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Renewable Energy in Remote Communities

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Renewable Energy in Remote Communities

Abstract

This research has demonstrated that even in a small urbanised country like Britain, communities can still be remote. The paper analyses the nature of remote settlements and suggests that beyond the rural idyll, there are deprived communities. In order to obtain real data, a study area in the North Pennines was selected. The types of remote communities were evident throughout the study area and one of each type was selected for further study. It became clear that villages with an industrial base had most potential, due to high energy demand, vulnerability and community involvement. A village with a high measure of multiple deprivation and suffering from fuel poverty was chosen for a more detailed investigation. Energy demand profiles were developed and candidate technologies nominated. The latter were tested by filters that assessed fitness for application, robustness and autonomy. The most appropriate combinations of technologies were proposed. The residents and their community representatives were involved in the process and recognised the benefits of the proposals to themselves and others.

Keywords: Renewable Energy; Remote Communities; Community Involvement; Local Energy Sources

1. Introduction and Background

In a highly populated, developed, urbanised, small country like the Britain, it may be difficult to conceive that communities could be remote. However, remoteness is a relative concept and one that is not necessarily based on distance. Significant regions of Britain contain settlements that range from an individual house to small towns with populations exceeding 1000 people. A dependence on energy derived from national-grid-based electricity and transported fuel are features that most of these settlements have in common. Thus the inhabitants are vulnerable to energy supplies that have reduced reliability and protracted repair times and can be more expensive at the point of use than in other parts of the United Kingdom. In major parts of the UK, electricity supply infrastructures are nearing the end of their economic life (DTI 2003). When all of these considerations are taken together, it is clear that remote communities require new methods of energy supply that are reliable, sustainable and afford a maximum degree of user-independence. In addition, the United Kingdom has an obligation to reduce carbon emissions by 12.5% of the prevailing 1990 level by 2008 – 2012, as part of the Kyoto agreement.

The purpose of this work is to develop a new approach to meeting the energy needs of remote rural communities, working with one of the communities to ensure that the key goals of robustness, autonomy and sustainability can be achieved.

2.Characteristics of Remote Communities

Significant parts of upland England – Pennines, Lake District; Dartmoor and Exmoor in the South West; a proportion of Wales and much of Scotland meet Hanley and Nevin's (1999) criteria of:

- Low population densities
- Limited conventional energy sources
- Lack of infrastructure
- Low levels of economic activity
- Physical access constraints
- Long distances to external markets

Cloke (2003) notes that the overwhelming perception of rural communities is based on the rural idyll concept. This finds its origins in the picturesque movement of the 18th century, and continues to be associated with privilege and wealth. While some land owners have been part of this concept for generations, analysis of communities shows that the majority are incomers (Bunce 2003). The argument proposed by cloke et al. (1997, 2003) is that the image of the rural idyll has excluded other types of community from view. By contrast, these types of community may be deprived and poor, marginalised and subordinated (Philo, 1992). Indigenous communities based on agriculture have been part of the idyll concept. However, this has become increasingly less convincing, and images associated with the 2001 foot-and-mouth disease outbreak, demonstrated a clear divide between the two types of community (Scott, Christie and Medmore, 2004). The Government Department for Environment, Food and Rural Affairs (DEFRA) also makes this distinction. It refers to *lagging areas*, which are typically remote and have often seen a decline in traditional industries such as agriculture and mining. These areas have a high incidence of low earnings, poor job opportunities, low workforce skills, health inequalities and poor housing (DEFRA 2005). In Teesdale, it does not seem to be the case that communities based on indigenous agriculture have moved from the idyll concept to the industrial model. They appear as a third distinct type of community that is maintaining its socio – economic position. Lobley and Potter (2004) and Prag (2005) suggest that while agriculture has been declining, the adaptability and diversification demonstrated by indigenous communities, has largely prevented them from becoming *lagging areas.* The latter are defined by DEFRA (2005) as having a measure on the Index of Multiple Deprivation of 25 and above. A related measure for concern is fuel poverty. This is defined as *households spending more than 10% of income on keeping themselves warm* (DEFRA & DTI 2006). DEFRA is targeting resources at areas of greatest need and Government is pledged to eradicate fuel poverty in vulnerable communities by 2010. This pledge particularly targets the elderly, disabled, and permanently ill, as being the most vulnerable in society. There are a number of mechanisms involved, for example the warm front scheme and decent homes standard, which are aimed at reducing energy loss and insulating existing houses. The Government's Community Energy Programme provides grants to support installation of community energy systems across the UK. One of its key aims is to help 100,000 people on low incomes to heat their homes. The Department of Trade and Industry has undertaken to provide mains gas connections to deprived communities, where viable. Where this is not viable, the Department has suggested that renewable energy solutions should be investigated (DEFRA & DTI 2006). A number of remote communities have started this process, as shown by activities on the Scottish Isles (Scottish Renewables 2006).

3.Study Area

In order to assess the nature of remote communities in practice, an area of England known as Teesdale was selected for the study. It is part of County Durham centred on the market town of Barnard Castle, and surrounds the upper reaches of the River Tees, from its source in the hills to where the river broadens out towards the Tees Valley. The area received publicity for its remoteness through the books and television appearances of Hannah Hauxwell (Hauxwell & Croft 1989). In 2001, it became part of a major Commission of the European Communities SAVE and ALTENER project titled *Practical Partnerships for Achieving 100% Renewable Energy Communities* which led to the Teesdale Renewable Energy Challenge (The Northern Energy Initiative 2003).

