Sheffield Hallam University
Knowledge Applied
Centre for Regional Economic and Social Research

What's the best way to decarbonise homes in off grid communities?

Professor Aimee Ambrose, Dr Yael Arbell, Dr Simon Lannon, Ella Schaefer, Professor Rokia Raslan, Tim Ashworth

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Introduction

Estimates suggest that circa 2,000 properties across the UK are 'off-grid', meaning they do not have a connection to the electricity or mains gas grid. A further four million have an electricity supply but no mains gas. A range of challenges are faced by people living 'off-grid', including increased risk of fuel poverty (struggling to afford to adequately heat their homes), maintaining energy supply, especially in adverse conditions and high fuel costs. Solutions favoured to move most homes in the UK closer to net zero, such as heat pumps and better insulation, may not be readily compatible with off grid homes or may be more complex to implement. Off grid households risk exclusion from the national energy transition.

Northern Powergrid and Northern Gas Networks understand that the diversity of housing types and household circumstances that exist in rural areas means that there is no 'one size fits all' approach to move off grid homes towards net zero. They commissioned us - a consortium of academics (social researchers, architects) and engineers - to research and understand the realities and practicalities of decarbonising off grid properties. This included understanding how off grid households felt about the prospect of decarbonising their homes, how they currently meet their energy needs, and modelling potential energy solutions for a variety of different off grid homes; factoring in the needs, expectations and concerns of households.

We developed six case studies (drawn from three geographical areas) showing possible routes to decarbonisation for six different types of home in the North of England, sensitised to the needs, wants and limitations of occupants. The case studies represent a range of different off grid and partially off-grid living scenarios and property types. We arrived at a set of decarbonisation pathways that are both technically viable and socially acceptable. This note summarises key learning for policy makers and practitioners working on improving the energy efficiency of off grid homes; whether for climate, fuel poverty, health or social and economic inclusion reasons.

We begin by highlighting the key messages for policy and practice, before outlining how we arrived at them.

A complete report is available on the Sheffield Hallam University website.

Ten things policy makers and practitioners need to know

1. Professional stakeholders working on decarbonising off grid homes assume that an electricity connection provides the best solution. Occupants disagree. This shows that stakeholders must directly engage with off-grid communities.
2. A mains electricity connection is not possible (or is too costly) for most of the six scenarios we explored.
3. Off grid homes are likely to be Complex to Decarbonise. This means that established decarbonisation solutions cannot easily and affordably be applied. Even deep retrofit is unlikely to bring the six properties we modelled to net zero.
4. Off grid households are at risk of fuel poverty and being stranded on expensive fossil fuels. They should be a top priority for retrofit innovation.
5. Most participants favoured limited retrofit, over deep retrofit due to concerns over costs and compatibility of available solutions with off grid homes.
6. Many households will need significant reassurance and success stories to encourage them to go further.
7. A phased approach (one measure at a time) holds promise for encouraging households to pursue deeper retrofit, aiding gradual adjustment.
8. Those with wood burners treasure them and are unlikely to relinquish these, as they bring pleasure and a sense of security. Usage may reduce once low emission options become more established.
9. Incentives to install secondary glazing would provide a 'quick win' to boost energy efficiency and thermal comfort and Hydrotreated Vegetable Oil (HVO) boilers would provide a fast route to reducing emissions associated with heating.
10. Off-grid communities are willing to consider community-based energy schemes, provided that they are aesthetically and financially viable and support security of energy supply.

How did we research this topic?

There were four phases to the research:

1. We spoke to **12 key stakeholders** working in

relevant areas of policy making and practice across national and local government; the third sector, energy companies and distribution networks. These interviews focussed on understanding what stakeholders felt was the most promising route to decarbonising off grid homes.

