to prevent one environmental problem being replaced by another. Within the UK, the use of biomass should be kept to a sustainable level and not outstrip domestically available biomass resources. FoE supports the generation of energy from anaerobic digestion of food, sewage sludge, agricultural waste and wood fuel from sustainable UK woodland management including sawmill and agricultural waste. They are in favour of local energy crops for local consumption, such as cereal straw, provided some is ploughed back into the soil to avoid nutrient leaching. They insist that biomass should be used close to the site of production preferably for the production of heat in district heating systems or for industrialised processes. They are opposed to the use of biomass imports such as wood fuel. The use of biomass should be restricted to the amount that can be grown sustainably in the UK. They are particularly opposed to the use of biomass in large-scale thermal electricity generation as they say that higher efficiencies are possible in generating heat than electricity. They also fear that an over-reliance on biomass for generation could undermine more renewable energy sources such as wind power. They are also concerned energy crop production will impair food production.

Though the use of biomass for energy production is classed as carbon neutral as the CO_2 released is equivalent to the CO_2 absorbed by the plants during growth, other factors must be included in the life cycle analysis. This includes the energy required for fertiliser production, harvesting, drying and transportation. The last factor is particularly relevant in the case of biomass as its low energy density means that considerable quantities of fuel need to be grown, harvested and transported especially for a

large-scale power plant. This increases life cycle CO_2 emissions. Large power plant are especially likely to rely on imported fuel that has been transported long distances without guarantees that the fuel was grown or harvested sustainably. Furthermore, FoE claim that the least efficient use of woody biomass is to generate electricity as biomass boilers generating heat can attain efficiencies approaching 90% whereas efficiency for electricity generation is much lower.

FoE distinguish between different types of biomass. Regarding forestry, they are concerned that the cumulative impact of increasing number of new wood-fuelled projects is problematical. New demand for wood is likely to result in more industrial tree plantations, more logging, more deforestation and land grabbing, much of it in the developing world. It is more sustainable to replace fossil fuel demand in producer countries than to ship wood to the UK. Cutting down trees for bioenergy makes no sense as it takes at least 30 years for the trees to absorb the equivalent amount of carbon released when the fuel is burnt. They also have concerns regarding the use of energy crops. If these crops are going to have a significant role in meeting energy needs, it will require a substantial increase in land area, which could otherwise be used for growing food or animal feed. Preference should be given to local production for local use which would minimise long-distance transport. Individual crops raise particular concerns. The production of miscanthus, for example, has a relatively high fertiliser requirement and high water requirements. Miscanthus planted in monoculture plantations will have a negative effect on local biodiversity and landscape. Short rotation coppice, such as willow, has moderate water requirements and can lock carbon into soils through underground rooting systems. During growth there can be a high reliance on pesticides which may continue in monoculture plantations but can be avoided if mixed varieties are planted. FoE are urging the Government to limit the amount of biomass used for energy to ensure that overall demand can be accommodated alongside other uses such as food production and nature conservation. There should be legally binding standards to ensure that biomass is produced in a sustainable way both socially and environmentally. There must be measures in place to ensure that the biomass is converted to energy in an efficient manner to maximise its benefits (Friends of the Earth, 2011).

6.3 World Wildlife Fund

The World Wildlife Fund (WWF) also considers that bioenergy can provide diverse alternatives to fossil fuels, additional incomes for rural communities and contribute to development under the right conditions. For this to be realised, however, bioenergy development must be carefully planned, implemented and continually monitored for its environmental and social sustainability. In the absence of this, bioenergy developments can result in adverse environmental and social impacts, including deforestation, biodiversity loss, soil erosion, excessive water use, conflicts over land rights and food shortages leading to spikes in staple food crop prices. WWF will support bioenergy only if the following issues are addressed:

(i) Bioenergy must deliver large positive energy and GHG balances over fossil fuels. Bioenergy GHG and energy balances vary widely and depend on the particular crop. In addition to crop selection, soil and climate, land use change, agricultural practices, use of by-products, conversion technology and final energy use will all affect the lifecycle GHG balance. Other factors such as land conversion of carbon-rich vegetation, for example, primary forests or peatlands can cancel out potential benefits of bioenergy feedstocks.

(ii) Bioenergy feedstock must be selected on the basis of the most efficient GHG balance calculated from production through to processing and use. Though conventional crops such as sugar cane are beneficial if produced and processed sustainably, future focus should be on ligno-cellulosic crops which have greater scope for reducing GHG emissions.

(iii) Bioenergy policies and programmes must address displacement effects that influence GHG balance, poverty and environment. If the biomass crop replaces an existing agricultural product, a high conservation value area may need to be replaced by agricultural land.

(iv) Areas of bioenergy production must not be established through the indiscriminate conversion of natural ecosystems such as natural or semi-natural forests, natural flood plains and peatlands,

that have high conservation values or critical carbon storage capabilities. In some countries, the enforcement authorities do not have adequate capability to prevent high conservation value areas being converted to biomass production. Any use of agricultural or forestry land for biomass production must maintain carbon storing capacity of the cultivated area.

(v) Biomass feedstocks must be produced using strictest best management practices to prevent unsustainable production contributing to soil, air and water pollution, depletion of water resources and degradation of soil.

(vi) Implementation of bioenergy policies must take food security into account. The growing demand of bioenergy is likely to lead to more frequent fluctuations and general increase in commodity prices. This would adversely affect the ability of the world's poor to purchase food. If agricultural land is currently utilised for food production is used for biomass production, the availability of food will also be adversely affected.

(vii) Social considerations and indigenous people's rights must be considered a priority in bioenergy development. WWF believe that the possible negative impacts of bioenergy development on indigenous peoples and local communities need to be recognised and avoided. The increasing involvement of large-scale conglomerates in the bioenergy business has led to fears of displacement and marginalisation of local communities, indigenous peoples and small holders.

At the international level, WWF insist that international bioenergy trade partners, organisations and governments must ensure the sustainability of the bioenergy industry. The development of international standards to facilitate trade in bioenergy products is strongly recommended. These standards must include social and environmental sustainability criteria. Many of the problems associated with bioenergy are longstanding issues affecting agriculture, forestry and natural resource management. In order to address these problems, fundamental, structural changes are needed and short-term, stop-gap measures focusing on bioenergy are insufficient (Denruyter and Máthé, 2008).

WWF have given their views on cofiring as part of their response to the UK government's consultation on the renewable obligation (RO). WWF do not agree that cofiring coal with biomass should get support under the RO in the long term. They firmly believe that the cap on cofiring should remain and they would prefer it if cofiring is removed as an eligible option altogether. They quote analysis suggesting that cofiring could even increase carbon emissions through displacements of more efficient and less polluting electricity generation. They do admit that cofiring does achieve substantial GHG savings and they suggest that the literature generally confirms that woody biomass gives a much greater GHG saving than energy crops. WWF believe that the RO support mechanism must be based on the best life-cycle GHG emissions reductions and lowest environmental impact and not on the desire to develop a new industry which is not truly zero carbon, such as energy crops. The primary aim of the RO is to tackle climate change and not serve as a tool for rural development (Kaszewski, 2012).

6.4 Institute for European Environmental Policy

This report was commissioned by the Royal Society for the Protection of Birds, Friends of the Earth, Greenpeace (UK) and the Woodland Trust on Securing Biomass for Energy (Kretschmer and others, 2011). The report acknowledges that bioenergy has the potential to be a valuable source of controllable renewable heat and power if delivered sustainably. This would enable the UK to lower greenhouse gas emissions and reduce reliance on fossil fuels. However, if undertaken badly, bioenergy could substitute the problem of fossil fuels with one of forest and habitat destruction, both of which are damaging to climate change.

The report considers that bioenergy can be produced from a range of different biomass sources which vary greatly in their characteristics and the implications of their use. The first group consists of waste streams such as food waste, municipal waste and sewage sludge. The second group comprises residues and co-products from the agricultural and forestry sectors including straw and residues from forestry and wood processing. Finally, there is dedicated biomass from forests and agricultural land. It

is essential the government policy makes a distinction between these sources rather than regarding them as a single group. In particular, given the different environmental sensitivities for different groups, the report proposes a sustainability hierarchy for the different types of biomass. The biomass types offering the greatest environmental benefits are at the top of the following list:

(i) genuine residual wastes;
(ii) residues from habitat conservation and land management;
(iii) agricultural and forestry co-products and residues;
(iv) biomass harvested from new and existing woodlands;
(v) dedicated energy crops.

