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1. Introduction

In 2003 the British Government released its *Energy White Paper* (DTI, 2003). In contrast to previous government energy policies, which often aimed to encourage competition in the sector and to preserve the stability of energy supply, the White Paper has a stronger emphasis on environmental issues associated with energy policy. The main focus of the White Paper was to develop procedures to minimise the contribution that the energy generation sector makes to UK emissions of greenhouse gases. To this end the paper set a target for a reduction in carbon dioxide emissions to 60% of 1990 levels, by 2050 (DTI, 2003). The method that is of most concern to this study is an increase in the volume of electricity, which is generated from renewable sources. The White Paper sets ambitious targets for renewable technologies to account for ten percent of UK energy by 2010 and twenty percent by 2020 (DTI, 2003).

Traditionally large-scale technologies have been the favoured method of renewable electricity generation, mainly due to the perceived economies of scale associated with these technologies and the fact that government policy offers limited support to small-scale schemes (Hain et al., 2005). However, recently there has been growing interest in small-scale micro-generation technologies, particularly domestic based technologies. Interest in micro-generation is also growing in government circles, with the UK Department for Trade and Industry (DTI) suggesting that by 2050 around 40-50% of UK energy needs could be met by micro-generation technologies (BWEA, 2006). Zahedi (1996, p. 916) predicts that ‘as alternative sources become more widely available, small-scale systems meeting local needs may start to replace central power stations’.

In recent years there has been increasing importance in locally based decision-making in the UK, which can be seen in the devolution agendas pursued in Scotland, Wales and Northern Ireland and the continued interest in regional government as well as the creation of elected regional assemblies throughout the UK. The *Strong and Prosperous Communities White Paper* (CLG, 2006) aims to give more freedom to local government and to engage the public in the decision-making process. Examples of this localisation of decision-making and the involvement of local residents in the decision-making process can be seen in a number of local government initiatives over recent years such as the *Local Agenda 21 process*, which involved working at the local level to encourage more sustainable practices. Although the policy was taken at an international level its implementation was conducted locally with local authorities across the UK. Growing importance of decision-making at the local level directly contrasts with the increasingly important role of the supranational European Union and multi-national energy companies in defining energy policies. However, there are attempts to reconcile these two levels of decision-making and conflicting interests, which is reflected in the *European Commission's Committee of the Regions* being described as the 'voice of local government' (EC, 2003, p.34). Still local governments often have limited input into the national energy policy agenda; however, council officers have a role in offering advice about energy efficiency and renewable options to local residents. Local authorities are also heavy energy users due to the number of buildings they operate and associated services they offer. Consequently councils have a large role to play in reducing their own energy use and in influencing energy consumption of local residents through information campaigns.

This paper investigates a local case study of different scales of renewable energy provision for local government in the UK, taking as its base the area of Kirklees, a district in northern England. In recent years the local authority – Kirklees Metropolitan Council – has chosen to invest heavily in small-scale renewable energy projects, a process which has seen a number of council buildings and municipal housing equipped with small-scale renewable plants. In this study we compare the perceived social, economic and environmental cost (SEE) of these small-scale energy technologies to larger-scale alternatives. Although the results gained from the study relate to the Kirklees area they will provide important insights for other areas of the UK and internationally.

In order to investigate if the energy could have been generated at a lower SEE cost if large-scale projects had been available a multi-criteria decision analysis (MCDA) methodology will be used to compare the advantages and disadvantages of a number of different renewable energy technologies. The data feeding into the MCDA is derived from financial analysis, Life-cycle analysis, (LCA) and other technical literature, and interviews with households, experts and members of the local council.

The study considers eight renewable energy technologies of differing scales: solar photovoltaic, micro-wind, micro-hydro, large-scale wind, large-scale hydro, energy from waste, landfill gas and biomass (wood chippings) based on the definition of renewable energy used by the UK government (DTI, 2003, p.131). Kirklees Council has chosen to invest in solar photovoltaic and micro-wind systems and is considering a micro-hydro scheme. An ‘energy-from-waste plant’ (i.e. incinerator) is currently operated by a private waste management company. The other options represent some of the most appropriate alternatives.

2. Motives for renewable energy policy

A number of factors have led to the increase in interest in renewable sources of energy and government targets set for such an increase. These will now be considered in more detail and with specific reference to the UK context.

Climatic change

The need to deliver reductions in Carbon emissions is one of the main drivers behind the increasing interest in renewables, as the electricity supply sector is responsible for around 37.5% of total CO_2 emissions (Sims et al., 2003). Increasing the share of UK electricity generated by renewables is one of the main ways in which the government aims to meet the challenging carbon reduction targets outlined in the Energy White Paper.