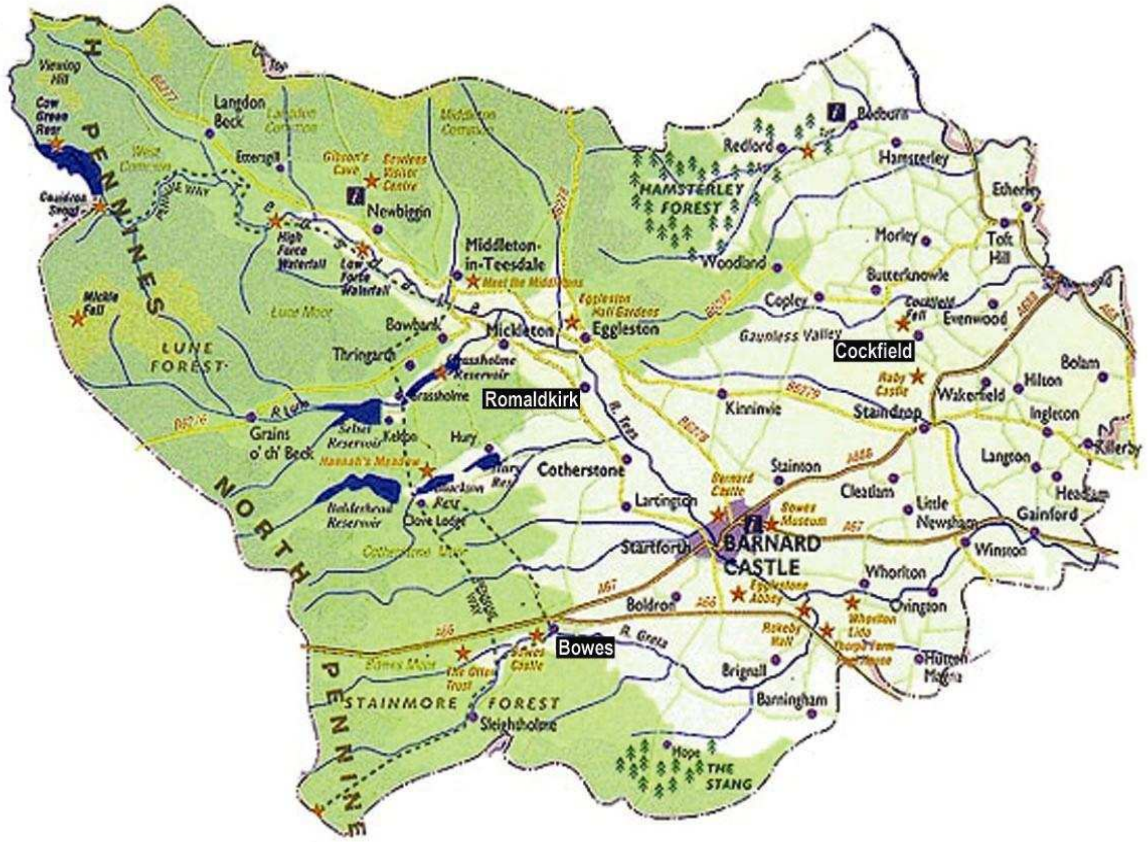

Figure 1: Teesdale Study Area

The models of remote communities as idyll, indigenous and industrial, were discovered throughout the area, and epitomised by three villages – Romaldkirk, Bowes and Cockfield. A socio-economic profile of the villages was summarised as follows:

	Romaldkirk Idyllic	**Bowes** Indigenous	**Cockfield** Industrial
Population	900	700	1500
Village Services	Low	Low	High
Good Health	Medium	High	Low
Permanent Ill	Low	Medium	High
Employed	High	High	Low
Retired	Medium	Low	High
Pensioners	Medium	Low	High
Children	Medium	Low	Low
Qualifications	Medium	Medium	Low
Council Rented	Low	Low	High
Without Car	Low	Low	Medium
2 Cars or more	High	High	Medium
Public transport	Low	Medium	Medium
Index of multiple deprivation	15.17	15.64	27.11

Table 1: Summary of Socio-economic Profile of the 3 Villages

(Teesdale District Council 2002a, Teesdale District Council 2002b, Teesdale District Council 2002c, National Statistics Online)

The aspects shown in the socio-economic profile generate the Index of Multiple Deprivation. It can be seen that idyllic and indigenous agricultural communities, as represented by Romaldkirk and Bowes are in a relatively comfortable position. By contrast, Cockfield's 27.11 places its community in the most vulnerable category, ie greater than 25. There is also a measure for fuel poverty. The percentage of households in fuel poverty nationally, averages 5.9% and the percentage for the North East is 9.5 (DEFRA & DTI 2006). Using the Centre for Sustainable Energy and Bristol University's Fuel Poverty Indicator, the figure for Cockfield is 28% (Teesdale District Council 2006). Following DTI policy, Powergen undertook a Teesdale Gas Mains Extension Feasibility Study that assessed the infrastructure cost of providing mains supply to the 759 properties in Cockfield at £956250 (Ludgate 2002). This did not achieve the level of viability required by the DTI's Business Model. In fact, the report states that the high capital costs associated with the connection of communities to mains gas has resulted in very few such connections since privatisation of the gas industry (Grant 2005). Thus it is in accordance with DTI strategy that renewable solutions should be investigated.

Remoteness from a social perspective means that there is less access to goods and services, where the latter can include education and entertainment (Hanley & Nevin 1999). Social exclusion can therefore occur if there is not sufficient cohesion within the community itself. The Government has stated that measures of success in community cohesion have not yet been addressed in a systematic manner (Office of the Deputy Prime Minister 2004). However other research highlights – commitment to the local area, informal social networks and organised community activities as major issues (Fitzpatrick 2004). There are no absolute measures of these criteria, but in the case of Cockfield, there is a Community Centre that is well used. Apart from meetings of the Parish Council and Ward Partnership, there are eighteen different, well-established community groups. There is a hard-working community association that provides services for residents and particularly young people. It publishes a newsletter *The Voice* which is distributed to each household; and there have been twenty two improvements implemented as a result of the previous community action plan (Teesdale District Council 2002c). The village took part in a *Planning for Real* exercise in 2000. This involved building a village model that proved to be an excellent method of involving local people. All these factors would seem to indicate an active and cohesive community.

In this case the figures also demonstrate large heating and electricity demands.

Village	**Heating Demand (GWh)**	**Electricity Demand (GWh)**	**Percentage of the total**	
Romaldkirk	2.12	0.399	12	14
Bowes	3.79	0.441	22	15
Cockfield	11.378	2.063	66	71
Total	17.288	2.903	100	100

Table 2: Annual Energy Demands for the 3 Villages

It was therefore decided to present Cockfield Village as a case study to examine the energy status of a remote community, and to propose alternatives. Electricity is supplied to the village and distributed through it, by overhead cables. These are liable to failure especially in the winter months. There is no gas supply. As a former coalfield, coal is supplied and is the most prevalent heat source, which has adverse effects on air quality and by implication the health of the residents. There are few examples of oil, liquid petroleum gas or renewable sources. Cockfield has been eligible for Single Regeneration Budget Funds, which is reflective of its position as a vulnerable community (Teesdale District Council, 2002c).

4.Energy Sources and Distribution

Across England, it is estimated that at least 2 million households suffer fuel poverty and with the recent sharp rise in fuel prices this is increasing (Fuel Poverty Advisory Group, 2005; NEA, 2005a). Research for National Energy Action indicates that fuel poverty is higher in rural than in urban areas (NEA, 2005b). The electricity supply is liable to price rises beyond the control of the consumer or the government, which can have serious impacts for individuals on pensions and low incomes. In response to the issues of climate change and international energy dependency, the British government has launched a debate on increasing the country's reliance on nuclear fission for electricity generation. It appears that, regardless of the debate, there is already strong commitment to such a policy within the senior levels of government (Adam, 2005; Wintour & Milner, 2005). However, for remote communities this is an irrelevance, as it does not attempt to resolve the distribution issues. In a number of countries there is already recognition that energy needs for remote communities can be met through renewables with environmental and economic benefits (Clark & Isherwood 2004). The Teesdale Renewable Energy Challenge focussed its attention on large-scale projects, such as: hydropower from the huge reservoirs, forestry harvesting, wind farms (The Northern Energy Initiative 2003). Some of these facilities have already been installed but again they do not benefit communities such as Cockfield because of the poor distribution network. In fact it is clear that most research and applications have either been based on renewable energy from large-scale installations that feed into the National Grid or packages for individual householders or businesses. The objectives for the Cockfield case study were therefore to improve the health and comfort of the community by reliable and tested sources of clean energy, that are not reliant on a widespread distribution network. In these kinds of communities, installations need to be able to operate at a village or sub-village scale. The technology must be capable of being maintained in an operative condition by local people, with some training. This technology must be a source of heat and power, but the primary objectives are independent and sustainable energy sources, as well as surety of supply – mainly in the event of an electricity distribution failure. A successful renewable energy policy may require the use of a basket of energy sources to meet different needs and to deal with the interrupted nature of at least some sources, such as wind and solar. In addition the supplying of renewable energy, for all or most needs, would use a different supply system from those presently used for electricity, oil and liquid petroleum gas.