The report is particularly concerned that if all proposed biomass plants in the planning process are built and government plans on expansion of the role of biomass are met, there will be a substantial increase in imports of biomass to the UK, and wood in particular. Such large-scale imports of biomass would have the same negative social and environmental impacts as imports for biofuel and put pressure on existing forests from increased harvesting and wood extraction. The use of land for new plantations could also be damaging for wildlife and climate. The current sustainability proposals are based on those developed for biofuels and are inadequate for bioenergy. The current criteria contain gaps and largely adopt a 'no harm' approach. A more proactive approach is needed. Environmentally preferable feedstocks should be promoted by changing the RO banding to reflect not only the economic costs but also the environmental impacts of the principal feedstocks. They are concerned that without urgent intervention the UK will host a bioenergy sector based on substantial wood imports thus increasing pressure on forests across the world. It would be preferable to base the industry on domestic forests, woody energy crops, agricultural residues and wastes. Not only will this enable the UK to meet its renewable energy targets but it will also help meet environmental aspirations by reducing landfill, bringing woodland back into management and provide opportunities for the rural economy.

The report urges the UK authorities to develop robust sustainability standards for bioenergy feedstocks, band the RO in such a way to reflect environmental impacts and enhance support to promote biomass CHP. They also recommend investing and facilitating local biomass supply chains, enhancing collection of genuine residual waste and protecting grassland of conservation value. Other suggestions include supporting farmers in utilising straw in sustainable ways and providing a package of support for undermanaged woodland for increasing appropriate and sustainable management of woodland.

6.5 Biofuelwatch

Biofuelwatch works to highlight the negative impacts of industrial biofuels and bioenergy on biodiversity, human rights, food sovereignty and climate change. In a recent report entitled *Sustainable biomass: a modern myth* they report that large-scale industrial bioenergy projects, mostly burning wood for electricity, are rapidly expanding with support policies that include subsidies and mandates for renewable energy. The UK is at the forefront of this expansion with industrial plans which, if implemented, would result in burning 90 million green tonnes of wood a year and would need to import wood on a globally unprecedented scale. As evidence of serious negative impacts mount, the solution proposed is to require fuel certification in accordance with sustainability standards. The mandatory standards proposed by the government and voluntary ones being drawn up by industry are being developed at the same time as creating a new artificial global market in wood. These sustainability standards cannot address the wider, largely indirect, impacts of creating a fast growing new market for wood given that the existing demand for wood, including for paper, is already unsustainable and is a major driver for deforestation and forest degradation. The UK will soon become the first country in the world to introduce mandatory biomass sustainability standards for all subsidised biomass. The Biofuelwatch report focuses on the UK but its comments are relevant wherever standards and certification are applied.

Wood for bioenergy in the UK is increasingly imported, primarily from Canada, SE USA, Eastern Europe, Russia and Scandinavia. Hence the impacts of this policy will be felt largely overseas. Though the generators talk of forestry wastes and residues, these are clearly not available in sufficient quantities and wood from whole trees will be required. Bioenergy companies repeatedly assert that plenty of biomass is available. Among the other myths that the report examines is the claim that large amounts of wood can be removed from the beetle infested forests in North America, greatly increased logging can reduce wildfires and that there are large areas of abandoned, marginal or waste land available for biomass production worldwide. Increased demand for bioenergy is already resulting in more intensive logging including whole tree harvesting and expansion of industrial tree plantations for bioenergy will lead to land grabbing and ensuing conflicts.

Biofuelwatch have considerable concerns regarding the certification industry which has become big business. These companies specialise in sustainability inspections, verification and certification and offer a broad array of certificates. Many of these also profit from carbon trading as accredited verifiers for the Clean Development Mechanism. Biofuelwatch contend that certification companies are not necessarily committed to sustainability but rather profit from whatever the certification industry requires. Complaints against the certificates awarded by these companies are all too common and in some cases resulted in suspension or revocation of their status as creditors. They further claim that the industry can shop around and find a certification company that will best serve its interests or develop its own internal procedures. Conflicts of interest and lack of independent regulatory oversight are thus inherent in voluntary as well as mandatory certification and standards. For example, they point out that RWe Npower have indicated that most of the wood required will be sourced from the southeast USA and Canada. Their wood pellets will be certified by Green Gold Label (GGL) accreditation scheme. However, Biofuelwatch claim that the independence of the GGL scheme is doubtful as they have institutional links with utilities.

They are also concerned that the UK government's announcements to date are not comprehensive nor in line with scientific findings on the wider impacts of bioenergy. They claim that human rights, land rights, impacts on food security, biodiversity impacts, soil and water depletion are not addressed by the proposed standards. For example, these standards will not prohibit the conversion of forests to industrial tree plantations. Indirect land use changes and the large carbon debt are also being ignored. Carbon debt is the length of time that bioenergy will lead to a carbon spike due to its high upfront carbon emissions compared with the time new trees and other vegetation will need to reabsorb this carbon. The urgency of the climate crisis requires immediate reductions in emissions, whereas studies suggest that bioenergy will increase them for decades or even centuries to come. Biofuelwatch also assert that feedstock-specific carbon debt forecasts are highly questionable. Firstly, they generally do not account for indirect impacts and secondly, carbon debt forecasts rely on assumptions about future tree growth which are highly uncertain. No international forest certification scheme can guarantee that the wood does not come from the destruction of highly biodiverse forests, is not linked to human rights abuses, such as eviction of communities, and does not come from monoculture tree plantations which have replaced biodiverse forests and grassland.

The report concludes that biomass standards are not a credible means to address the serious adverse impacts of bioenergy, which are the direct result of government policies, namely subsidies, which in the UK are paid in the form of renewable obligation certificates. Instead, renewable energy policies and subsidies need to be fundamentally reformed to ensure that support goes to those forms of energy which are genuinely renewable and not to large-scale industrial biomass.

6.6 Environmental Defense Fund

The Environmental Defense Fund (EDF) was founded in 1967 with the aim of proposing long-lasting solutions to environmental problems based on best scientific research. They work directly with business, government and communities. Their present focus is on global warming, which they

consider the most critical environmental challenge of our time. They are also concerned about factors affecting land, water, and wildlife, especially the fate of endangered species. They campaign to protect critical areas of oceans and on issues affecting public health such as air pollution. They have recently focused on bioenergy and deforestation. They claim their approach is based on sound science, through corporate partnerships, economic incentives and getting the correct legal framework.

EDF have addressed issues relating to bioenergy. EDF accept that emerging bioenergy markets offer improved economic and management opportunities but also raises difficult questions regarding environmental sustainability. They report that as the USA seeks new renewable energy sources, biomass is often the cheapest and most readily available energy feedstock. They expect bioenergy to be the fastest growing source of energy in the USA over the next 25 years, growing from 1% to 5.5% of electricity produced by 2035. Demand for wood biomass will grow by 38 million trees in the next four years, which will consume the output from 20 to 30 new paper mills. The Southern States are expected to see a 75% increase in the demand for biomass and a 35% increase in bioenergy facilities. EDF accept that new bioenergy markets could improve sustainability of farms and forests under appropriate conditions. They could fund ecological restoration, improved forest management and insect and disease control. Additional markets for landowners could create new incentives to keep forests as forests and encourage farmers to plant less nutrient-intensive crops. It is, however, possible that the available biomass resources are already being utilised. The new biomass requirements could affect broad swathes of countryside resulting in net carbon emissions, less wildlife, reduced water quality and loss of important natural habitats. Altering the existing markets for biomass could result in net job losses. For example, the pulp and paper industries provide well-paid employment for rural communities which could be affected by new bioenergy facilities (Environment Defense Fund, 2012).