Security of supply

Another issue that has come to the fore in recent years is that of the security of energy supply, which may mean that society becomes increasingly vulnerable to energy supply disruptions (Correlje and Van Der Linde, 2006). Due to their often local nature, many renewable sources are not as subject to concerns regarding the vulnerability of supply.

European Union policy

The European Union also has an important influence on UK national energy policies. The European Commission has a target of doubling EU renewable energy use, from 6% to 12% by 2010. The *European Directive on the Promotion of Electricity from Renewable Energy Sources in the Internal Electricity Market* sets a target for 22% of European electricity to come from renewable sources by 2010. Member states are required to adopt a target that is consistent with the EU's target of 22%; for the UK this target is 10% by 2010 (DTI, 2005a).

The Renewables Obligation

The Renewables Obligation, launched in 2002, is a major driver for the diffusion of renewables in the UK. Under the obligation suppliers must source a percentage of their energy from renewable sources; for each megawatt hour of renewable generation the supplier receives a Renewables Obligation Certificate (ROC). Suppliers can meet their obligation by: (1) acquiring ROCs, (2) paying a buy-out price of £30/megawatt hour or (3) a combination of ROCs and paying a buy-out price (DTI, 2005b). Despite being technology non-specific, the Renewables Obligation has been criticised for favouring large-scale energy generation technologies (Mitchell and Connor, 2004; Hain et al., 2005). One of the main reasons for this is that technologies with a generating capacity of less than one megawatt are excluded from the Renewables Obligation scheme; this applies to many small-scale applications.

Energy Planning Guidelines and Public Involvement

The British planning system is based upon a number of Acts of Parliament; however, these only provide a framework, which is to be interpreted for each individual case, in the light of secondary legislation (Planning Policy Guidance) and based on case-specific factors (material considerations). Central government planning policy is often communicated in the form of Planning Policy Guidance notes (PPG) and Planning Policy Statements (PPS): the relevant statement for renewable energy is the PPS22. Public opinion is a very important determinant of which technology is selected for which application. The PPS22 states that:

> ‘Local planning authorities, regional stakeholders and Local Strategic Partnerships should foster community involvement in renewable energy projects and seek to promote knowledge of and greater acceptance by the public of prospective renewable energy developments that are appropriately located’ (ODPM, 2004).

In some cases local opposition has hindered the development of renewable energy schemes; this has had a negative impact upon the achievement of renewables targets. In other cases renewables schemes have been developed within local communities, often through local energy cooperatives. By giving local residents a stake in the project they are less likely to see the development as being imposed upon them, consequently the development is likely to encounter less opposition at the planning stage and is likely to be more popular among local residents (for a discussion in the participation literature see e.g. Arnstein, 1969; Smith, 2003; Stringer et al., 2006). A second reason for participation mentioned in the literature is normative in that it focuses on what ‘ought to be’ in a democratic society based on the idea of enhanced legitimacy of the process itself, the inclusion of the relevant stakeholders, and notions of fairness (O’Connor et al., 1996; O’Neill, 2001; Gross, 2007). Finally and most commonly, participation is propagated for its ability to generate better data as it incorporates local and diverse knowledge. This is based on the idea that local people are the real ‘experts’ of their respective local environments (Backstrand, 2004; Fiorino, 1990; Funtowicz and Ravetz 1991).

Often the outcome in favour of one technology over another is down to management of the participation of the relevant stakeholders and communication between them (Wüstenhagen, 2007). There is widespread recognition of this in the literature but often the institutional capacity is lacking. For example, the spatial planning systems in some countries, such as in the Netherlands or Sweden, do not encourage collaborative planning processes or community involvement in e.g. wind power developments (Wolsink, 2007).

Participation has many different dimensions and can take on different forms throughout complex processes especially those associated with regards to investment and facility siting decisions of energy technologies. Such decisions affect not only the investor but have effects on the local or regional community (e.g. Wüstenhagen et al. 2007). In our paper we are only referring to a weaker form of participation in eliciting data from residents as inputs to a multicriteria decision aid. .

3. Rationale for the use of MCDA and introduction to MCDA methods

Multi-criteria decision analysis (MCDA) techniques have become increasingly popular in recent years and are widely used in energy planning (e.g. Carallaro and Ciraolo, 2005; Gamboa and Munda, 2007, Stagl, 2006). Major advantages of the MCDA methodology over other decision support methods are that the methodology acknowledges that decision-making is a complex process and helps to provide a rational basis for the structuring of decision-making. Energy decision problems are often complex. Energy installations or plants need to satisfy a number of objectives, across a wide range of issues; for example, a new plant may need to provide good value for money, low maintenance costs, whilst at the same time having a large and stable energy output and positive social and environmental effects. Reconciling the different objectives within the decision-making process often provides a challenge.