As well as helping to respond to climate change and peak oil prices, development of local renewable energy would also have benefits of increased sustainability. Among the features of a sustainable community are that it meets *the diverse needs of all existing and future residents* … [and] *also limits the adverse external effects on the environment, society and economy* (Kearns & Turok, 2003). Renewable energy supply would use a number of energy sources with a significant proportion originating near to the place of use. Many consumers could at times also be suppliers of energy; and more of the money would stay in the locality. Local production of renewable energy would also have potentially wider benefits such as community involvement in decisions about energy production and local employment. Some of the features of a local renewable energy system for a remote community would be that it is carbon neutral; uses reliable and available technology; meets the heating, light and power needs of households; ensures secure and autonomous supply; is able to be locally controlled and is appropriate to the community and location. In order to ensure a match of supply and demand for energy it was necessary to capture the details of these patterns. To develop a robust model, leading to implementation of a renewable energy supply, a whole system approach would be necessary.

In summary, the applicable technologies to meet the requirements of the remote community characterised by Cockfield Village are required to fulfil the following objectives:

- Be robust and thus meet the requirement for reliability
- Offer autonomy and thus meet the requirement for minimum operating and maintenance skills with manageable local training provisions
- Be sustainable in order to respond to the wider national agenda for future energy supplies

5.Renewable Energy Technologies

Following consideration of the requirements, a range of suitable technologies was analysed. To meet the sustainability criterion, various renewable energy resources were matched against available resources at Cockfield village. Thus it was considered that the potential for small-scale hydro is low, and geothermal is uncertain. Therefore the main sources of energy would be solar, wind and biomass.

Resource	Availability at Cockfield
Solar	Moderate
Wind	High
Biomass	High
Hydro	Low
Wave & Tidal	None
Geothermal	Uncertain

Table 3: Availability of Energy Sources

A wide range of potential technologies to supply renewable energy were analysed through a two stage filter process to test which would be appropriate in a renewable energy strategy for the village. The filters determined whether the technologies were commercially available and reliable, their likely lifespan, and the necessary level of operating and maintenance support.

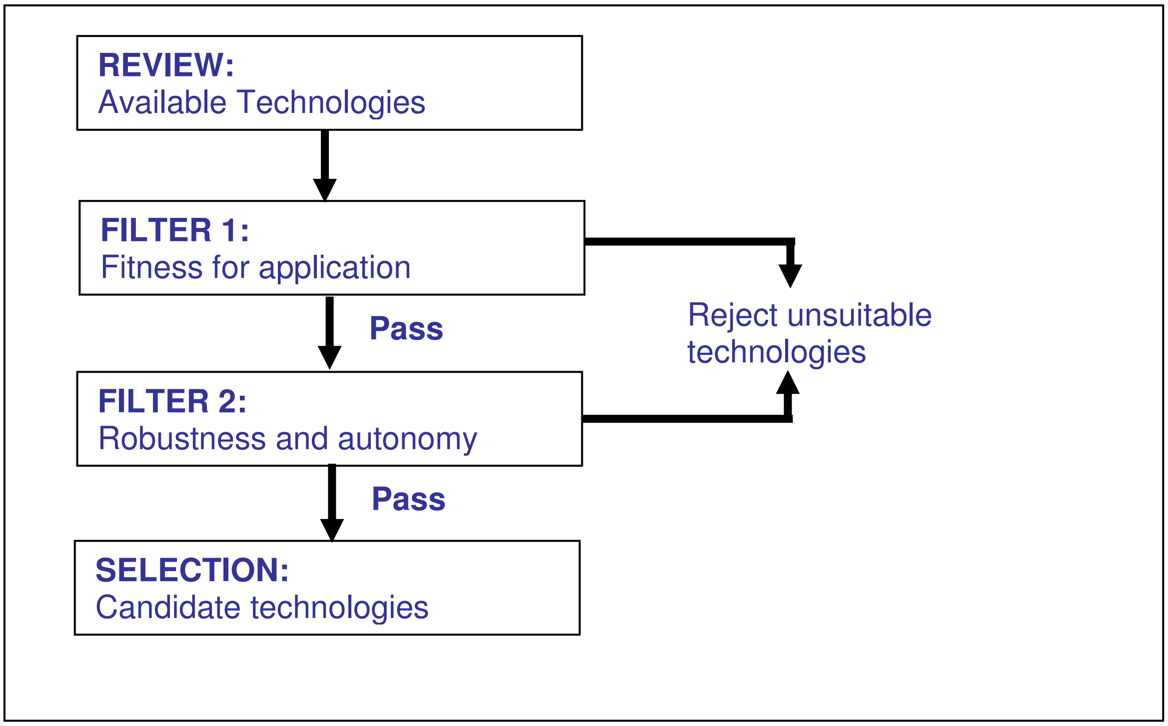

Figure 2: Filters for Selection of Candidate Technologies

Barriers to the market take-up of renewable energy systems can be attributed to poor economic prospects and issues concerning component reliability. Numerous studies have been conducted into these aspects related to individual technologies for domestic applications. Bahaj et al. (2006) deal with both small vertical axis and small horizontal axis wind turbines for direct use on building roofs or high points on buildings. They identify a performance benefit of the vertical axis type when dealing with the sort of skewed flow conditions that arise over building surfaces.

As photovoltaic building cladding materials evolve and mature, focus has been placed on fault detection and diagnosis methods in order to improve system robustness. For satisfying base-load power and heat demands at domestic scale, several researchers have analysed the economic and reliability merits of fuel cells (Hawkes & Leach 2005; Alanne et al. 2006; Tanrioven & Alam 2006). Entchev et al. (2004) reported on the field monitoring of a small domestic (0.736kW electrical capacity) Stirling engine CHP system in houses in Canada and concluded that the unit satisfied all of the space and water heating together with a significant proportion of the electrical demand with some periods of grid-exportation. Onovwiona & Ugursal (2006) reviewed a range of domestic CHP methods including internal combustion engines, fuel cells and Stirling engines, concluding that Stirling engines appear to have the most promise as far as potential reliability is concerned. However Cockcroft & Kelly (2006) show that the relatively low power efficiencies and overall fuel utilisation of these systems means that they struggle to compete with air source heat pumps in terms of carbon emission when used in domestic applications with conventional fuel and electricity supplies.

The technical and economic benefits of *microgrids* have also received recent attention. A microgrid is a cluster of several technologies designed to provide local decentralised heat and power with either grid-independence or grid connection. Tanrioven (2005) reported on a method for assessing reliability and cost benefits of an independent microgrid utilising a fuel cell, photovoltaic and wind turbine inputs, although it was applied only to an exemplar system. Abu-Sharkh et al. (2006) considered the matching of a microgrid using micro-CHP and photovoltaic modules and concluded that grid-independence could be achieved for most small house types in UK conditions if a battery pack with an electrical capacity of up to 2.7kWh electrical is used.

The objective of technology-filtering is to arrive at a small set of technologies that are both fit for application and fit for purpose. Of essence, the technologies require to be either carbon-neutral or renewable to be consistent with the aim of developing a solution that is suitable for future energy solutions in remote communities. Fitness for application is taken to mean that a technology is feasible for use at domestic scale and can be commercially sourced. Fitness for purpose means that a technology meets certain criteria that are specific to the needs of a remote community with limited access to specialist maintenance skills. There was no intention to include financial economics in this filtering and there are two reasons for this omission:

1. Whilst the technologies considered are commercially-available they mostly fall within an emerging market that is likely to see reductions in manufacturing cost as they mature.