EDF are concerned that despite the rapid growth of bioenergy, Federal and State policies are lagging behind market practices. Without science-based policies in place, the new bioenergy markets could undermine attempts to reduce greenhouse gas emissions and increase threats to water quality and wildlife. Only a few Midwestern and New England States have taken the lead in developing biomass harvest guidelines which can effectively protect the environment. EDF claim that no Southern State has biomass harvest guidelines to assist landowners. EDF is a member of the Council for Sustainable Biomass Production which is developing a voluntary certification system for biomass. They are also developing a carbon accounting model for bioenergy production. This is needed as, unlike fossil fuels, bioenergy has the potential to dramatically alter the cycle of carbon sequestration and emissions that naturally occurs in nature. Harvesting biomass removes carbon that has been stored in farmland and forests but growing biomass may recapture the carbon to varying degrees over time. For example, paper mill residues and logging debris decompose rapidly and burning these creates short-lived or no net climate impacts. Mature forests, on the other hand, store carbon over extended periods and harvesting this source for energy will reduce the amount of carbon stored and increase greenhouse gas emissions. EDF suggests that what is currently lacking is a thorough scientific framework to ensure that the use of biomass for energy generation achieves climate change goals. EDF have supported the development of a computer model which shows how biomass could be used to meet renewable energy targets in North Carolina, South Carolina and Georgia. They have also supported a comprehensive assessment of the amount of biomass that can be sustainably harvested from Northeastern forests (Buchholz and Hamburg, 2011). The study addressed both the amount of biomass that could be harvested sustainably for energy purposes and which conversion technologies were most effective for reducing greenhouse gas emissions. The analysis yielded significantly lower estimates for the sustainable supply of biomass from Northeastern forests. The study also showed that there are significant differences in how much energy can be produced from a given quantity of biomass. Highly efficient biomass power plants and cofiring plant show significant substitution potentials. Replacing one metric tonne of coal with biomass by cofiring is nearly four times more effective in reducing CO_2 reductions than substituting gasoline with cellulosic biomass derived liquid fuels.

6.7 Clean Air Task Force

Another US organisation that campaigns for a cleaner environment is the Clean Air Task Force (CATF). This was founded in 1994 and is non-profit-making and has the aim of restoring clean air and a healthy environment through scientific research, public education and legal advocacy. Controlling power plant emissions has been a major focus of their efforts. They regularly publish reports which are well-written, well-presented, adequately referenced, seemingly authoritative and at times very critical of coal-fired power plant. Regarding the need to address climate change, CATF are in support of CCS and gasification technologies. Their report *Coal without carbon* (Clean Air Task Force, 2009) focuses on underground coal gasification, surface-based coal gasification, advanced technologies for post-combustion CO_2 capture and geological CO_2 sequestration. They are highly sceptical of the use of bioenergy. They joined other environmental groups in August 2011 in filing a lawsuit challenging the US Environmental Protection Agency's decision to exempt large-scale biomass-burning facilities from CO_2 limits under the Clean Air Act for the next three years. They contend that the EPA's ruling will cause immediate harm and encourage the construction of biomass power plants without accounting for or controlling CO_2 emissions. The EPA's actions will, in the near term, increase CO_2 emissions that will persist in the atmosphere and cause climate change for more than a century. CATF claim that the South is already seeing a huge increase in the number of new and retrofitted facilities that burn woody biomass, which will create increasing pressure to cut native standing trees for fuel. CATF accept that while certain types of biomass must be part of the USA's move to clean, sustainable energy sources, the scientific evidence shows that cutting whole trees often adds to carbon output. They quote a 2010 report from the Massachusetts-based Manomet Centre which found that, when biomass is used to generate electricity in utility-based plants, the net CO_2 emissions would exceed those from coal-fired power plant for more than 40 years and would exceed the CO_2 emissions from natural gas fired power plant for more than 90 years. In their reply to the EPA's call for information on greenhouse gas emissions from bioenergy, they state that the literature showed that: first, many bioenergy systems achieve carbon neutrality only after years or decades; second that carbon neutrality is a highly subjective designation, dependent on system boundaries and accounting methods employed; and third, carbon neutrality does not imply climate neutrality since biogenic CO_2 contributes to climate change between combustion and uptake by new biomass (Clean Air Task Force, 2010a,b and 2011).

6.8 Sierra Club

The Sierra Club has been campaigning for the environment since 1892. It has the aim of protecting communities, wild places and the planet itself. They claim to be the most influential environmental grassroots organisation in the USA. They consider biomass as one type of renewable energy in a list that includes wind, solar and geothermal. They assert that increasing energy efficiency and reducing electricity consumption is the simplest and most effective way of combating global warming. They say that biomass can be utilised to provide heat, electricity and transportation fuel. With the right technologies and responsible land-management practices, the energy contained in plants can be harnessed in a renewable manner. Biomass may be any organic matter including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residues, animal waste and other organic waste. Biomass is considered by many to be a renewable source of energy because the carbon involved is functioning in a short cycle and regrowth balances the emissions. However, unsustainable land use practices may release soil carbon to the atmosphere. They are concerned that accelerated and poorly-managed harvesting of forests and crops as fuel accompanied by the conversion of natural ecosystems to 'fuel farms' will increase global warming and degrade the environment. They believe that though biomass projects can be sustainable, many are not. They are not confident that extensive biomass resources can be harvested without risking soil and forest health, given the lack of commitment by governments and industry to preservation, restoration and conservation of natural resources. They are cautious in supporting projects based on 'clean' construction waste, forest by-product waste or sustainable waste such as municipal tree trimmings

because of the strong incentives for plant managers to use unsustainable and contaminated fuel if the intended supply runs short. The Sierra Club are concerned that biomass projects might rely on or create incentives for fuel derived from unsustainable forestry and agricultural practices.

Native forests which are the largest source of fuel for projects defined as biomass are a particular concern. They oppose all biomass energy generation processes which result in the destruction of existing forests, including national or native ones. They oppose projects which rely on ecologically destructive clear-cutting, in-wood chipping where excessive amounts of biomass are removed from the land and conversions to non-native species which undermine native biodiversity. Regarding energy crops, they encourage their activists to consider whether an individual project involves environmentally beneficial or detrimental conversion of land use. Generally, smaller, local projects which avoid inefficient transportation of fuel stocks by providing distributed power directly to end users or at sections of the electric grid remote from power plants are most advantageous. The Sierra Club opposes farming practices which supplant wilderness or other natural land, reduce genetic diversity, require greater energy and material input per unit of production, increase use of manufactured fertiliser and biocides on existing agricultural lands, displace indigenous people or accelerate the conversion of family farms to agribusinesses. At present, adequate controls are not in place domestically or internationally to prevent the water requirements of fuel farms from taking over water from subsistence farming. Sierra Club have also considered the use of waste to produce energy. They favour the reduction of waste generation by minimising the use of materials. Waste combustion, with or without energy recovery, is only appropriate in very narrow circumstances. They also favour the return of agricultural waste to stubble, where possible (Sierra Club, 2012a,b).

In summary, the organisations sceptical of bioenergy do accept that bioenergy could play a role in combating climate change but they have objections which frequently centre on issues related to sustainability. The cultivation of biomass must not damage the ecosystem, affect food security or the local population. They are opposed to change in land use and anything that would reduce the existing carbon storing capacity of the land. The energy balance of such projects must be substantially positive. They are keener on small-scale local projects rather than larger projects which require the biomass to be transported over long distances. They would support the use of biomass to produce heat or CHP schemes more than the sole generation of electricity. They have particular objections to certain types of biomass. The objections to energy crops focus on whether it may affect food production. They do not accept that the use of wood from forests is carbon neutral as there are significant energy requirements for forest bioenergy production. Furthermore, it may take several decades or even centuries for the forests to regenerate. It is suggested that the harvesting of mature forests could increase greenhouse gas emissions. In the USA, there is concern that regulatory policies are lagging behind market practices.

7 Independent assessments

There have been several independent assessments of bioenergy and the conclusions of some of these assessments are summarised in this chapter.

7.1 Intergovernmental Panel on Climate Change (IPCC)

The IPCC have assessed the potential of renewable energy sources for climate change mitigation. They accept that bioenergy has a significant GHG mitigation potential, provided that resources are developed sustainably and that efficient bioenergy systems are used. Certain current systems and some future options including perennial cropping, use of biomass residues and wastes are able to deliver 80–90% emission reductions compared to the fossil energy baseline. However, land use conversion and forest management that lead to a loss of carbon stocks or indirect land use change can lessen and in some cases more than eliminate the net positive GHG mitigation impacts. Climate change impacts such as temperature rises, rainfall pattern and changes and increased frequency of extreme events could affect the biomass resource potential. This interaction is poorly understood but is likely to exhibit strong regional differences. Though climate change will affect biomass feedstock production, if global temperature rise is limited to 2ºC, the impacts will be manageable.