All energy developments will impact upon a number of different stakeholders in different ways; thus reaching a consensus of opinion among stakeholders is often one of the most time-consuming and difficult stages of the planning process (for an example of stakeholder participation in an MCDA process evaluating alternative energy scenarios see the Artemis project)[1].

The difficulty of reaching consensus of opinion among stakeholders is further complicated by the fact that the effects of many decisions are subject to long time horizons, which provide a greater level of uncertainty. This is especially so in fast changing areas such as the energy sector; uncertainty of future trends in the sector and the price of energy in future years increases the challenge on the decision-maker.

The issue of monetary valuation of impacts also complicates the decision-making process. Many of the criteria that a decision-maker must take into account are difficult to quantify, especially when dealing with information about environmental and social costs and benefits; this can make comparison of these criteria with ones that are tangible, such as financial estimates, difficult.

[1] This project seeks 'to further develop and apply a participatory tool for the multi-criteria evaluation of alternative renewable energy scenarios for Austria'. A large part of the project involves investigating issues relating to stakeholder participation in the MCDA process, including considering the differences between decisions made by 'citizens' and 'policy makers' and investigating how active participation in the MCDA process affects the participants' energy utilisation. The study also considers differences in the decision making process at national, regional and local levels (http://www.project-artemis.net).

MCDA helps to overcome some of these issues to a greater extent than other decision support tools, such as cost-benefit analysis. The methodology is capable of considering a number of different objectives, which can be weighted to reflect the hierarchy of objectives. The methodology often involves widespread stakeholder participation; this can act to improve the accountability and transparency of decisions reached and to provide greater levels of ownership over the decision-making process and its outcomes. For these reasons diverse applications of MCDA are often used in government and public sector planning where the accountability of decisions to the public is vital. This involvement of stakeholders is one of the main drivers behind the development and use of MCDA. This method facilitates the process of decision-making by making clear the assumptions of the various stakeholders by providing a structured process with an audit trail supporting learning and evaluation. This allows for transparency to stakeholders and can be easily followed by local residents. However, the transparency surrounding the methodology does not necessarily lead to social acceptance of the decision outcome. Social acceptance is based on complex processes involving a variety of cognitive and emotive elements and different social actors will have different and possibly contrasting viewpoints, in cases where such conflicts arise full social acceptance may be impossible to achieve. Although social acceptance may be difficult to achieve the transparency surrounding the method does allow stakeholders to see the processes that were undertaken in the decision-making exercise, even if they do not fully agree with the final decision outcome.

Despite being an improvement on many other decision support tools the stakeholder participation techniques used in MCDA are far from perfect and it is still often difficult to reconcile competing priorities among stakeholders and reach a consensus of views. Hobbs and Meier (2000) identify two further weaknesses in the stakeholder participation processes employed by MCDA: (1) the issue of information pollution, whereby so much information is generated in the analysis that stakeholders find it difficult to consider all of the information resulting from the analysis and (2) that MCDA techniques are often difficult to repeat or verify due to the cost involved with assembling a wide range of stakeholder groups. As the methodology allows scoring of criteria, as opposed to the use of direct monetary estimates, it is better able to cope with decisions where intangible attributes need to be considered.

These strengths of the MCDA methodology have led to its rapid development over recent years and a number of different methods of MCDA have been developed including: ELECTRE III (Roy, 1978), Analytical Hierarchy Process (Saaty, 1980), PROMETHEE II (Brans et al., 1985), NAIADE (Munda, 1995) and MACBETH (Bana e Costa and Vansnick, 1997, 1999). MCDA methods can generally be split into two classes: multiple objective decision making, where the alternatives are not predetermined but a set of objective functions is optimised until the most efficient solution is found and multiple attribute decision making, where alternatives are determined and the decision-maker indicates his preference for each objective, until an efficient solution is found (Haung et al., 1995).

This study uses the MACBETH method. MACBETH involves a series of pairwise comparisons, where the decision-maker is asked to specify the difference in attractiveness between all of the alternatives. From this information the programme calculates a set of scores that is consistent with the comparisons. (For more information on MACBETH consult Bana e Costa and Vansnick, 1997, 1999). MACBETH was chosen for use in this study due to the ease with which the method can handle values that cannot be easily quantified. Qualitative judgments can be entered into the model, these are then verified by the software in order to check that they are consistent with other judgments, before the software produces a quantitative model of the decision context.

4. Methodology

Two main methods of data analysis were utilised in this study: a MCDA using the MACBETH method and a cost-benefit analysis. Diakoulaki and Karangelis (2006, p.718) suggest that both methodologies have the same goal: that of broadening 'the evaluation perspective so as to incorporate all aspects that should guide the decision procedure'.