2. We conducted **qualitative interviews with 24 households** living in fully off-grid (no gas or electricity connection) or partially off-grid (no gas connection) homes in Northumberland (small villages, remote living, farms), Cumbria (small villages, remote living, farms) and North Yorkshire (historic town and urban fringe). We spoke to people in a range of circumstances, such as: tenant farmers; social housing tenants; low income home-owners; well-off homeowners; private renters. There was also a mixture of different household structures within our sample: families, multi-generational families, couples and single occupants. We asked participants about how well their home meets their current energy needs, how their lifestyles and energy needs are likely to evolve in the coming years and how they felt about the need to improve the energy efficiency of their homes. We also gathered details about their homes including its age, type of construction, heating and power generation arrangements and details of any energy efficiency measures already installed.
3. We **transformed this data into six 'stories'** (featured at the end of this report), which integrated different elements of the 24 households we studied. The six stories represented a diverse range of off grid living scenarios. Each story was based around a real property with a postcode, allowing us to examine its current energy performance and suitability for different solutions (i.e. suitability for a grid connection or a community wind energy scheme). For each story, we modelled and costed:
   - A 'do nothing' scenario where residents carried on as they are, with perhaps minor improvements.
   - A moderate retrofit scenario that incorporated well established measures, but did not represent deep retrofit.
   - A comprehensive retrofit scenario, that took the building to the best Energy Performance Certificate (EPC) possible for that property.
   - Decarbonisation assessment, that offered potential solutions for achieving net zero, or at least significantly reducing the carbon emissions, of the household's energy supply.
   - An estimated return on investment for the decarbonisation options and retrofits (i.e. when the occupant is likely to make back the money invested in the decarbonisation option or retrofit of the home).

   These scenarios were tailored to the current and likely future needs of the occupants. **You can view summaries of them at the end of this document.**
4. We **took our six stories back to a sub-set of our 24 participants** to sense-check our proposed pathways from their perspectives. We ran two focus groups gaining detailed feedback from ten participants and used this to adjust the details of the scenarios proposed for each story. The focus groups also allowed us to explore how participants felt about the different retrofit scenarios proposed.

What did we find?

Findings from the qualitative interviews (stakeholders and occupants):

- **Differences of opinion:** Stakeholders felt that replacing oil heating with biofuels and/or getting a mains electricity connection to enable use of electric heating (i.e. heat pumps) was the most promising way to progress the decarbonisation of off grid homes. Occupants disagreed, primarily on financial grounds.
- **Households are well informed:** Professional stakeholders felt off grid households had limited knowledge about their options, but we found them to be well informed and inventive.
- **Affordability** of interventions (up front and running costs) is by far the most important consideration for occupants. They perceived the solutions available to them to be too expensive and regarded current grants and financial incentives (i.e. Boiler Upgrade Scheme) as financially insufficient, bureaucratic or not suited to off grid homes.
- **Expert knowledge and providers** of energy efficiency or decarbonisation solutions are regarded as scarce, especially in relation to completely off-grid homes. Participants reported struggling (where they had tried) to find local tradespeople who could offer reliable, expert advice and deliver high quality retrofit measures.
- **The comfort of simple solutions:** where people had simple and familiar heating and power solutions (such as oil boilers and diesel

generators), they were reluctant to replace them with more sustainable ones and had well established regimes for fuel delivery. In areas prone to power cuts and delayed fuel deliveries, the additional option of a wood burner provided comfort and joy (thermal delight). As related larger scale studies we have undertaken have shown, households like to have multiple options available for meeting their heating needs (this is known as stacking or bricolage).