Bioenergy is currently the largest renewable energy source and is likely to remain one of the largest sources for the first half of the century. There is considerable growth potential and assessments in the recent literature suggest that the technical potential for bioenergy may be as large as 500 EJ/y by 2050. However, large uncertainties exist about important factors such as market and policy constraints that could affect this potential. The assessments in the report suggest that the potential deployment levels by 2050 could be in the range 100–300 EJ/y. Realising this potential would be a major challenge but would make a substantial contribution to global primary energy demand. Bioenergy has significant potential to mitigate GHG emissions subject to the provisos mentioned above relating to sustainability and efficiency. In order to achieve the high potential deployment levels of bioenergy, increases in competing food and fibre demand must be moderate, land must be properly managed and agricultural and forestry yields must increase substantially. Expansion of bioenergy without adequate monitoring and good governance of land risks conflicts regarding food production, water resources and biodiversity as well as risking low GHG benefits. Conversely, the cultivation of biomass could have positive outcomes such as rural development, land amelioration and climate change mitigation. The impacts and benefit of biomass production and use are region- and site-specific. Hence bioenergy policies need to consider regional conditions and priorities as well as the agricultural and forestry sectors. Several important bioenergy options such as sugar cane-ethanol production in Brazil, some waste-to-energy systems and biomass-based CHP are competitive today and can provide important synergies with longer-term options. Combining biomass conversion with CCS raises the possibility of achieving GHG removal from the atmosphere. Achieving the full potential of bioenergy production will require sustained investments to reduce the cost of key technologies, improved biomass production and supply infrastructure and implementation strategies that can gain public and political acceptance (Intergovernmental Panel on Climate Change, 2011).

7.2 Committee on Climate Change

The Committee on Climate Change (the Committee) is an independent statutory body established under the Climate Change Act (2008) to advise the UK government on setting and meeting carbon budgets and preparing for climate change. They published a Bioenergy report (Turner, 2011) in which they assessed the role of bioenergy in meeting climate budgets, in particular to what extent bioenergy is sustainable. They acknowledged that the role of bioenergy in climate change mitigation is

controversial. Specifically, there are questions over the extent to which bioenergy use results in emissions reductions when lifecycle impacts are included. They concluded that it would be difficult to meet the overall 2050 emissions target unless bioenergy can provide about 10% of UK primary energy and that CCS is feasible. Their scenarios for global land use which take account of the need for food production suggest that a reasonable UK share of potential sustainable bioenergy supply could amount to about 10% (200 TWh) of primary energy demand by 2050. At present, it would be inadvisable to assume any higher levels of bioenergy supply, and even the 10% level might require some trade-off with other desirable environmental and social objectives. If CCS is not available at the scale envisaged, the amount of bioenergy required to meet the 2050 target would be significantly higher than 10% and this would result in land use change exceeding currently estimated sustainability limits. In this case, attaining the 2050 target would require a bioenergy technology breakthrough. The Committee also concluded that it was important that the role of bioenergy in a low carbon strategy reflects realistic estimates of total lifecycle emissions for different types of feedstock, including both direct and indirect land use impacts. The existing EU and UK regulatory approaches do not fully address the emissions from land use change emissions and should be strengthened.

The Committee considered power generation and concluded that there should be limited, if any, support for new large-scale dedicated biomass generation. Any longer-term role for new dedicated biomass power plant without CCS should be very limited given its relatively high costs compared with other renewable options. Detailed analysis of the power sector suggested that any near-term investment should be confined to biomass cofiring and conversion of existing coal-fired plant to fire biomass. The Committee supported the government's focus on cofiring and conversion where appropriate. For new dedicated biomass plant, support should be limited to small-scale plants or CHP plant.

The Committee commissioned a review of the economics of cofiring, conversion and new dedicated biomass plant from Mott MacDonald (MML) and this suggested that biomass cofiring and conversion of existing coal-fired power plants to solid biomass are cost-effective options for meeting renewable energy targets. However, this is unlikely to be the case for new dedicated biomass power plant. The MML modelling suggested that the conversion of existing coal-fired plants, most of which are due to come off the grid in the next decade, offers the opportunity for biomass power generation at a cost of around 80–90 £/MWh. Similarly cofiring at low levels (5–10%) is likely to cost around 70 £/MWh and enhanced cofiring, up to 50%, around 80–90 £/MWh. In contrast, new dedicated solid biomass plant would cost around 130–145 £/MWh, which is similar to the cost of offshore wind (Turner, 2011).

7.3 World Bank

The World Bank has considered issues relating to bioenergy. In a report entitled *Bioenergy Development* they have assessed recent developments in the consumption and production of bioenergy (Cushion and others, 2010). It has examined the main issues and possible economic implications of these developments and considered their potential impacts on land use and the environment, especially with respect to forests. The report notes that in the last five to ten years there has been a strong resurgence of interest in bioenergy, accompanied by the gradual development of more modern and efficient bioenergy production systems. This resurgence has been driven by higher oil prices, surging energy demand from developing nations, mitigation of climate change and the belief that biofuels are less expensive than fossil fuels. Bioenergy systems present opportunities for countries with land resources suitable for energy crop cultivation to develop a national source of renewable energy with the possibility of export revenues. The development of bioenergy presents both opportunities and challenges for economic development and the environment. But significant concerns remain about its effect on combating climate change and the environment; on agriculture, food security and sustainable forest management; and on people, particularly the poor in developing countries who will be affected by the changes in land use, land tenure and land rights which may result.

The main findings of the report are firstly that solid biomass will continue to provide a principal source of energy and should not be overlooked. At the global level in 2005, primary solid biomass accounted for 95% of total primary energy supply from bioenergy. The report also concludes that there will be major land use implications resulting from bioenergy developments. The important question is whether the biomass crop can be grown on unused or degraded land or will take land out of agriculture or forestry. It was also critical to consider trade-offs including those relating to poverty, equity and the environment when choosing bioenergy systems. In most countries bioenergy policies have a number of objectives that require careful analysis. For example, it may be necessary to weigh up energy security and rural development on one hand and food price implications and natural resource impacts on the other. Increased consumption of bioenergy is likely to result in increased competition for land that has potential to impact agriculture and forestry and could negatively affect the poor in other ways, such as through changes in access to resources and overall environmental quality. Another finding was that there was considerable potential for greater use of forestry and timber waste as a bioenergy feedstock. The final finding was that the climate benefits of bioenergy development were uncertain and highly location- and feedstock-specific. The climate change impacts have the potential to be both positive and negative. The impacts of increased bioenergy production from primary solid biomass are complex. Increased traditional uses of biomass are likely to result in some forest degradation and possible increased greenhouse gas emissions, where wood fuel is not collected sustainably but increased production of heat and power using waste residues could have a positive impact on climate change. If agricultural or forested land is converted for bioenergy production, the carbon emissions may increase compared to fossil fuel emissions especially if the land converted is forested peatlands.

Regarding policy implications, the report concluded that, for consumer countries, it was important to consider the upstream impacts of their bioenergy mandates and targets including both social and environmental effects. In producer countries, it was important to balance production targets with environmental and social concerns including food security.

The report also considered in general terms the economic viability of utilising solid biomass for energy production. Though the capital costs of biopower has fallen in recent years, for large-scale power production, it still remains 10–20% higher than the capital cost of coal-fired generation. This arises because of the lower heat content of biomass, hence greater volumes are required to produce each unit of power output. In addition, more space is required to store the biofuel and the equipment required for preparing the biofuel is generally more expensive. Operational and maintenance costs are also higher for biofuels than for coal, partly because of the larger volumes of biofuel needed for each unit of power output and partly as other factors, such as moisture content and fuel variability, increase these costs. The higher production costs, in most cases for biomass, and lower energy content make it more expensive than coal and more comparable to oil and gas. Another factor is the efficiency of energy production which is generally lower for biomass than for fossil fuels. The conversion efficiency of biomass has improved over the past few years and is now close to the levels achieved by coal plant. Overall, cofiring with coal is roughly 0.02–0.03 $/kWh more expensive than coal only plant (Cushion and others, 2010).