The MCDA considered the relative efficacy of the eight technologies in relation to the following eight criteria: (1) capital cost, (2) operation and maintenance cost, (3) generation capacity, (4) lifespan, (5) carbon emissions, (6) noise, (7) impact upon the natural environment, (8) social effects. These criteria were selected following consideration of the main issues surrounding the viability of renewable energy developments and due to the need to have a breadth of criteria covering social, economic and environmental issues. The scores for 'capital cost' and 'operation and maintenance cost' were based on costs for different renewable technologies provided by De Noorde et al. (2004). For non-cost criteria a score was created between 0 (very poor) and 100 (excellent) depending upon how well the technology under consideration performed towards that criterion. Details of the scores used in this study can be found in appendix 1

Interviews were carried out with five professionals with experience in the energy sector three of these were from Kirklees Council, a further two were from other organisations. All of the interviewees have experience in a professional context with energy or have an interest in energy and all have a good knowledge of energy issues. One of the interviewees is an officer in the Council's Environment Unit, who had responsibility for managing the Council's renewable energy policy and had been responsible for the planning of the Council's current renewable projects and two of the interviewees are local councillors, both of whom have an interest in energy issues and have been actively involved in encouraging renewables proliferation at Kirklees. Of the two non-council energy professionals one is an advisor to the Renewable Energy Association and one is a local environmental campaigner with an interest in energy issues. These interviews were used to inform the scores to be given to some of the criteria in situations where valuation was difficult.

The social scores are heavily dependent upon public perception. Consequently these scores were defined with the aid of a series of householder interviews. These interviews were conducted with twenty-five householders and aimed to elicit their opinion about the merits of each technology. The interviews were conducted with each interviewee separately rather than using a decision conference or focus group approach. It was thought that conducting the interviews in this way would ensure that the interviewees were not influenced by each other.[2] The interviewees were selected using a quota method, to ensure that the respondents were representative

[2] For an interesting example of the different types of information elicited through the different methods, albeit in a different context, see Burgess et al. (1998).

of the demographic characteristics of the area. In order to limit variation in the interview a structured interview format was utilised, with the questions and question order being the same for all interviewees. Of course the sample size is too small to allow for a statistical representation of the whole population in that area but does give some indicative assessment of the questions at hand. The interviewees were generally consistent with their judgements (with low standard deviations of 21). The social interviewees were asked to rate each technology, out of one hundred, based upon their pre-existing knowledge of those technologies. This approach may seem arbitrary and open to bias, especially if the interviewees are misinformed about particular aspects of technologies. However, as a publicly accountable body led by elected representatives the council considers public opinion in the decision-making process. Thus the aim of this tool was to gain an assessment of how members of the public saw the advantages and disadvantages of each technology and thus the level of public support for each technology.

The weights used in the MCDA were derived from the interviews with the energy professionals. We decided to use the input of the council representatives to define the weights, as they would be able to provide information as to how important each criterion is deemed to be by the council. The input of the two interviewees who were not representatives of the council was used in order to provide further strength to the information gained from the council representatives. To provide simplicity in the process of defining weights the interviewees were each asked to rate each criterion from one to ten with ten being very important and one being very unimportant, a simple average was then calculated to provide the final weights used in the analysis. Details of the final weights used can be found in appendix 1.

In order to identify which of the technologies included in the study, and consequently which scale of technology, was the most financially viable a cost-benefit analysis was carried out that involved calculating the net present value (NPV) for each technology, using the cost and revenue streams over a thirty-year period[3]. Data relating to the costs (capital and operational) of each technology were acquired from a study by De Noorde et al. (2004). For the electricity produced a rate of €0.15 per kilowatt was used: a figure broadly in line with current market rates.

This combination of various types of data used in a multicriteria framework is both a strength and a weakness, as there are a number of data problems that come with the nature of the data. One problem is that the capital costs associated with technologies vary widely depending upon the type and manufacturer of the technology chosen and the exact design specification required. This was somewhat counterbalanced by using the same source for all of the cost data (De Noorde et al., 2004). Another limitation is that the consideration of the lifecycle costs of each technology was limited to technologies for which such data could be found. In situations where this could not be found this information was ascertained from the knowledge of the expert interviewees; this may have limited the consideration of the lifecycle cost associated with each technology. The relatively small sample size of the expert interviews may have biased the collected information somewhat. As the information derived from the interviewed experts did not vary too much we feel that the number of interviews conducted provided an adequate basis for the study. There are also some validity considerations with questionnaires. For example, some of the householder interviewees found it difficult to grasp the concepts

[3] All of the financial calculations were calculated over a period of 30 years except wind technologies which were calculated over a period of 25 years, as this is at the upper end of the lifespan for wind technologies.

associated with the interviews and some seemed to be discussing issues outside of the scope of the question being asked. A sensitivity of the interviewer and a careful prodding is sometimes necessary to ensure that we elicit appropriate responses. And finally, the selection of the criteria on which the alternatives are assessed and the assigned weights are of crucial importance. It is thus very important to include the relevant stakeholders to elicit this information.