- **Fears about 'new' technologies:** Participants' concerns about new technologies (especially heat pumps) included the cost (installation, running costs and maintenance), noise, space taken up, the length and complexity of the installation process and its impact on the current structure or appearance of the house, as well as (erroneous) concerns that the technology is not developed enough. Some households had combined established technologies (i.e. diesel generators) with newer technologies (i.e. batteries).
- **The house calls the shots:** the structure, location, age, size, character and conservation status of the house often determined what solutions were considered and possible. Some locations cannot be connected to the grid due to planning restrictions (i.e. requirement for underground cables), high costs or lack of consent from landowners. Some locations are unsuitable for renewables due to natural conditions or planning restrictions (i.e. national park status). Some required comprehensive work, which is disruptive for residents and can adversely affect treasured period features.
- **Rural/urban divides:** Many off-grid homes are in isolated, rural areas and this has implications for potential solutions. Participants were worried about being subject to policies shaped by a government based in the urban South and felt disproportionately blamed for air pollution (i.e. from wood burners).

Occupant responses to the different scenarios for homes like theirs:

Participants engaged thoughtfully with the proposals for different decarbonisation scenarios, and made the following points:

- They raised concerns about more comprehensive sets of measures that entailed significant disruption, and which would end established arrangements. However, a phased approach felt more acceptable to most, where one measure is installed at a time and allowed to 'bed in' before the next.
- Where they did not own their own homes, participants were concerned that landlords would not consent to retrofit.
- They paid close attention to the estimated costs and tended to think that the forecast costs for heat pumps (taking account of available subsidies) and community energy schemes were lower than expected. Although community schemes still felt prohibitively expensive and difficult to enable.
- Most participants had not heard of VAWTs but were surprised at how discrete their appearance was and found the price surprisingly low. However, most singular domestic scale VAWT could only produce enough energy to 'top up' the household supply.
- Some advocated alternative solutions that they had employed themselves, such as using wall mounted electric heating (with reverse settings for air conditioning) and running them off electricity from Photo Voltaic (PV) panels and batteries.
- However, participants also highlighted potential mismatches between the output possible from PV and their electricity needs (which are likely to grow as EVs become more common), making them unlikely to part with their generators.
- Participants felt that secondary glazing represented an acceptable way to better insulate windows without altering the external appearance.
- They emphasised that many off grid homes do not have appropriate infrastructure to enable air to water heat pumps (i.e. the correct pipework and radiators). This, combined with the cosmetic repairs that would need to follow the work, made this type of heat pump too expensive. Air to air heat pumps would circumvent some of these issues, but they are not currently eligible for any subsidy.
- The idea of substituting oil for biomass was not welcomed, due to the need to substitute an oil boiler for a larger biomass system and a perception that biomass was a more expensive fuel.
- Hydrotreated Vegetable Oil (HVO) that is compatible with oil boilers was greeted with some enthusiasm by participants- seen as an easy win.

Case Study 1

In a nutshell

Motivation and willingness: Keen to decarbonize, mainly for financial reasons

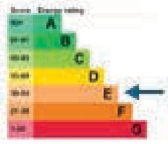
Barriers and ability to decarbonise: Financial barriers; access to trained professionals; planning regulations; dependency on landlord.

Rural farmhouse, no young children, off grid, national park, private rent ***Energy Performance Certificate E***

House Details	
Building type	Rural – isolated, Detached House pre 1919
Grid connection	Not connected to gas or electric grid
Energy source(s)	Solid fuel back burner, diesel generator, bottled gas, wind turbine, solar PV, BESS
Fabric	Limestone walls, single glazing, poor insulation standards

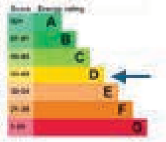
Anticipated Retrofit
Internally insulate the walls and high-quality windows.
Install a new oil combi boiler
Energy Performance Certificate E

62% Decarbonised
11% reduced fuel bill
£23,000 Retrofit costs
Very High Disruption



Decarbonised Retrofit
Insulate the walls, floor and roof, high quality windows.
Install a new oil combi boiler
Energy Performance Certificate D

89% Decarbonised
35% reduced fuel bill
£29,000 Retrofit costs
Very High Disruption



Hydrotreated Vegetable Oil → (**10-15%** cost increase)