Independent assessments of bioenergy have also concluded that bioenergy has significant GHG reduction potential and will be necessary if CO_2 reduction targets are to be met. However, the sustainability of projects must be addressed, particularly in relation to land use conversion and forest management, to prevent loss of existing carbon stocks which might counter any GHG reductions. The effect on food production, water resources and biodiversity and indigenous people must also be considered hence there will be an upper limit for the proportion of energy production possible from sustainably produced bioenergy in a given country. Regarding power generation, cofiring biomass in existing plant and plant conversion will be much more cost effective than the construction of new dedicated biomass plant. Though capital costs of biopower have decreased in recent years, they are still significantly more than for coal-fired generation.

8 Organisations supportive of the coal industry

Though generation of electricity from coal has considerable disadvantages relating to greenhouse gas emissions, the disadvantages borne by other sources of generation relating to security of fuel supplies, cost and availability mean that coal will remain the main source of power generation worldwide for many years. Coal has many advantages which are not always recognised. Coal is easy to store and transport and can be obtained from a diverse range of suppliers worldwide. PCC units are able to operate at varying loads, which is particularly useful in meeting peak demand, and they can compensate for the intermittency of some renewable sources. In addition, with widely fluctuating high prices for oil and gas, coal-fired generation is frequently the lowest cost option for power generation. Given the considerable concerns about greenhouse gas emissions emitted from coal-fired plant and until CCS is proven on large scale to be technically feasible and economically affordable, the current technologies for reducing CO_2 emissions from coal plant are increasing the efficiency, which is achieved by installing supercritical and ultra-supercritical boilers, biomass cofiring and utilising IGCC. The simplest of these to implement at an existing plant is biomass cofiring. Thus it is not possible to discuss the necessity for biomass cofiring in coal-fired plant without mentioning the advantages of coal-fired plant and this is something plant operators are reluctant to do. The availability of biomass worldwide is finite and it is inconceivable that it will ever be possible to generate global power requirements from bioenergy alone.

The World Coal Association (WCA) is a global industry association comprising major international coal producers and stakeholders. It was founded in 1985 to provide a forum for the exchange of information and discussion of challenges relating to the coal industry. Their mission is to engage constructively and openly with governments, the scientific community, multinational organisations, the media and others on global issues such as CO_2 emissions reduction and sustainable development and local issues including environmental and socio-economic benefits and effects from coal mining and coal use. WCA accepts that the coal industry, including both internationally traded and domestic coal needs to present a united front to the challenges it faces this decade and beyond. It contends that the orthodoxy that views coal only as a CO_2 emitter, without regard to its role in economic and social development, electricity generation and steel manufacture, may be at a turning point.

WCA regularly publishes reports on issues affecting the coal industry. It has published a report entitled *The Coal Resource* which provides a comprehensive overview of coal and the role it plays in society. This report covers how coal is formed, mined and how it is used and how it affects society and the natural environment. It accepts that the world faces a major environmental challenge regarding global warming and say that the coal industry is committed to minimising its emissions. The report discusses several technologies for reducing carbon emissions. Firstly by increasing thermal efficiencies by the installation of supercritical and ultra-supercritical boilers and secondly by gasifying the coal as in IGCC. The option they consider to be the most promising is CCS. It suggests that while further development is needed to demonstrate the viability of separating out CO_2 from high volume, low CO_2 concentration flue gas, CCS is a realistic option for the future. There is only one sentence on cofiring which says that the economics and efficiency of biomass renewables can also be improved by cofiring with coal (World Coal Association, 2005). WCA has also produced a report on *Coal meeting the climate change* which also advocates CCS and efficiency improvements but makes no mention of cofiring (World Coal Association, 2007). More recently, it has produced a short document on cofiring biomass with coal. The document states that biomass can be considered to be carbon neutral but the supply chain is not entirely carbon free. GHG emissions over the lifecycle can be reduced if the biomass is sourced locally and not transported over long distances. It also says that equipment designed to burn coal is easily adaptable to burn biomass and co-combustion up to 5–10% of biomass requires only minor plant changes. Cofiring as opposed to burning biomass on its own, improves the overall thermal efficiency and the capital costs of dedicated biomass plant are three to five times that of cofiring. The document mentions that despite recent large-scale use of biomass in the UK,

Netherlands and Denmark, its worldwide share of power generation is low. In 2009, biomass and waste accounted for 1.5% of global electricity generation and barely 8% of renewable electricity generation. It briefly mentions storage and handling issues. It concludes by turning to the issue of feedstock availability. Ensuring a long-term and stable supply of biomass might prove difficult as more power plants turn to cofiring. Though the document mentions most of the important points, as it is only one and a half pages long, the level of detail is necessarily scant (World Coal Association, 2012).

In the USA one major organisation supportive of the coal industry is the National Coal Council (NCC). This advisory council was founded in 1985 to advise, inform and make recommendations to the Secretary of Energy with respect to any matter relating to coal or the coal industry that he may request. It has a membership of 125 individuals, appointed by the Secretary of Energy, who represent all segments of the coal industry. The NCC recognise the need to limit man-made CO_2 emissions to combat global warming. In their opinion CO_2 capture and geological storage is the key enabling technology for the reduction of CO_2 emissions from coal-based power generation. In a report entitled *Carbon dioxide capture and storage: the future of sustainable coal use* (National Coal Council, 2012), they predict that CCS is likely to be commercially available for baseload power generation around 2025-30. An earlier report *Low-carbon coal: meeting US energy, employment and* CO_2 *emission goals with 21st century technologies* only discusses CCS and underground coal gasification (National Coal Council, 2009). There is no mention of bioenergy or cofiring. Cofiring with biomass is mentioned in their report *The urgency of sustainable coal* (2008). In this they claim that biomass cofiring can be used to reduce carbon emissions in both existing coal boilers and in IGCC units. They discuss how in a closed-loop system, where energy crops are cofired, the entire process – planting, harvesting, transportation and conversion to electricity – can be considered to be a small but positive net emitter of CO_2. The report also discusses open-loop cofiring and the impact on traditional users of biomass such as the forest products industry. They quote the US Energy Information Administration saying that biomass is expected to generate 0.3% of total generation in 2020 but in scenarios that include a 20% renewable portfolio standard, electricity generation from biomass is projected to increase substantially. It lists the issues that need to be addressed before implementation of cofiring as being:

- availability of biomass;
- life cycle analysis of CO_2 reductions, including growth, transportation and preparation;
- competition of biomass with other land needs, such as food production;
- change in ash properties for plants selling fly ash;
- fouling, slagging and corrosion in the boiler;
- reduction in output.

The report indicated that the percentage of coal that can be replaced by biomass is very site specific. It quotes an EPRI study which suggests that cofiring can be economically advantageous at levels greater than 5% (mass). The section concludes by listing the nine coal-fired plant which at the time were cofiring biomass. The assessment of biomass cofiring is contained in two pages of the report.

Two other pro-coal organisations, EURACOAL and ACCCE (American Coalition for Clean Coal Electricity) have not published any technical papers on biomass cofiring. It is apparent that organisations supportive of the coal industry generally regard efficiency improvements and CCS as the pathways to reduce greenhouse gas emissions rather than biomass cofiring. Any mention of biomass cofiring in their reports are brief. It is possible that as CCS technology has not advanced as rapidly as initially hoped, there may be more focus on biomass cofiring in the future.

9 Organisations supportive of biomass cofiring

There are many organisations supportive of bioenergy but few focus on cofiring biomass in coal-fired power plant. The main organisation supportive of cofiring is IEA Bioenergy Task 32: Biomass Combustion and Co-firing. This operates within the IEA Bioenergy agreement with the aim to further expand the use of biomass combustion for heat and power generation with special emphasis on small- and medium-scale CHP plants and cofiring biomass in coal-fired boilers. Having considered the broad range of experiences of biomass cofiring in coal-fired power plants in various configurations worldwide, they assert that:

- cofiring has been demonstrated successfully at over 150 installations worldwide for most combinations of fuels and boiler types;
- cofiring offers among the highest electrical conversion efficiencies of any biomass power option;
- cofiring biomass residues in existing coal-fired boilers is among the lowest cost biomass power production options;
- well-managed cofiring projects involve low technical risk;
- in addition to CO_2 mitigation, biomass cofiring in existing coal-fired boilers usually leads to reduced NOx, SO_2 and other flue gas components.