5. Discussion

5.1 Social indicators

Although primarily to provide input into the MCDA exercise the results of the householder interviews provided interesting information about how the technologies are seen by residents, consequently we will discuss some of the results gained in greater detail.

Noise is a recurring issue, especially in conjunction with wind energy, in the planning process for new energy developments. Although sound can be measured objectively noise is often subjective and a particular level of noise may bother some people but not others (see for example, Munksgaard and Larsen (1998) who found wide differences in the extent to which sound from a wind farm was a nuisance to surrounding residents, a finding that was confirmed in our expert interviews). Noise was also an important issue amongst the householders interviewed and proved to be one of the most important issues in defining their views on the social acceptability of each technology. In terms of noise, small-scale applications were generally superior; this can mainly be attributed to the fact that larger technologies will generally create a greater level of sound during operation.

Figure 1

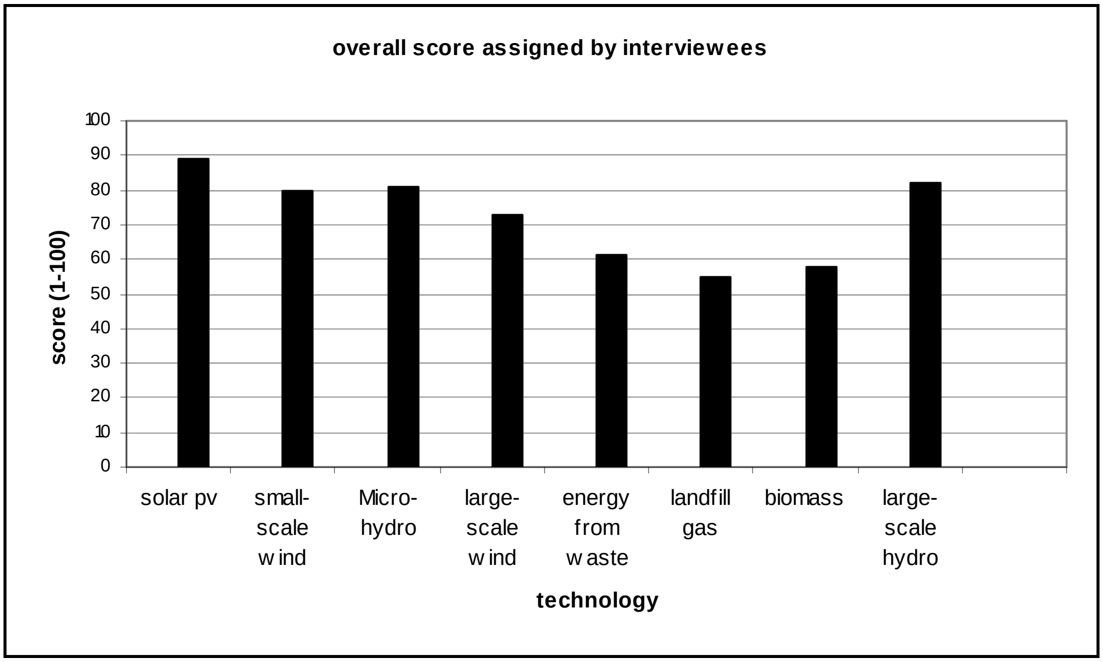

Fig. 1. Social score (1-100) assigned to each technology during the householder interviews, the score 1 being least favourable and 100 being most favourable.

Figure 1 presents the score assigned by the householder interviewees. This exercise asked the interviewees to rate the technology, based upon their prior knowledge of the technologies. Consequently the question elicits a public opinion score for the technology which was used to inform an overall social score criterion in the MCDA exercise. Generally the small-scale technologies were deemed to be the most favourable among the interviewees. On average the overall score assigned to small-scale technologies was twenty-six per cent higher than that assigned to large-scale technologies. This indicates that the public are generally more comfortable with the use of small-scale technologies in their locale. Whether they would be happier without any energy generation technology in their local area will now be considered.