- Least invasive
- Most cost effective
- Requires fuel storage
- Potential to reduce CO_2 emissions by up to 90%
- Not an entirely 'clean' energy source
- Supply could be affected by severe weather events

Air Source Heat Pump & BESS → (~**£3,500** with grant , ~**£11,000** without grant)

- Air to water heat pump (5 kW), compatible hot water cylinder and an increase in BESS capacity
- Combined with suggested retrofits for maximum efficiency
- If existing renewables are less than required supply, additional sources may be required

Ground Source Heat Pump & BESS → (~**16,500** with grant , ~**£24,000** without grant)

- Ground source heat pump (5 kW), compatible hot water cylinder and an increase in BESS capacity
- Combined with suggested retrofits for maximum efficiency
- If existing renewables are less than required supply, additional sources may be required

BESS → (cost unknown)

- Increase in BESS capacity for efficient storage to meet electrical demands of the property
- The installation and maintenance cost will be dependent on the BESS capacity required

*Battery Energy Storage System (BESS)

Case Study 2

In a nutshell

Motivation and willingness: Keen to decarbonize, mainly for financial reasons

Barriers and ability to decarbonise: Access to trained professionals; planning regulations.

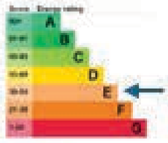
Rural brick house, off gas, homeowners, retired environmentalist ***Energy Performance Certificate E***

House Details	
Building type	Village edge, Detached Bungalow 1960s
Grid connection	Not connected to gas grid, connected to electric grid
Energy source(s)	Solar PV, heat pump, BESS
Fabric	Cavity wall with insulation, double glazing, average insulation standard

Anticipated Retrofit
High-quality windows.

Energy Performance Certificate E

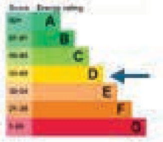
84% Decarbonised
4% reduced fuel bill
£16,000 Retrofit costs
Medium Disruption



Decarbonised Retrofit
Insulate the floor and roof, high quality windows.

Energy Performance Certificate D

89% Decarbonised
45% reduced fuel bill
£22,000 Retrofit costs
Very High Disruption



Vertical Axis Wind Turbine (VAWT) → (~**£4000**, no grant available)

- Single wall or roof mounted VAWT (2 kW)
- Could provide up to 480 kWh per year
- Will not provide the full electrical requirement for the household

5 x VAWTs → (~**£32,000** , no grant available)

- 5 wall or roof mounted VAWT (2 kW)
- Increase to 40.5 kW BESS capacity
- Would require an approximate area of 16 m² available for siting and approval from the local authority

Standalone VAWT → (~**£66,000** , no grant available)

- Single standalone VAWT (18 m mast height, 7.5 kW)
- Increase to 40.5 kW BESS capacity
- Would require an approximate area of 26 m² available for siting and approval from the local authority
- Potential for up to £430 - £860 generated per year

Community Based Scheme → (£304,000 - **£7,600** per household)

- 600 m² of solar PV (fixed axis, 0.2 MW array)
- 4 mid-size HAWT (80 kW)
- 400 kW BESS
- Would require buy in from the community, and an approximate area of 2240 m² available for siting
- Significant maintenance costs (additional)
- Cost per household would likely be too high for the scheme to be viable

*Battery Energy Storage System (BESS)

Case Study 3

In a nutshell

Motivation and willingness: Keen to decarbonise for financial and environmental reasons

Barriers and ability to decarbonise: Dependency on landlord; financial; local infrastructure.

Rural flat, off gas, social rent, disability, fuel poverty

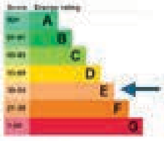
Energy Performance Certificate E

House Details	
Building type	Village, Semi-detached Ground floor flat pre 1919
Grid connection	Not connected to gas grid, connected to electric grid
Energy source(s)	Ground source heat pump, solar PV
Fabric	Limestone walls, double glazing, average insulation standard

Anticipated Retrofit
Internally insulate the walls and high-quality windows.