2. Fuel and electricity are in a period of considerable turbulence at present and are likely to remain so for some time, due partly to the transition from energy self-sufficiency to import-dependence that the UK is currently experiencing and due partly to expected new fiscal measures applied to fuel and electricity prices since the publication of the Stern report (Stern, 2006).

Taken together, the uncertainty in manufacturing cost trajectories and future fuel and electricity prices, means that any attempt at analysing financial economics is likely to be uncertain and speculative.

Filter 1 is designed to pass technologies that are *fit for application*. In this context, passing the fitness for application (F) criterion shows that each type of technology considered, is capable of satisfying the low and seasonally-varying demands for heat or power (or both) that are expected with small (2-bed) and medium (3-bed) UK houses. Conditional flags are included as follows:

H	indicates a heating demand can be satisfied
P	indicates a power demand can be satisfied
D	indicates if this technology delivers a dispatchable output

A dispatchable output is one that is guaranteed. Thus a wind turbine or solar panel represents a technology that is non-dispatchable whereas a biofuel-based technology using fuel from a managed plantation represents a technology which is dispatchable.

A long list of candidate technologies was drawn up by considering renewable energy equipment that might potentially meet the fitness for application criterion and was thought to be at, or close to, commercialisation and therefore available. Table 4 represents a truth table of the resulting long list of candidate technologies where conventional Boolean logic switches have been applied (i.e. “1” implies a true outcome and “0” implies a false outcome). The truth table switches were set by conducting extensive searches for examples of commercially-available equipment and checking that the equipment was available at capacities applicable to housing and suitable for UK application. As an illustration, a search under photovoltaic roof coverings identified a product of *sunslates* with direct applicability to UK slate roof coverings (Sunslates, 2006).

Class	Item	Description	Filter 1 Conditions			
			F	H	P	D
1. Solar	1	PV roof coverings	1	0	1	0
	2	PV modules	1	0	1	0
	3	Flat plate collectors	1	1	0	0
	4	Evacuated tube collectors	1	1	0	0
	5	PV-coupled air source heat pumps	1	1	0	0
	6	PV-coupled geothermal source heat pumps	1	1	0	0
2. Wind	7	Horizontal axis wind turbines	1	0	1	0
	8	Vertical axis wind turbines	1	0	1	0
	9	Ducted embedded wind turbines	0	0	1	0
	10	WT-coupled air source heat pumps	1	1	0	0
	11	WT-coupled geothermal source heat pumps	1	1	0	0
3. Biofuel	12	Biomass boilers	1	1	0	1
	13	Biogas boilers	1	1	0	1
	14	Fuel cell CHP	1	1	1	1
	15	Internal combustion engine CHP	1	1	1	1
	16	External combustion engine CHP	1	1	1	1
	17	Microturbine CHP	0	1	1	1

Table 4: Filter 1 Truth Table

The following rules were applied to reduce the longlist of candidate technologies to a viable shortlist. Application of the rules is predicated on the possibility that two or more items (within or between classes) may be combined. In addition, at least one item present must be capable of delivering dispatchable heat and power in order to ensure that essential demands are met at times when solar and wind resources are limited or unavailable.

RULE 1: Each item MUST pass F: fitness for application
RULE 2: For any combination, at least one dispatchable item MUST be present with P = 1 and H = 1

Application of the above rules removes the following items from the longlist:

- Ducted embedded wind turbines
- Biomass boilers
- Biogas boilers
- Microturbine CHP

No commercial examples of microturbine CHP could be found with power output capacities within the typical housing demand envelope. Biomass and biogas boilers both failed the dispatchable power test.

Filter 2 is designed to pass technologies that satisfy the criteria for robustness, autonomy, and ease of installation and servicing. In this context, robustness and autonomy are inferred from evidence of service life longevity and time periods between breakdowns. Evidence to support these concepts was based on declared manufacturers' warranties and information on expected equipment service life. The data are summarised as follows:

Class	Technology	Typical Parts-only Warranty Period	Typical Expected Service Life
Supplementary (power)	PV roof coverings	2 years	20 years
	PV modules	2 years	20 years
	Horizontal axis wind turbines	2 years	20 years
	Vertical axis wind turbines	5 years	30 years
Supplementary (heat)	Evacuated tube collectors	10 years	20 years
	Flat plate collectors	10 years	30 years
	Air source heat pumps	5 years	15 years
	Geothermal source heat pumps	5 years	15 years
Dispatchable (heat & power)	Fuel cell CHP	3000 operating hours	6 years
	Internal combustion engine CHP	1200 operating hours	5 years
	External combustion engine CHP	6500 operating hours	10 years

Table 5: Warranty and Service Life Expectations

Scores for all three criteria were allocated to each technology option and fuzzy set theory was used to weight each score and aggregate them using rules in order to arrive and an overall fitness selection score for each option. Fuzzy set theory was used at this point because it is applicable to problems that are uncertain or can only be partly defined. Details of the method and its application to problems of the kind dealt with here can be found in Underwood (2006). A summary of the results is as follows:

Class	Technology	Overall Fitness Score
Supplementary (power)	PV roof coverings	0.53
	PV modules	0.26
	Horizontal axis wind turbines	0.45
	Vertical axis wind turbines	0.83
Supplementary (heat)	Evacuated tube collectors	0.73
	Flat plate collectors	0.83
	Air source heat pumps	0.50
	Geothermal source heat pumps	0.26
Dispatchable (heat & power)	Fuel cell CHP	0.52
	Internal combustion engine CHP	0.20
	External combustion engine CHP	0.83

Table 6: Results from the Application of Filter 2

The final reasoning to be applied to the outcomes of Filter 2 concerns complementary technologies. Wind turbines complement photovoltaics because they deliver energy drawn from differing sources. Likewise a heat pump can complement a solar panel due to the capacity of the former to contribute in winter. However the existence of an essential dispatchable technology means that a baseload of heat is assured at all times with a typical ratio of at least two units of heat per unit of power. So two supplementary heat sources are unlikely to be required whereas two supplementary power sources are likely to be desirable. On this basis a microgrid for a remote community is evident from the best fitness scores in Table 6, specifically:

- Stirling engine CHP
- PV roof coverings
- Vertical axis wind turbine
- Flat plate solar collector

Microgrid interconnections between these components are illustrated as follows:

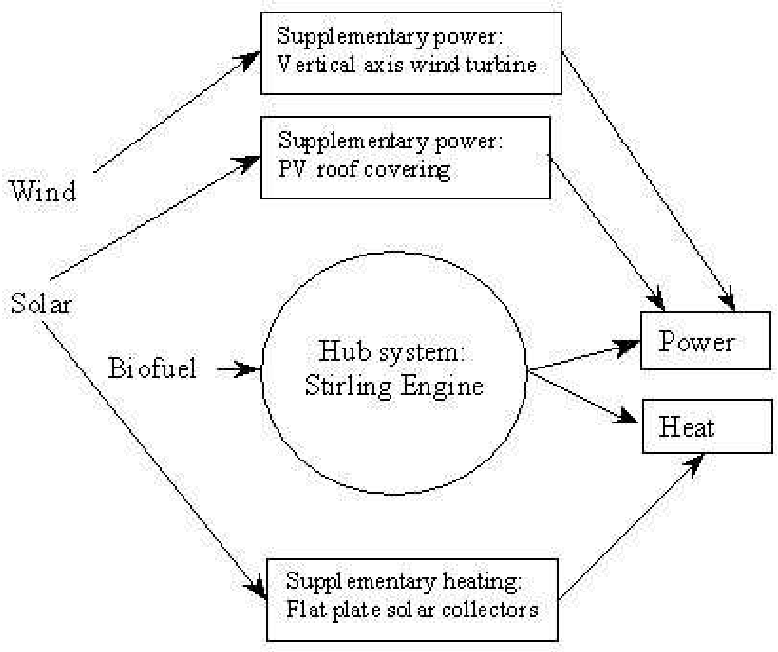

Figure 3: Microgrid for a Remote community

6.Energy Demand

In contrast to most past studies on the potential for renewable energy which have taken a broad brush approach, this study considered in detail the energy demand and possible renewable supply for a remote community. This is necessary in order to map supply and demand fluctuations, both during the day and throughout the year.