The concept of NIMBYISM (not in my backyard) is based on the idea that public support for renewable energy is generally high; however, when it is proposed to build a development in a particular area this support seems to disappear. However, the concept has been subject to a great deal of debate about its credibility suggesting that it is an oversimplification of complex processes and other factors that are behind local opposition to schemes (Wolsink, 1994, 2000, 2007; Hunter and Leyden, 1995). Warren et al. (2005) found NIMBY attitudes did occur among the public; however, they also found an 'inverse NIMBYISM' where people living closest to the technology were most in favour of it. The debate over the validity of the NIMBY hypothesis is beyond the scope of the present study; however, if it holds it forms an important driver on the social acceptance of renewable technologies and thus is worthy of mention. The findings of this study imply that public acceptance of the small-scale technologies was generally higher than that of the large-scale technologies. A number of reasons for this may exist: (1) Small-scale technologies, by definition are often much smaller; this means that their negative impacts upon the local community is perceived as being lower. This includes the visual impact and other operational impacts such as noise, air pollution etc., as well as the impact upon the local built and natural environment. In terms of the visual aspect it is highly probable that smaller applications will have an improved public perception due to their scale; however, a paradox arises in that due to their lower generation potential a greater number of plants will be needed to generate the same amount of electricity. (2) The social acceptance of a technology is heavily dependent upon personal tastes and preferences. This could clearly be seen in the score given to the large-scale wind turbines in the householder interviews, with some interviewees giving very low scores and others relatively high scores. (3) People may feel threatened by large developments. This is likely to be a psychological reaction based upon the public's knowledge (correctly or incorrectly) that a particular technology or scale of technology poses a risk. For example, people often worry about the health effects of emissions from energy from waste plants (Reams and Templet, 1996) and those living near large-scale hydroelectricity plants may worry about the safety of such plants and the threat of terrorism.

Another social issue relating to small-scale technologies is that the development of such technologies is often more community based, with local residents having more interaction in the planning of the development and sometimes in its operation. A good example of this from Kirklees is the micro-wind development at Spen Valley Sports College, near Dewsbury; this development was planned and developed by pupils as part of the school curriculum. This helped the pupils and their parents to develop a greater understanding about the benefit of renewable energy.

5.2 Economic effectiveness

Table 1 presents the results of the cost-benefit analysis. The results of the analysis show that all of the technologies considered in the analysis were financially viable (an NPV above zero); however, the large-scale technologies were generally more viable, with the large-scale hydro development delivering the best value for money over the period; this was despite the large capital and operation and maintenance costs associated with this technology. The three small-scale technologies offered the least value for money.

Table 1

Rank	**Renewable technology**	**Scale**	**Net Present value (000) Euros over a 30**

			year period)
1	Large-scale hydro	Large	350,444
2	Energy from waste	Large	139,845
3	Landfill gas	Large	37,866
4	Biomass	Large	28,610
5	Large-scale wind*	Large	9,003,
6	Micro –hydro	Small	6,211,
7	Solar PV	Small	1,185,
8	Micro-wind*	Small	289

Table 1 Net present values (NPV) for renewable energy technologies (discount rate of 3.5%)

* Wind technologies were calculated over a period of 25 years.

The picture presented of economic effectiveness shows the opposite of what we have seen with social effectiveness, where the smaller-schemes were generally more favourable. It should be noted that small-scale projects often have a better record at keeping money in the local area, boosting the local economy and often helping to bring about community regeneration, through the provision of jobs in the local area. The NPV calculations considered only the directly quantifiable costs and benefits; consequently the calculations did not take into account indirect economic benefits such as the employment of local people in installing and maintaining the technologies. Consideration of these benefits may act to improve the financial viability of small-scale schemes.

Although capital costs of large-scale projects are much higher, they generally generate a much larger volume of electricity, helping to offset the large capital costs. Due to their greater output large energy suppliers often favour large-scale generation options leading to investments and thus innovations and efficiency gains for large-scale technologies which further helped to reduce the cost per unit of electricity generated from large-scale applications. Such a scale of research and development activity has not been present in the development of small-scale applications, thus the price reductions associated with technological development are only just starting to reduce the price of small–scale electricity. Although the price of energy from many small-scale applications has been continuously declining in recent years, in many cases the cost per unit output of small-scale technologies continues to be high compared to that of large-scale technologies.

Current renewable energy policy in the UK generally supports large-scale applications (Mitchell and Connor, 2004; Hain et al., 2005); this has an impact upon the financial viability of small-scale schemes. It is often difficult for energy generated from small-scale applications to be sold back to the national grid (see also earlier discussion on the Renewables Obligation scheme).

5.3 Environmental effectiveness

In terms of environmental effectiveness small-scale applications were generally more favourable. In this study two criteria were considered to be indicators of environmental effectiveness: ‘carbon emissions’ and the ‘impact upon the natural environment’, which had more general scope, considering issues such as the impact of the technology on the flora and fauna in the locale of the technologies. The ‘carbon emissions’ criterion attempted to quantify both the emissions from that particular technology (where appropriate) and also emissions resultant from the manufacture and construction of the technologies; this part of the analysis is based on the use of lifecycle data (where available) and also information from expert interviews. All carbon analysis was done on a per-unit-of-output basis. The ‘impact upon the natural environment’ criterion embraced information provided by the expert interviewees about the relative impacts of the technologies on the environment and also appropriate literature about the environmental impact of the technologies.