Energy Performance Certificate E

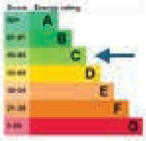
86% Decarbonised
20% reduced fuel bill
£15,000 Retrofit costs
High Disruption



Decarbonised Retrofit
Insulate the walls, floor and roof, high quality windows.

Energy Performance Certificate C

90% Decarbonised
50% reduced fuel bill
£19,000 Retrofit costs
Very High Disruption



BESS → (£5,000 to **£7,500**)

- BESS (10 kW)
- Ensures that the property receives continuous electricity
- Would require an approximate area of 0.2 m²
- Must be outdoor or in garage and can be wall mounted

Community Based Scheme (Wind & Solar) → (£340,000 - **£6,800** per household)

- 750 m² of solar PV (fixed axis, 134 kW array)
- 2 mid-size HAWT (80 kW)
- 1.0 MW BESS
- Would require buy in from the community, and an approximate area of 1625 m² available for siting
- Significant maintenance costs (additional)

Community Based Scheme (Solar) → (£560,000 - **£11,200** per household)

- 1500 m² of solar PV (fixed axis, 0.27 MW array)
- 800 kW BESS
- Would require buy in from the community, and an approximate area of 1660 m² available for siting
- Significant maintenance costs (additional)

Community Based Scheme (Wind) → (£520,000 - **£10,400** per household)

- 4 mid-size HAWT (80 kW)
- 1.2 MW BESS
- Would require buy in from the community, and an approximate area of 1590 m² available for siting
- Significant maintenance costs (additional)
- Unlikely to be approved by local planning authorities

*Battery Energy Storage System (BESS)

Case Study 4

In a nutshell

Motivation and willingness: Willing to decarbonise to save money

Barriers and ability to decarbonise: Financial; dependency on landlord; habits and preference for high temperatures.

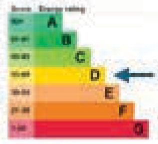
Urban semi, off gas, family, social rent, saving on heating

Energy Performance Certificate G

House Details	
Building type	Town, Semi-detached House 1960s
Grid connection	Not connected to gas grid, connected to electric grid
Energy source(s)	Mains electric
Fabric	Cavity walls with insulation, double glazing, average insulation standard

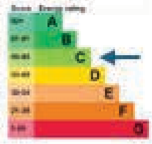
Anticipated Retrofit
High-quality windows.
Install a heat pump
Energy Performance Certificate D

91% Decarbonised
55% reduced fuel bill
£15,000 Retrofit costs
High Disruption



Decarbonised Retrofit
Insulate the floor and roof, high quality windows.
Install a heat pump
Energy Performance Certificate C

93% Decarbonised
69% reduced fuel bill
£20,000 Retrofit costs
Very High Disruption



Community Based Scheme (Wind & Solar) → (£907,000 - **£18,145** per household)

- 2000 m² of solar PV (fixed axis, 350 kW array)
- 3 mid-size HAWT (80 kW)
- 1.2 MW BESS
- Would require buy in from the community, and an approximate area of 3400 m² available for siting
- Significant maintenance costs (additional)

Community Based Scheme (Solar) → (£820,000 - **£16,400** per household)

- 3000 m² of solar PV (fixed axis, 0.53 MW array)
- 600 kW BESS
- Would require buy in from the community, and an approximate area of 3305 m² available for siting
- Significant maintenance costs (additional)

Community Based Scheme (Wind) → (£640,000 - **£13,600** per household)

- 8 mid-size HAWT (80 kW)
- 1.2 MW BESS
- Would require buy in from the community, and an approximate area of 3155 m² available for siting
- Significant maintenance costs (additional)
- Unlikely to be approved by local planning authorities

Air Source Heat Pump → (~**£3,500** with grant , ~**£11,000** without grant)

- Air to water heat pump (5 kW), assuming existing pipework is compatible
- Combined with suggested retrofits for maximum efficiency
- Using current mains electric supply, significant additional electric cost

*Battery Energy Storage System (BESS)

Case Study 5

In a nutshell

Motivation and willingness: Willing to reduce carbon emission while balancing other needs such as habits, aesthetics and value for money.