They have published a 16-page overview of biomass cofiring entitled *Biomass Combustion and Co-firing: An Overview*. The report discusses the principles of biomass cofiring, the types of fuel available and its supply and treatment. It goes on to consider the different types of biomass combustion systems. In the section on co-combustion the report briefly describes fuel characteristics, fuel preparation and handling, emissions, ash deposition, corrosion and ash utilisation. The report concentrates on the technical issues that need to be considered which affect the coal plant itself when cofiring biomass. It does not consider the availability or the sustainability of the biomass. IEA Task 32 also hold workshops and conferences in which these technical issues are considered in greater detail. The proceedings of these events are available online but the content of these proceedings are aimed at those having significant understanding of the subject and not the informed public (IEA Bioenergy Task 32, 2002). They have also produced a Handbook of Biomass Combustion and Co-firing which gives a very thorough technical coverage of the relevant topics for the plant itself but does not address issues relating to fuel availability or sustainability (van Loo and Koppejan, 2008).

There are other Bioenergy Task groups which focus on bioenergy in general rather than on cofiring. These include Task 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems and Task 40: Sustainable International Bioenergy Trade – Securing Supply and Demand. Some of the published material for these Tasks is relevant to biomass cofiring. For example, the Task 38 report *Greenhouse Gas Balances of Biomass Import Chains for Green Electricity Production in the Netherlands* has considered the production, transport and cofiring of wood pellets from Canada and palm kernel shells (PKS) from Malaysia in a 600 MW coal-fired power plant in the Netherlands. The production and transport of pellets and PKS represented 10–12% of the biomass heating value when cofiring compared to 3–8% when used in the country of origin. In the most optimistic scenario, pellet cofiring avoids methane emissions that would have occurred if the pellets decomposed at landfills and were not cofired. In the most pessimistic scenario, palm kernel shell cofiring competes with their use for fodder production requiring the production and transport of soybeans as an alternative resource (Damen and Faaij, 2005).

KEMA in the Netherlands have extensive experience in direct and indirect cofiring of biomass. In addition to publishing papers in technical journals and presenting in conferences, they have produced reviews of cofiring which are available online. They co-ordinated a report for Task 32 in collaboration with other authors on the Technical Status of Biomass Cofiring. This describes the technical issues relating to biomass cofiring in coal-fired plant and the status of cofiring in IEA countries. There is no discussion of biomass availability or sustainability (Cremers, 2009). They have also produced a report

Co-firing biomass with coal. In this report they have concentrated more on the phases of a cofiring project and, in addition to technical considerations, they have also examined regulatory, environmental and economic considerations (KEMA, 2009).

Power plant operators themselves can present the case for biomass cofiring to the public, the press and government. Drax Power have made considerable efforts in this regard in recent years. Their Chief Executive writes regularly in the national press on the need for bioenergy and biomass cofiring to reduce GHG emissions and the case for sufficient financial subsidy and the reduction of regulatory uncertainties. Station staff also give frequent interviews to the local press and articles in the local press are generally supportive of the cofiring activities at Drax. They opened a new visitor centre in 2007 which is geared towards all age groups and through a combination of activity tables, plasma screens, image displays and message boards allows the visitor to discover how the power plant operates, their efforts in recent years, including biomass cofiring, to reduce emissions and improve the environment. Visitors can also undertake a station tour. In 2010, they had over 7500 visitors including students from schools, colleges, engineering institutes and universities. Visits take place practically every weekday. The station has particular links with Leeds University and students and attendees of relevant courses and conferences regularly visit the station. Station staff present papers at conferences and give public lectures. Drax have hosted a IEA CCC workshop on biomass cofiring at the station. They have also published a very readable and informative 16 page report entitled *Biomass: the fourth energy source* detailing the advantages of biomass cofiring which is aimed at the general public (Drax Group, 2011). As a result of these activities, Drax generally receive favourable coverage from the local and national press and little public criticism (Ghent, 2011).

There are many organisations worldwide which extol the benefits of bioenergy. These tend to focus on plant firing solely biomass and their publications do not generally discuss cofiring biomass in coal-fired plant in detail. One exception is the Biomass Energy Centre whose website (www.biomassenergycentre.org.uk) contains a considerable amount of information on cofiring. Their website contains their own summaries of cofiring technologies, fuels, output and pros and cons and papers on cofiring published by other organisations.

10 Conclusions

There is substantial interest in producing energy from renewable sources given the continuing concerns regarding climate change. One attractive renewable source for power generation is the use of biomass. Cofiring biomass is one of the simplest ways to reduce GHG emissions from coal-fired power plant. When doing so, in addition to addressing technical factors, it is important to consider public attitudes, as these shape government policies. Most environmental concerns regarding biomass cofiring centre on sustainability issues, which are complex and controversial. Surveys of public attitudes to energy usually include renewable sources such as wind, solar and hydro. Bioenergy is sometimes included but cofiring seldom so. Cofiring is a niche technology which has hardly entered the consciousness of the public or pollsters. Hence this report has focused on polls which include bioenergy. When assessing public attitudes, it is instructive to consider what information is freely available to the public; hence information provided by major national or international organisations either in favour or against cofiring are described.

Polls of global attitudes to climate change hardly ever mention bioenergy but one survey of attitudes in the USA, Sweden, UK and Japan did so. Solar energy had substantial support and bioenergy was favoured by about two-thirds of the respondents with least opposition in the UK. There have been more surveys of attitudes to bioenergy in Europe mainly as part of the Eurobarometer series. These surveys show that there was substantial support for solar wind and hydro but only moderate support for bioenergy. The countries in northern and central Europe were most favourable to biomass whereas the countries bordering the Mediterranean were the least. This is unsurprising given that northern and central Europe contain extensive forests and the local population are used to timber being used as a fuel. The same survey examined views on energy sources for the future. The chief energy sources for the future were expected to be solar, wind and nuclear. Though biomass was expected to increase substantially from current usage, fewer than a fifth thought that it would be among the three most important sources. In a recent 2011 survey covering 12 EU countries, nearly 90% of respondents were in favour of solar, wind and hydro. Surprisingly 80% were in favour of natural gas and there was a significant drop with 60% supporting biomass. A relatively large proportion of nearly a third did not know that biomass was an energy source. One small survey in the Netherlands did question the respondents on their attitudes to bioenergy and cofiring. In the survey only 8% regarded bioenergy as being renewable and when asked which concepts associated with bioenergy they regarded as being green, cofiring was the least popular with half the respondents not regarding it as green and only 30% thinking so.

Several surveys have been conducted in recent years in the UK into the public's attitudes towards renewable energy. In a 2003 survey, over three quarters said that they were not aware of bioenergy as an energy source. Though a substantial majority considered solar, wind and hydro to be a good idea, the proportion favouring bioenergy was much smaller but was nevertheless a majority. A pair of surveys were conducted in 2005 and 2010 of the UK public's attitudes towards climate change and the future of energy production. In both surveys solar, wind and hydro had substantial support. A majority supported bioenergy with support levels similar to gas. The proportion opposing natural gas was greater than for bioenergy. More general assessments of UK public's attitudes, understanding and engagement in relation to low-carbon energy have also shown that bioenergy remains one of the least familiar renewable energy technologies to the public. Opposition to individual projects were generally on local issues such as congestion, air pollution, odour and appearance of the plant. There is a tendency to associate bioenergy with incineration. A survey focusing on utilising forestry products for bioenergy was particularly negative. A slight majority thought that cutting down forests and woodland makes climate change worse, even if they are replanted. Indeed, not even a majority thought using wood for fuel was better for climate change than using fossil fuels. These results were reinforced by a recent survey of where the public thought there should be investment to meet out future electricity needs. There was significant support for solar, wind, nuclear and tidal. Only 2% supported biomass, a figure on a par with oil and coal.

Biomass cofiring activity in coal-fired plant is currently limited in the USA, and neither cofiring nor bioenergy are considered to be sufficiently important to be included in the many opinion surveys conducted in the USA on the public's attitudes to energy sources. The few that have included bioenergy have indicated that there was majority support for bioenergy but the level of support was considerably less than for solar, hydro and wind. There is also a lack of knowledge about bioenergy and doubts about its sustainability especially regarding wood-based fuels.