The demand for household heat and power was modelled in detail, using specially developed software. Among the factors considered were:

- The housing types – predominantly 2 storey terrace and 2 storey semi-detached but also 3 storey terrace, large detached, average detached, and small single storey detached
- Age of house
- Level of insulation
- Level of occupancy of house - empty, household out during weekdays for work and school, or continuous occupation
- Orientation of main living space
- Having an open fire
- Having a conservatory

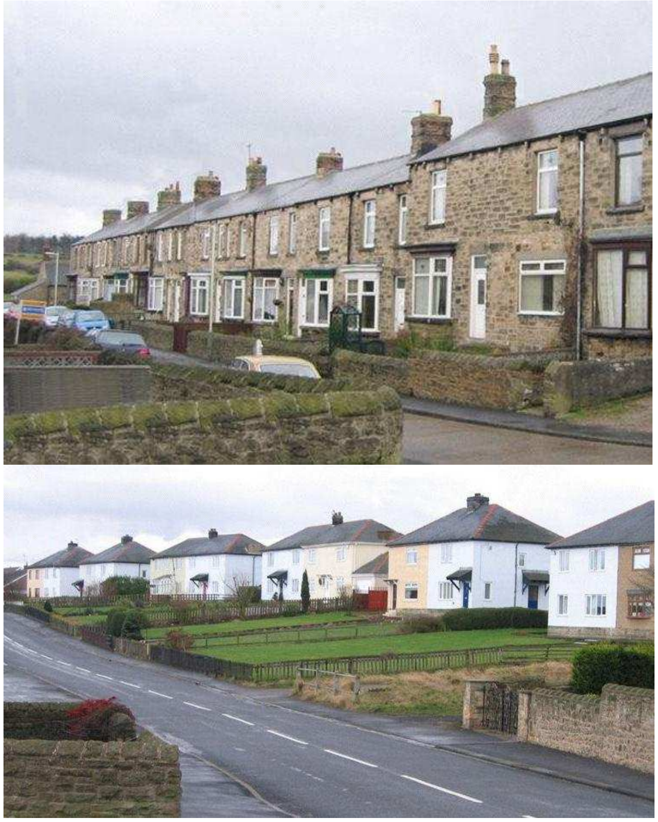

Figure 4: Typical Terrace and Semi-detached Houses in Cockfield

On the basis of these features combined with the temperature and solar flux patterns for the area, an output of the hourly pattern of heat and electricity demand for the village was obtained.

The demand model developed for this purpose was titled the macro scale domestic energy model (MacroDEM), based on the Building Research Establishment domestic energy model (Bredem-12 (BRE 2002)) with refinements to give more detailed predictions for a large number of houses rather than an individual house, as with Bredem-12. The weather data – external temperature and solar flux – were based on daily values rather than monthly readings and this combined with a daily activity schedule, produced a daily pattern of demand. The resulting daily patterns were then further resolved to hourly energy demands with the application of user-profiles. This high degree of time resolution in the modelling was considered essential for matching the temporal random energy yields from wind and solar sources to the energy demands imposed at both the individual house level as well as for the entire community. The model is able to calculate energy demand values for both heat and electricity in groups of houses of similar types and these can be combined to give demand values for the entire village.

7.Energy Modelling Results

The energy demand for Cockfield was calculated on housing data obtained from Teesdale Council, the 2001 Census and Ordnance survey maps, as well as observations made during visits. On the basis of these data, it was possible to compile a profile of the house type, covering features such as age, types (terrace, semi-detached, etc), level of insulation and occupancy. A file of measured meteorological data representing a typical weather year for the northeast region of the UK was analysed.

Whole village results for a sample of months throughout the year are illustrated in Figure 5 and annual totals are given in Table 7. Electricity demand does not vary greatly throughout the year. The daily weekday pattern has a nighttime trough, a morning peak, lower mid-day demand and then a second longer peak in the evening. Demand over the weekend is more consistent throughout the day, at a level higher than the weekday trough but lower than the morning peak. Heat demand varies considerably more during the year, with a secondary daily cycle of morning and evening peaks, a moderate mid-day trough and a nighttime trough.

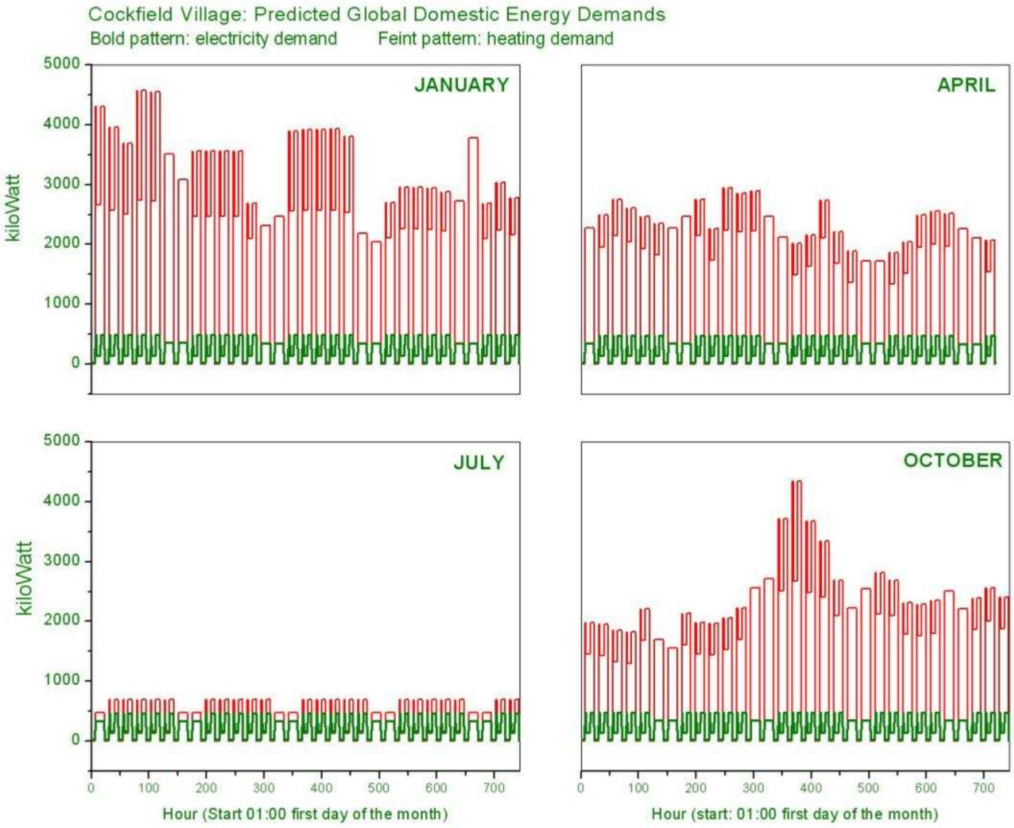

Figure 5: Energy Demands for Cockfield

Energy Type	Season	Time of Day	Demand (kW)
Electricity	All Year	Peak (morning & evening)	500
		Mid-day Trough	150
		Night-time Trough	30
		Weekend Peak	350
Heating	Winter	Peak	2000-4000
		Mid-day Trough	1500-2500
		Night-time Trough	Near 0
	Summer	Peak	700
		Mid-day Trough	1500-2500