In relation to both environmental criteria considered small-scale technologies generally performed best. In terms of the ‘impact upon the natural environment’ criterion being smaller in scale meant having lower impacts upon their surroundings; however, this gives rise to a paradox in that due to the lower generation potential of small-scale applications a greater number are required, this may limit the difference between the environmental efficacy of small and large-scale applications. There is apparently a trade-off between local consumption and production through small-scale technology more focused on the local demand and higher efficiency and concentrated production of energy for more remote areas.

5.4 Overall social, economic and environmental effectiveness of technology

Table 2 and Figure 2 presented show the results of the MCDA. This analysis was used in order to discover how each technology and scale of technology performed in relation to the overall SEE effectiveness. In table 2 the performance of each technology is shown by the MACBETH rating, the higher the rating the better performing that action.

Technology	Scale	MACBETH rating
Solar PV	Small	88.33
Micro-hydro	Small	69.28

Micro-wind	Small	50.66
Biomass	Medium	50.14
Large-scale wind	Large	48.73
Landfill gas	Large	48.19
Large-scale hydro	Large	36.54
Energy from waste	Large	33.58

Table 2 Results of the MCDA

Note: a score of 100 indicates that the alternative is very favourable whereas a score of 0 indicates that the alternative is not favourable]

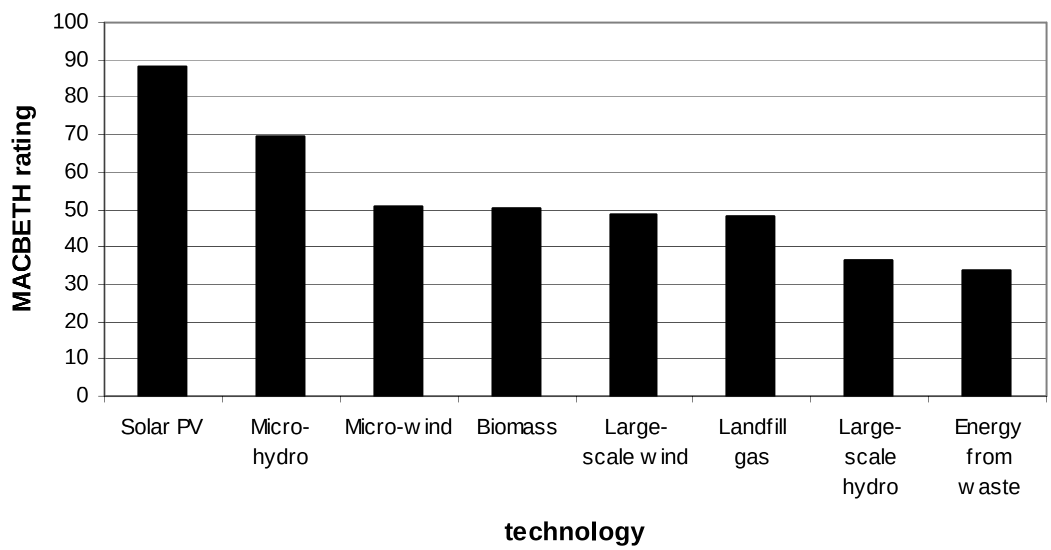

Fig. 2. Performance of each technology in the MCDA

The results of the analysis indicate that the small-scale developments are the most SEE effective, with the three small-scale applications being ranked as the three most favourable technologies. This is probably due to the fact that the small-scale technologies were favoured by both the social and environmental criteria as well as by some of the financial criteria as they generally had low capital, operation and maintenance costs.

A sensitivity analysis was conducted using the sensitivity function built into the MACBETH software. This analysis showed the range of weights within which the dominant alternative was stable. The results of this analysis are shown in table 3.

criterion	Dominant alternative	Original weight	Range within which the dominant alternative is stable	
			Min	Max
Capital cost	Solar PV	13	0.00	100.00
Operation and maintenance	Solar PV	12	0.00	100.00
Generation capacity	Solar PV/ Energy from Waste	15	0.00	50.1
Lifespan	Solar PV	13	0.00	100.00
Carbon emissions	Solar PV	15	0.00	100.00
Noise	Solar PV	9	0.00	100.00
Natural environment	Solar PV	10	0.00	100.00
Social score	Solar PV	13	0.00	100.00

Table 3 Stability intervals for the MCDA

The large range of weights within which the dominant alternative remains dominant indicates that the overall ranking is not sensitive to a change in weights. Only for one criterion, generation capacity, can a change in the weight lead to a change in the dominant alternative and this would require a very large weight, over 50% of importance, to be assigned to this criterion.