When assessing public attitudes, it is instructive to consider what information is freely available both favourable and unfavourable which could influence public opinion. Most environmental organisations do accept that bioenergy can be part of the solution to combat climate change but they are sceptical of cofiring biomass in coal-fired plant. Greenpeace have campaigned globally for a cleaner environment for many decades and support the use of biomass produced under strict sustainability criteria for decentralised heat and power generation and bioenergy. They are particularly opposed to the use of forestry products for electricity generation. They refute the belief that burning wood is carbon neutral as forests take many decades or even centuries before regenerating and recapturing the CO_2 released on combustion. They also state that carbon in forest biomass stays intact within the forest for decades and is recycled in the soil. Friends of the Earth also accept that bioenergy has a role in reducing GHG emissions and support the use of sustainably cultivated energy crops and locally sourced energy crops. They support the use of biomass in CHP schemes but oppose its use for thermal power generation. They are opposed to imported wood fuel. The World Wildlife Fund also accept that bioenergy can provide a diverse alternative to fossil fuels, provided that strict sustainability criteria are met. They are opposed to cofiring biomass in coal-fired plant and do not support any public subsidy for cofiring.

In the USA, the Environmental Defense Fund accept that the emerging bioenergy markets offer improved economic and management opportunities but also raise difficult questions regarding environmental sustainability. They expect bioenergy to be the fastest growing source of energy in the USA over the next 25 years but they are concerned that Federal and State policies are lagging behind market practices. Without science-based policies in place, the new bioenergy markets could undermine efforts to reduce GHG emissions and increase threats to water quality and wildlife. They are developing models to assess the impacts of bioenergy and to predict how much biomass could be cultivated sustainably. The Clean Air Task Force are in favour of CCS and gasification but are highly sceptical of the use of bioenergy. They contend that many bioenergy systems will achieve carbon neutrality after many years or decades and increased power generation from woody biomass will increase the pressure to cut native, standing trees. The Sierra Club also accept that biomass can be utilised renewably to provide heat, electricity and transportation fuels but only some biomass projects are sustainable. They are concerned that accelerated and poorly-managed harvesting of forests and crops will increase global warming and degrade the environment. They are particularly opposed to the destruction of existing forests, including national or native ones.

There have been several independent assessments of bioenergy. The International Panel on Climate Change accepts that bioenergy has a significant GHG mitigation potential, provided that resources are developed sustainably and that efficient bioenergy systems are used. Unsustainable bioenergy production could lead to loss of carbon stocks and lessen or even eliminate the net positive GHG mitigation impacts. Expansion of bioenergy without adequate monitoring risks conflicts regarding food production, water resources as well as risking low GHG benefits. Achieving the full potential of bioenergy production will require sustained investments to reduce the cost of key technologies, improved biomass production and the implementation that can gain public acceptance. The UK government's Committee on Climate Change acknowledges that the role of bioenergy in climate change mitigation is controversial but it would be difficult for the UK to meet its 2050 targets without it. Taking account of the need of land for food production, a reasonable UK share of potentially sustainable bioenergy supply could amount to 10% of primary demand by 2050. The Committee considered power generation and decided that there should be limited, if any, support for new large-scale dedicated biomass generation given its high costs. The Committee supported the government's focus on cofiring and conversions where appropriate. The World Bank has considered issues relating

to bioenergy. The development of bioenergy presents opportunities and challenges for economic development and the environment. Significant concerns remain about its effect on agriculture and people. The Bank found that there was considerable potential for greater use of forestry and timber waste as a bioenergy feedstock. Though the capital cost of biopower has fallen in recent years, for large-scale power production, it remains higher than those of coal-fired generation.

There are several organisations worldwide which represent the coal industry and they claim that though coal generation incurs considerable disadvantages relating to greenhouse gas emissions, the disadvantages borne by other sources regarding security of supply, cost and availability will mean that coal generation will remain the main source of power generation for many years. The main options for reducing GHG emissions from coal generation are CCS, increasing efficiency either by installing supercritical plant or gasification or biomass cofiring. The reports produced by the World Coal Association concentrate on CCS and increasing efficiency and there is only brief mention of biomass cofiring. The National Coal Council also publishes reports on the sustainable use of coal but it, too, concentrates on CCS and only briefly considers biomass cofiring. Other pro-coal organisations EURACOAL and ACCCE do not mention biomass cofiring in their reports.

The main worldwide organisation supportive of biomass cofiring in coal-fired plant is IEA Bioenergy Task 32. They hold conferences and workshops and also publish reports and handbooks on the subject including a database of cofiring plant worldwide. Their documentation concentrates on technical issues such as fuel preparation and handling, emissions, ash deposition, corrosion and ash utilisation which arise when firing biomass in coal-fired power plant. They do not address issues relating to fuel sustainability or fuel availability in any detail. Other Bioenergy Task groups do consider sustainability and biomass availability in detail but mainly in the context of biomass only plant. There are many organisations which extol the benefits of bioenergy but their publications focus on pure biomass plant rather than biomass cofiring.

It is apparent that the public in most countries have little knowledge of bioenergy as a renewable energy source and most opinion polls do not even address the issue of the public's attitudes towards it. The few polls that have been conducted indicate that solar, wind and hydro are much more popular than bioenergy. Bioenergy is more popular in countries such as in Northern Europe which have extensive experience in using wood products as an energy source. Opposition to cofiring biomass in coal-fired plant are mainly on the grounds of biomass availability and sustainability. Yet the power industry publications concentrate on the technical issues for the plant when cofiring biomass. It is essential that those promoting biomass cofiring in coal-fired plant disseminate information intended for the public which addresses in detail these availability and sustainability concerns.

11 References

Biofuelwatch (2012) *Sustainable biomass: a modern myth*. Available from: www.biofuelwatch.org.uk 46 pp (2012)

Buchholz T, Hamburg S P (2011) *Forest biomass and bioenergy: opportunities and constraints in the northeastern United States*. Available from: www.edf.org 76 pp (2011)

Clean Air Task Force (2009) *Coal without carbon: an investment plan for federal action*. Available from: www.catf.us 92 pp (2009)

Clean Air Task Force (2010a) *Clean Air Task Force releases independent analysis of Manomet bioenergy study*. Available from: www.catf.us 2 pp (July 9, 2010)

Clean Air Task Force (2010b) *Clean Air Task Force, Conservation Law Foundation, Natural Resources Council of Maine, Natural Resources Defense Council, Sierra Club, Southern Environmental Law Center on the Environmental Protection Agency's call for information*. Available from: www.catf.us 5 pp (July 15, 2010)

Clean Air Task Force (2011) *Lawsuit challenges Clean Air Act exemption for biomass burners*. Available from: www.catf.us 2 pp (Aug 15, 2011)

Cotter J, Tirado R (2006) *Greenpeace policy on bioenergy*, Available from: www.pcij.org 7 pp (2006)

Cremers M F G (2009) *Technical status of biomass co-firing*, IEA Bioenergy Task 32, Available from: www.ieabcc.nl 43 pp (2009)

Cushion E, Whiteman A, Dieterle G (2010) *Bioenergy development*. Available from: www.siteresources.worldbank.org 272 pp (2010)

Curry T E (2004) *Public awareness of carbon capture and storage: a survey of attitudes toward climate change mitigation*. Master of Science thesis, Cambridge, MA, USA, Massachusetts Institute of Technology, 94 pp (2004)

Curry T E, Reiner D M, de Figueiredo M A, Herzog H J (2005) *A survey of public attitudes towards energy & environment in Great Britain*. MIT LFEE 2005-001 WP, Cambridge, MA, USA, Massachusetts Institute of Technology, 35 pp (2005)

Curry T E, Ansolabehere S, Herzog H (2007) *A survey of public attitudes towards climate change and climate change mitigation technologies in the United States: Analyses of 2006 results*. LFEE 2007-01 WP, Cambridge, MA, USA, Massachusetts Institute of Technology, 48pp (2007)

Damen K, Faaij A (2005) *Greenhouse gas balances of biomass import chains for 'green' electricity production in The Netherlands*. Available from: www.ieabioenergy-task38.org 6 pp (2005)

Davidson R M (1999) *Experience of cofiring waste with coal*. CCC/15, London, UK, IEA Clean Coal Centre, 63 pp (1999)