Table 7: Pattern of Energy Demand in Cockfield

The annual results include two other Teesdale villages considered in the community appraisals for comparison (Table 8). Also included is a second entry for Cockfield village referred to as - *Cockfield reduced*. This line of results shows what the annual energy demands might be if vigorous energy efficiency measures were to be implemented in Cockfield village. It is argued that such a campaign must form a necessary precursor to the implementation of any local renewable energy minigrid. Key features of such an energy efficiency campaign included in the results are:

- Upgrading of all fabric insulation to the highest *practical* standards.
- Replacement of all existing single glazing with double low-emissivity glazing.
- Upgrading of all demand side heating controls and hot water cylinder insulation standards.
- Replacement of all lamps with low wattage fluorescent lamps.

The results show that potential savings over existing energy demand levels, amounting to 25% (heating fuel) and 6.6% (electricity), might be possible prior to the implementation of renewable energy measures in the village.

Village	**Heating Demand (GWh)**	**Electricity Demand (GWh)**
Romaldkirk	2.12	0.399
Bowes	3.79	0.441
Cockfield *Cockfield reduced*	11.378 8.546	2.063 1.926

Table 8: Annual Energy Demands for the 3 Villages,
with reduced values for Cockfield

8.Renewable Energy Strategy

The final stages of the modelling were to combine the needs of the area, practical sources of energy and suitable technologies. Solar power could provide a proportion of domestic hot water using solar collectors and photovoltaics. The model revealed that a saving of approximately 20% of the annual energy for domestic hot water could be achieved if flat plate solar collectors were to be installed. The wind could be used to drive small house mounted turbines for electricity. The energy modelling however revealed that, because of the intermittent nature of these sources, there remains a shortfall of around 45% of total energy needs. On winter nights, for example, there is no sun for heat and possibly no wind. One of the strategies could be to view renewable sources as supplementary to the traditional supply. However, without complicated storage facilities, this does have the significant disadvantage that distribution system failure is most likely to occur when at least the solar power generators are inoperative. Moreover, this would not tackle the air pollution and residents' ill health, due to the high usage of coal. An alternative could be the provision of biomass. The technology filter passed a number of technologies to harness biomass. Ideally combined heat and power would be applied to produce both heat and electricity. It can either be provided through a central plant with district heating and power distribution, or a biogas distribution network with local Stirling engines. The latter would have the advantage of simpler distribution, greater flexibility, lower losses and slightly easier maintenance overall. One other option might be to develop a domestic pulverised biomass Stirling engine as current Stirling engine technology cannot run on solid fuel without a separate combustor that increases technical and maintenance issues. This development would obviate the need for centralised gasification of the biomass, with a local gas distribution network. Yet, there would be a need for a solid fuel distribution system. This may be popular locally, as the employment associated with coal deliveries would not be lost but transferred to pulverised wood delivery. As one of the aims of the research was to develop a local supply system allowing autonomy and local control, it was proposed that a major source of electricity and some heat would be from locally grown biomass. This could be from local coppiced willow or from the maintenance programmes of the existing nearby forests. It has been estimated that 2,500 tonne/year of pre-dried biomass would be needed if gasified centrally for use in local combined heat and power plants based on an average biomass calorific value of 17MJ/kg. This would include additional local combustion equipment to meet heating demands when these could not be entirely met from Stirling engine heat recovery. Heat pumps were not considered as they would only be a renewable option if the electricity to power them was from a renewable source, which might be in short supply at the very times when heat is needed. In addition, with the use of combined heat and power, there is likely to be spare heat so there would be no need for heat pumps in this particular strategy. The resulting package of energy sources would be solar for electricity and water heating, micro wind for electricity and biomass for base load electricity and heat.

An imperative for a local energy system is reliability of supply. Although present conventional grids are perceived by the public as reliable, because in the past they have usually met demand through spare capacity that can be brought into use if needed - remote communities have a different view based on distribution system failure, usually when light and heat are most needed. To successfully introduce new technology, it needs to operate effectively without inconvenience to the users. To be self sufficient, an autonomous local system would need to be reliable and have some spare capacity to cope with extreme peaks in demand. Renewable energy systems use *distributed generation* networks with a two-way flow of energy, so that households at times are consumers and at other times are producers of energy. This approach is very different to the one-way conventional systems. In a remote community, a microgrid could be used to distribute electricity and perhaps heat, in a district-heating scheme (for houses and other premises grouped together), to clusters of loads drawing on a mix of small-scale local sources. In addition a successful renewable grid would require capacity that can respond to these peaks in demand.