The results of the financial calculations used in this study show the antithesis of the results of the MCDA, with the financial calculations showing the small-scale approaches to be the least effective whilst the MDCA shows the small-scale applications to be the most effective. In this respect the results of this study compare to those of Mirasgedis et al. (2000) who found that methods which considered only the internal costs and benefits gave results which were different to those when the wider costs and benefits associated with a technology were considered. As such the results of our study add to the debate surrounding the use of multi-criteria methods of project appraisal as opposed to the use of the cost benefit analysis, which traditionally considers only financial aspects, although the process of contingent valuation is often used to attempt to value environmental and social costs for use in cost benefit analysis. Decisions reached following the use of MCDA are likely to be more effectual in that they take into account wider costs and benefits, some of which may be difficult to quantify; however, this may lead to greater levels of conflict among stakeholders over the values and weights used in the MCDA.

5.5. Limitations

There are a number of limitations associated with the study, mainly with the data collection aspects. One issue relates to the awareness of the householder interviewees. The interviewees were asked to rate each technology based upon their current knowledge. Although some interviewees were more aware of the different aspects surrounding the technologies this may have introduced a bias in that interviewees’ pre-existing knowledge of a technology may be in some cases inaccurate or incorrect. However, social acceptance of new developments is based upon the publics' awareness of the different aspects and consequently it was thought that this method was the best way of eliciting the social score.

Another issue relates to the expert interviewees. Due to resource constraints only five experts were interviewed. Three of these were representatives of the local authority, as the aim of the exercise was to ascertain the priorities of the local authority, a further two were from other organisations, these interviewees gave more greater perspective to the data and would help reduce any bias that would arise from all of the interviewees working for the same organisation.

6. Conclusion

The need to increase the share of renewables in the overall energy mix has become increasingly important in recent years; the target set in the Energy White Paper for 10% of UK energy to come from renewable sources by 2010, and similar commitments by other governments, demonstrate this. This study has considered whether small-scale or large-scale approaches to renewable energy provision are best placed to help meet these targets at the lowest social, economic and environmental cost.

The results indicate that small-scale approaches have more merit from a social and environmental perspective and that large-scale approaches are more economically viable given current cost structures. In terms of the overall social, economic and environmental cost, the results demonstrate that small-scale approaches are more effectual in this case study.

Although the results of this study have shown that small-scale approaches are often more favourable in terms of overall social, economic and environmental effectiveness there will be situations in which large-scale approaches are more effective and it is likely that all scales of renewable technology have a place in helping to meet the targets for renewables proliferation.

At the current time, the majority of demand for renewable energy comes through 'renewable tariffs' provided by electricity companies, as opposed to home generation options. These companies often favour large-scale generation options, due to the higher levels of output achieved by these technologies, as does government policy through the Renewables Obligation; these issues may mean that growth in the small-scale generation sector remains difficult to achieve.

Practice from other countries provides an interesting contrast to UK policy. A number of countries have more formalised feed-in tariff mechanisms based upon a premium price paid for renewable energy combined with responsibilities placed upon energy companies to source a certain percentage of energy from renewable sources. In Spain the government has set targets for renewables generation by technology. In terms of the feed-in tariff suppliers could choose either a fixed premium (on top of the market price) or a fixed total price (Del Rio and Gaul, 2007) Denmark had originally planned a system of green certificates, under the scheme 'Danish consumers had an obligation to buy 20% of the electricity consumption from renewable sources' (Agnolucci, 2007, p. 955), this scheme was eventually scrapped and replaced by a premium price paid for renewable energy fed into the grid. Such a scheme would contrast with UK policy in two ways. One is that it targeted the consumer whereas the targets in the UK Renewables Obligation apply to the energy companies. The second is that in the UK suppliers can absolve themselves of their responsibilities under the renewables obligation by paying a buy-out price.

Despite these differences in the various institutional frameworks, the problems of wide spread adoption of renewable energy schemes do show similar elements, such as the cost structure and acceptability based on perceived social and environmental impacts. Thus a transparent decision aid such as MCDA provides structure and greater transparency and would be an important component to help further diffuse environmentally friendly technologies.

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Appendix

Appendix 1 scores and weights used in the MCDA

	Capital cost	Operation & maintenance	Generation capacity	Lifespan	Carbon emissions	Noise	Impact on natural environment	Social score
Solar PV	100	100	22.22	100	100	100	100	100
Micro-hydro	80	85.71	33.33	57.14	100	83.33	50.00	66.70
Micro-wind	100	28.57	0.00	0	100	50.00	75.00	55.66
Large-scale wind	60.00	71.43	55.56	0	60.00	33.33	62.50	44.44
Large-scale hydro	0.00	0.00	66.67	57.14	40.00	33.33	0	77.78
Biomass	60.00	57.14	44.44	57.14	60.00	50.00	50.00	22.22
Landfill gas	40.00	42.86	77.78	57.14	60.00	66.67	37.50	0
Energy from waste	20.00	14.29	100	57.14	0	0	25.00	33.33
Weights	12	11	13	13	13	8	8	14

Table 4