Denruyter J-P, Máthé C (2008) *WWF position paper on bioenergy*. Available from: www.awsassets.panda.org 12 pp (2008)

Drax Group (2011) *Biomass; the fourth energy source*. Available from www.draxgroup.co.uk, 20 pp (Nov 2011)

Dwivedi P, Alavalapati J R R (2009) Stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. *Energy Policy*; 37; 1999-2007 (2009)

Environmental Defense Fund (2012) *Sustainable bioenergy: policies and practices*. Available from: www.edf.org 8pp (2012)

Eurobarometer (2007) *Energy technologies: knowledge, perception, measures*. Available from: www.ec.europa.eu/public_opinion Brussels, Belgium, European Commission, 111 pp (2007)

Eurobarometer (2009) *Europeans' attitudes towards climate change*. Available from: www.ec.europa.eu/public_opinion Brussels, Belgium, European Commission, 134 pp (2009)

Eurobarometer (2010) *Biotechnology*. Available from: www.ec.europa.eu/public_opinion Brussels, Belgium, European Commission, 385 pp (2010)

Eurobarometer (2011) *Public awareness and acceptance of CO_2 capture and storage*. Available from: www.ec.europa.eu/public_opinion Brussels, Belgium, European Commission, 185 pp (2011)

Eurobarometer (2012) *Energy for all: EU support for developing countries*. Available from:

www.ec.europa.eu/public_opinion Brussels, Belgium, European Commission, 48 pp (2012)
Fernando R P (2002) *Experience of indirect cofiring of biomass and coal*. CCC/64, London, UK, IEA Clean Coal Centre, 40 pp (2002)
Fernando R P (2005) *Fuels for biomass cofiring*. CCC/102, London, UK, IEA Clean Coal Centre, 37 pp (2005)
Fernando R P (2006) *Public attitudes to coal-fired power plant.* CCC/117, London, UK, IEA Clean Coal Centre, 43 pp (2006)
Fernando R P (2007) *Cofiring coal with waste fuels*. CCC/126, London, UK, IEA Clean Coal Centre, 34 pp (2007)
Fernando R P (2009) *Co-gasification and indirect cofiring of coal and biomass*. CCC/158, London, UK, IEA Clean Coal Centre, 37 pp (2009)
Fernando R P (2010) *Public attitudes to coal-fired power plant in the context of global warming.* CCC/177, London, UK, IEA Clean Coal Centre, 81 pp (2010)
Forestry Commissions (2011) *Public opinion of forestry 2011, UK and England*. Available from: www.forestry.gov.uk 37 pp (2011)
Friends of the Earth (2011) *Energy from biomass: straw man or future fuel?* Available from: www.foe.co.uk 18 pp (2011)
Ghent R (2011) Selby, UK, Drax Power, *personal communication* (Nov 2011)
Howell R, Shackley S, Mabon L (2012) *Public perceptions of low carbon technologies*. Available from: www.globalccsinstitue.com 115 pp (2012)
IEA Bioenergy Task 32 (2002) *Biomass combustion and co-firing: an overview*. Available from: www.ieabcc.nl 16 pp (2002)
Intergovernmental Panel on Climate Change (2011) *Special report on renewable energy sources and climate change mitigation*. Available from: www.srren.ipcc-wg3.de/report 1088 pp (2011)
Kaszewski A (2012) *WWF-UK response to the government consultation on the reform of the renewables obligation (part 1)*. Available from: www.assets.wwf.org.uk 13 pp (2012)
KEMA (2009) *Co-firing biomass with coal*. Available from: www.kema.com 16 pp (2009)
Kretschmer B, Watkins E, Baldock D, Allen B, Keenleyside C, Tucker G (2011) *Securing biomass for energy*. Available from: www.ieep.eu 79 pp (2011)
Mainville N (2011) *Fuelling a biomess*, Available from: www.greenpeace.ca 40 pp (2011)
Monroe M C, Carter D R, Hodges A W, Langholtz M, McDonell L, Oxarart A, Plate R, Hermansen-Baez A, Badger P, Schroeder R, Staudhammer C, Pullamannuppallil P (2007) *Using wood for energy in Gainesville, Florida*. Available from: www.sfrc.ufl.edu 4 pp (2007)
MORI (2005) *Attitudes to nuclear energy*. Available from: www.ipsos-mori.com 27 pp, (Nov 2005)
National Coal Council (2008) *The urgency of sustainable coal.* Available from: www.nationalcoalcouncil.org Washington, DC, USA, 172 pp (2008)
National Coal Council (2009) *Low-carbon-coal: meeting US energy, employment and CO_2 goals with 21st century technologies.* Available from: www.nationalcoalcouncil.org Washington, DC, USA, 162 pp (2009)
National Coal Council (2012) *Carbon dioxide capture and storage: the future for sustainable coal use.* Available from: www.nationalcoalcouncil.org Washington, DC, USA, 4 pp (2012)
Plate R R, Monroe M C, Oxarart A (2010) Public perceptions of using woody biomass as a renewable energy source. *Journal of Extension*; 48 (3); 15 pp (2010)
Populus (2011) *British Science Festival: Nuclear Power Research*, Available from: www.populus.co.uk 2 pp (Aug 2011)
Poortinga W, Pidgeon N, Lorenzoni I (2006) *Public perceptions on nuclear power, climate change and energy options in Britain*. Available from: www.tyndall.ac.uk Norwich, UK, Tyndall Centre for Climate Change Research, 23 pp (2006)
Reiner D, Curry T, de Figueiredo M, Herzog H, Ansolabehere S, Itaoka K, Akai M, Johnsson F, Odeenberger M (2006) An international comparison of public attitudes towards carbon capture and storage. In: *Eighth international conference on greenhouse gas control technology*, Trondheim, Norway, 19-22 June 2006. Available from: www.geos.ed.ac.uk 6 pp (2006)
Richert W (2008) *Greenpeace position on bioenergy*, Available from: www.greenpeace.org 11 pp (2008)

Rohracher H, Bogner T, Späth P, Faber F (2004) *Improving the public perception of bioenergy in the EU*. Available from: www.ec.europe.eu 95 pp (2004)
Sierra Club (2012a) *Clean Energy Solutions: Renewable Energy*. Available from: www.sierraclub.org 4 pp (2012)
Sierra Club (2012b) *Sierra Club conservation policies*. Available from: www.sierraclub.org 5 pp (2012)
Spence A, Venables D, Pidgeon N, Poortinga W, Demski C (2010) *Public perceptions of climate change and energy futures in Britain*. Available from: www.cf.ac.uk Cardiff, UK, Cardiff University, 48 pp (2010)
TNS (2003) *Attitudes and knowledge of renewable energy amongst the general public*. JN9419 and JN9385, London, UK, TNS, 97 pp (2003)
Turner A (2011) *Bioenergy review*. Available from: www.theccc.org.uk 87 pp (7 Dec 2011)
Upham P (2009) Applying environmental behaviour concepts to renewable energy siting controversy: reflections on a longitudinal bioenergy case study. *Energy policy*; 37; 4273-4283 (2009)
Upham P, Shackley S (2007) Local public opinion of a proposed 21.5 MWe biomass gasifier in Winkleigh, Devon. *Biomass and Bioenergy*; 31 (6); 433-441 (2007)
Upham P, Shackley S, Waterman H (2007) Public and stakeholder perceptions of 2030 bioenergy scenarios for the Yorkshire and Humber region. *Energy Policy*; 35; 4403-4412 (2007)
van Loo S, Koppejan J (2008) *The handbook of biomass combustion and co-firing*, London, UK, Earthscan, 442 pp (2008)
Whitmarsh L, Upham P, Poortinga W, McLachlan C, Darnton A, Devine-Wright P, Demski C, Sheery-Brennan F (2011) *Public attitudes, understanding and engagement in relation to Low-carbon energy: a selective review of academic and non-academic literatures*. Available from: www.rcuk.ac.uk 180 pp (2011)
World Coal Association (2005) *The Coal Resource*. Available from: www.worldcoal.org 48 pp (2005)
World Coal Association (2007) *Coal Meeting the Climate Challenge*. Available from: www.worldcoal.org 52 pp (2007)
World Coal Association (2012) *Co-firing biomass with coal*. Available from: www.worldcoal.org 2 pp (2012)