9.Community Engagement

Vital to the success of introducing renewable energy is the support of the local community. A primary aim of local scale renewable energy is community ownership and control of the system through community participation. Consultation about the Gas Main Extension in 2002 had been quite superficial. Under the logo of Teesdale Distict Council, a letter was sent without further information to 1137 residents living in Cockfield, Butterknowle, Copley and Woodlands (see figure 1). It contained one question – *If gas were made available would you be interested in connecting to the network?* There were 370 replies (Ludgate 2002). As Denscombe (1998) points out – the proportion of people who respond to such *cold* postal questionnaires is invariably quite low, and 20% return rate is not unusual. In the circumstances, a return rate of 32.5% might be viewed as relatively successful. The report concluded that *public opinion is generally in favour of connecting to the gas main.* The actual figure for Cockfield was 55% interested in connecting. In a village with substantial fuel poverty, this might appear to be a low percentage. It was clear from the replies that the unknown cost of connection and replacement of central heating, cookers etc., were great concerns to many residents (Ludgate 2002). Had the Gas Main Extension gone ahead, it appears that it would have continued the tradition of a top-down process to development with the community being notified rather than engaged. The use of Participatory Rural Appraisal in the Renewable Energy in Remote Communities project, represented a major shift to capturing the realities of the community, primarily through their representatives. Indeed it had been disenchantment with questionnaire surveys that was one of the reasons behind the emergence of Participatory Rural Appraisal in the first instance (Kumar 2002). The main pillars of the process are empowerment, respect, localisation, enjoyment and inclusiveness. It is essential that any new heat and power system is shared with, and owned by local people. In this process, the researchers listen to local aspirations, and creatively use the local context. The community and it representatives should find it an enjoyable process and while many residents are content to be represented, nobody is actually excluded. The risks are that the researchers may be perceived as external and exploitative, driving their own agenda. However, the greatest danger is that local expectations can easily be raised. If nothing tangible emerges, the community may come to see the process as a transient external phenomenon (International Institute for Sustainable Development 2006). Initially, the research team appointed a renewable energy consultant from The Northern Energy Initiative (TNEI 2006), who had also been Teesdale District Council's (TDC 2006) lead on the Teesdale Renewable Energy Challenge (TREC), to chair the discussions with Teesdale District Council's Principal Planning Policy Officer, Head of Local Strategic Partnership the Regeneration Officer; and the Teesdale Community Network Co-ordinator (2D 2006). With reference to socio-economic profiles (Teesdale District Council 2002) the group identified candidate villages for the study, based on an established set of criteria from the Participatory Rural Appraisal. This led to groupings of settlements under types of idyll, indigenous agricultural and former industrial. It immediately became apparent that the former industrial villages represented greatest need. Of these, Cockfield was identified as the study village. As Durham County Council has pointed out – Cockfield is an attractive village with a green leafy character, but it also scores highly on the Index of Multiple Deprivation – with high unemployment, an ageing population, poor health record and rural isolation (Richardson 2006). As part of the project, a forum was conceived to engage with the community. Statements of energy problems and strategies for their resolution were developed with community representatives that included Local Councillors at Parish, District and County levels, Chair of the Cockfield Community Association, Teesdale Social Inclusion Project Officer, the Community Development Worker for Cockfield and Evenwood (Durham Rural Community Council), Teesdale Community Network Co-ordinator from Support for Voluntary and Community Sector in Teesdale and Wear Valley (2D), Renewable Energy at the Local Level (REALL) Project Worker, Head of Cockfield Primary School and the local Vicar. Progress on the project was reported in each issue of *The Voice* and following an article in the Teesdale Mercury, the process culminated in a presentation by the research team and a debate involving the community representatives and thirty other residents. The high level of interest was mainly measured by responses from local residents through the Community Association and local elected representatives. The debate encompassed topics such as: the economic viability of 2 or 3 larger turbines, rather than locating on individual properties; extending the proposals to local industry; harnessing methane from dairy farms and sewage works; feasibility of driving Stirling engines from wood-burning stoves; using new housing developments to pilot renewables; exporting excess energy to the grid; cost of biogas distribution network; plant maintenance and responsibility, options for storing power in batteries, the Planning Department's view of the proposals; extending the scheme to other settlements; and support for the visual characteristics of the proposals

(Minutes of Public Meeting 2005). The outcome has been that a Cockfield Regeneration Scheme has been included in Durham County Council's South West Durham Heritage Corridor. Media criticism in 2006, that Teesdale has the second worst carbon footprint per household in the UK has placed Cockfield as very high priority in the South West Durham Heritage Corridor Energy Project, led by Durham County Council Local Action 21 Partnership but including twenty five different interested parties including the research team (Bosanquet 2006).

Success in Participatory Rural Appraisal is measured by legitimising local knowledge and promoting empowerment. Durham County Council has acknowledged that improvements will be community led. A Teesdale Warm Zone is to be funded by an energy supply company, and there will be training for installers of Stirling engines, wind turbines, solar collectors photovoltaics – who will be local residents.

It has been established that one of the risks in Participatory Rural Appraisal is where local expectations can easily be raised. If nothing tangible emerges, local communities may come to see the process as wasted effort (International institute for Sustainable Development 2006). It was for these reasons that most of the participation process was conducted through community representatives. It was also important to avoid tokenism. It can actually be quite counterproductive to spend great quantities of people's time working through every option, when objective analysis demonstrates that certain technologies just do not meet the criteria.

10.Conclusion

This paper has examined the concept of remote communities and discovered that there are real issues about energy supply – even in a country such as Britain. The types of remote community also indicate a hierarchy of need. Communities that are based on former industrial sites are particularly prone to fuel poverty, ill health, aging population, lack of mobility, high unemployment and a number of other issues that place them in the category of highest need. However, they also score very highly in terms of cohesive and active community structures. Places such as the village investigated in Teesdale have fragile energy distribution networks. Electricity is distributed by overhead power lines that fail frequently during the winter months. There is no gas supply; and oil and liquid petroleum gas are expensive and physically difficult to deliver. These communities are sufficiently numerous and remote that, in the present context, renewing the infrastructure for electricity supply and developing gas pipelines would be prohibitively expensive. Moreover, as many of the villages are former mining communities – coal is delivered at preferential rates and is the most common form of heating on open fires. Setting aside debates about carbon dioxide emissions, this practice generates poor air quality and contributes to ill health among the residents. The research team therefore set out to identify clean fuels that do not require excessive infrastructure investment. The energy demand was calculated using specially developed software and a wide range of potential renewable energy sources were investigated. They were filtered in two stages for fitness for application, and robustness and autonomy. It is essential that the selected technologies would be well established, reliable and easy to maintain by the community itself. A strategy was developed that proposed solar collectors, photovoltaic slates and chimney-mounted turbines for electricity. This would account for 55% of total energy needs. The balance of demand could be met by biomass systems. There are two options. First, locally grown biomass could fuel a central plant in the village as part of a district-heating scheme. Secondly, a Stirling engine could be devised that runs on solid fuel without a separate combustor and this represents an area of future research and development. Such engines could be installed in every property. Equally as important as energy demands and candidate technologies, is the willingness of the community to become engaged in these proposals. In the test case of the village in Teesdale, residents were enthusiastically responsive to the suggestions and recognised the benefits of the proposals to themselves and others. In order to protect individual owner-occupiers, negotiations have commenced with a social landlord about installations within its properties that are occupied by tenants who are enthusiastic about the principles. The objectives are to install an energy generating system that is reliable, not dependent on large-scale distribution networks, clean and healthy for the residents, where the community is part of the decision-making process and has ownership of the system that can be maintained by the community itself.

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References

Abu-Sharkh, S. et al., 2006. Can microgrids make a major contribution to UK energy supply? Renewable & Sustainable Energy Reviews, vol. 10, 78 - 127.

Adam, D., 2005. Chief scientist backs nuclear power revival. The Guardian, October 21.

Alanne, K., et al., 2006. The financial viability of an SOFC cogeneration system in single-family dwellings. *Journal of Power Sources*, vol. 158, 403–16.

Bahaj, A.S., Myers, L., James, P.A.B., 2006. Urban energy generation: Influence of micro-wind turbine output on electricity consumption in buildings. Energy & Buildings http://www.sciencedirect.com/ (accessed: 6 November 2006).

Bosanquet, M., 2006, South West Durham Heritage Corridor Energy Project, Durham County Council Background Paper.

BRE, 2002. BREDEM-12 Model Description. Building Research Establishment, Watford.

Bunce, M., 2003. Reproducing rural idylls, in Cloke, P. (ed) Country Visions. Prentice Hall, Harlow, England.

Clark, W., Isherwood, W., 2004. Distributed Generation, Remote Power Systems, with Advanced Storage Facilities. Energy Policy, vol. 32.

Cloke, P., Little, J., (eds) 1997, Contested Countryside Cultures – otherness, marginalisation and rurality. Routledge, London.

Cloke, P., 2003, Knowing ruralities? – moving beyond the rural idyll, in Cloke, P. (ed) Country Visions. Prentice Hall, Harlow, England.

Cockroft, J., Kelly, N., 2006. A comparative assessment of future heat and power sources for the UK domestic sector. Energy Conversion & Management, vol. 47, 2349–60.

DEFRA, 2005. Rural Strategy http://www.defra.gov.uk/rural/strategy/ (accessed 21 November 2006)

DEFRA & DTI, 2006. The UK Fuel Poverty Strategy, 4th Annual Progress Report. DEFRA, London.

Denscombe, M., 1998. The Good Research Guide for small - scale social research projects. Open University Press, Milton Keynes.

DTI, 2003. Energy White Paper: Our energy future – creating a low carbon economy. The Stationery Office, London.

Entchev, E., et al., 2004. Micro-generation technology assessment for housing technology. Energy & Buildings, vol. 36, 925–31.

Fitzpatrick, S., 2004, Poverty of Place. Keynote Address, JRF Centenary Conference, Poverty and Place: Policies for Tomorrow, University of York.

Fuel Poverty Advisory Group (for England), 2005. Third Annual Report. Department of Trade and Industry, London.

Grant, R., (ed), 2005. Leap-Frogging the Status Quo. Design and Demonstration Unit First Annual Report October 2003 – March 2005. DDU, London.

Hanley, N., Nevin, C., 1999. Appraising renewable energy developments in remote communities: the case of the North Assynt Estate, Scotland. Energy Policy, 27, 527-547.

Hauxwell, H., Croft, B., 1989. Seasons of My Life. Arrow Books, London.

Hawkes, A., Leach, M., 2005. Solid oxide fuel cell systems for residential micro-combined heat and power in the UK: Key economic drivers. Journal of Power Sources, vol. 149, 72–83.

International Institute for Sustainable Development, 2006 http://www.iisd.org/casl/CASLGuide/PRA.htm (accessed 20 November 2006)

Keans, A., Turok, I., 2003. Sustainable Communities, Dimensions and Challenges. ODPM, Urban Neighbourhood Studies Research Network, London.

Kumar, S., 2002. Methods for Community Participation. ITDG Publishing, London.

Lobley, M., Potter, C., 2004. Agricultural change and Restructuring: recent evidence from a survey of agricultural households in England. Journal of Rural Studies, vol. 20, issue, 4, 499 – 510.

Ludgate, D., 2002. Teesdale Gas Mains Extension Final Report. Tees and Durham Local Authority Support. Energy Saving Trust Innovation Programme.

Minutes of Public Meeting, 2005. Cockfield Community Centre, 29 January.

National Statistics Online, 2006. http://www.statistics.gov.uk/census2001; http://www.neighbourhood.statistics.gov.uk (accessed 21 November 2006)

NEA, 2005a. The Fall and Rise of Fuel Prices and Fuel Poverty. National Energy Action, Newcastle upon Tyne.

NEA, 2005b. Rural Fuel Poverty: Research Report. National Energy Action, Newcastle upon Tyne.

Office of the Deputy Prime Minister, 2004. Housing, Planning, Local Government and Regions Committee. Social Cohesion: Sixth Report of Session 2003-04. The Stationary Office Limited, London.

Onovwiona, H.I., Ugursal, V.I., 2006. Residential cogeneration systems: Review of the current technology. Renewable & Sustainable Energy Reviews, vol. 10, 389–431.

Philo, C., 1992. Neglected Rural Geographies. Journal of Rural Studies, vol. 8, issue 2, 193 – 207.

Pragg, P., 2005. Renewable energy in the countryside. EG Books, London.

REALL, 2006. http://www.countryside.gov.uk/ (accessed 21 November 2006)

Richardson, J., 2006. South West Durham Heritage Corridor, Durham County Council, Cabinet Paper, April.

Scott, A., Christie, M., Medmore, P., Impact of the 2001 foot-and-mouth disease outbreak in Britain: implications for rural studies. Journal of Rural Studies, vol. 20, issue 1, 1 – 14.

Stern, N., 2006. Stern review on the economics of climate change, http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economic_climate_change/stern_review_report.cfm (accessed 11 November 2006).

Scottish Renewables, 2006. http://www.scottishrenewables.com/ (accessed 15 November 2006)

Sunslates, http://www.solarcentury.com/content/download/1442/11298/file/Sunslates.pdf (accessed 30 October 2006).

Tanrioven, M., 2005. Reliability and cost-benefits of adding alternate power sources to an independent micro-grid community. Journal of Power Sources, vol. 150, 136–49.

Tanrioven, M., Alam, M.S., 2006. Reliability modelling and analysis of stand-alone PEM fuel cell power plants. *Renewable Energy*, vol. 31, 915 - 933.

TDC, 2006. http://www.teesdale.gov.uk/ (accessed 21 November 2006)

Teesdale District Council, 2002a. Romaldkirk Ward Community Appraisal. Teesdale District Council, Barnard Castle.

Teesdale District Council, 2002b. Greta Ward Community Appraisal. Teesdale District Council, Barnard Castle.

Teesdale District Council, 2002c. Cockfield Ward Community Appraisal. Teesdale District Council, Barnard Castle.

The Newcastle Energy Initiative, 2003. Teesdale's Renewable Energy Challenge, TNEI, Newcastle upon Tyne.

TNEI, 2006. http://www.tnei.org.uk/ (accessed 21 November 2006)

Underwood, C.P., 2006. The application of fuzzy systems to control and modelling of building systems, in Kalogirou, S. (ed.) Artificial Intelligence in Energy and Renewable Energy Systems. Nova Science Publishers, Hauppauge, NY.

Wintour, P., Milner, M., 2005. Cabinet challenge to nuclear proposals. The Guardian, October 1.

2D, 2006. http://www.2d.org.uk (accessed 21 November 2006)

Appendix: Summary of Socio-economic Profile of the Villages

	Romaldkirk Idyllic	**Bowes** Indigenous	**Cockfield** Industrial
Community Involvement	low	low	high
Village Services	low	low	high
Shops	0	1	7
Pubs and Clubs	2	2	3
Businesses	0	2	4
Population- number	900	700	1500
- change from 1991 to 2001	+9%	+15%	-7%
- younger people < 30	28%	30%	29%
- older people >60	25%	17%	29%
Marital Status - single	21%	21%	25%
- married	65%	63%	52%
- separated	1%	3%	4%
- divorced	6%	5%	7%
- widowed	7%	8%	12%
White Ethnic Group	99%	100%	99%
Christian Religion	83%	81%	87%
No Religion/not stated	17%	18%	13%
Health - Good	76%	79%	58%
- Poor	7%	7%	15%
- Long Term Illness	17%	14%	27%
Employed	70%	71%	54%
Self employed	22%	23%	7%
Retired	16%	10%	19%
Students	3%	4%	2%
No Qualifications	23%	28%	45%
Degrees and higher	29%	20%	8%
Households - pensioners	24%	14%	31%
- children	25%	31%	23%
- single parent	6%	1%	5%
- size	2.4	2.5	2.2
- no. of rooms	6.4	6.7	5.0
- without CH	8%	12%	7%
Owner Occupied	73%	66%	68%
Rented - Council	3%	0%	20%
- Housing Assoc.	1%	2%	2%
- Private	23%	32%	10%
Car Ownership - without	10%	9%	30%
- 2 or more	55%	51%	27%
Public Transport	low	medium	medium
Index of multiple deprivation	15.17	15.64	27.11

(Teesdale District Council 2002a, Teesdale District Council 2002b, Teesdale District Council 2002c, National Statistics Online)