Barriers and ability to decarbonise: Habit; planning; expert advice.

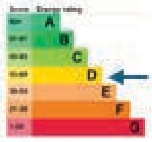
Detached stone house, off gas, homeowners, retired older couple ***Energy Performance Certificate E***

House Details	
Building type	Rural, Detached House pre 1919
Grid connection	Not connected to gas or electric grid
Energy source(s)	Solar PV, oil, BESS
Fabric	Limestone walls, single glazing, poor insulation standards

Anticipated Retrofit
Internally insulate the walls and high-quality windows.

Energy Performance Certificate D

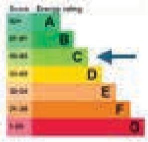
63% Decarbonised
28% reduced fuel bill
£23,000 Retrofit costs
Very High Disruption



Decarbonised Retrofit
Insulate the walls, floor and roof, high quality windows.
Install a heat pump

Energy Performance Certificate C

93% Decarbonised
57% reduced fuel bill
£35,000 Retrofit costs
Very High Disruption



Hydrotreated Vegetable Oil → (**10-15%** cost increase)

- Least invasive
- Most cost effective
- Requires fuel storage
- Potential to reduce CO_2 emissions by up to 90%
- Not an entirely 'clean' energy source
- Supply could be affected by severe weather events

Biomass Boiler → (**~£15,000** with grant , **~£20,000** without grant)

- Requires fuel storage
- Not an entirely 'clean' energy source, but potential to be CO_2 neutral, depending on fuel sourcing
- Estimated annual fuel cost of up to £575

Air Source Heat Pump → (**~£3,500** with grant , **~£11,000** without grant)

- Air to water heat pump (5 kW), assuming existing pipework is compatible
- Combined with suggested retrofits for maximum efficiency
- Would likely require an additional electric source, which could be provided by the mains electric connection, or additional renewable sources

Ground Source Heat Pump → (**~16,500** with grant , **~£24,000** without grant)

- Ground source heat pump (5 kW), assuming existing pipework is compatible
- Combined with suggested retrofits for maximum efficiency
- Would likely require an additional electric source, which could be provided by the mains electric connection, or additional renewable sources

Case Study 6

In a nutshell

Motivation and willingness: There is a willingness and a desire to improve the energy efficiency of the house, mainly for financial reasons and for warmth.

Barriers and ability to decarbonise: Financial barriers, as well as reluctance to engage in disruptive renovations.

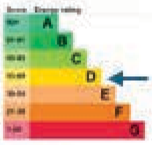
Old detached house, oil boiler, homeowners, couple with one child ***Energy Performance Certificate E***

House Details	
Building type	Village, Detached House pre 1919
Grid connection	Not connected to gas or electric grid
Energy source(s)	Oil, mains electric
Fabric	Limestone walls, single glazing, poor insulation standards

Anticipated Retrofit
Internally insulate the walls and high-quality windows.

Energy Performance Certificate D

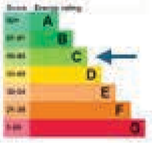
47% Decarbonised
30% reduced fuel bill
£18,000 Retrofit costs
High Disruption



Decarbonised Retrofit
Insulate the walls, floor and roof, high quality windows.
Install a heat pump

Energy Performance Certificate C

90% Decarbonised
56% reduced fuel bill
£27,000 Retrofit costs
Very High Disruption



New Gas Connection → (~£1,400,000 - **£35,000** per household)

- Provided that a property uptake of 30% is met (estimated to be 9 – 12 properties)
- Not a 'clean' energy, but will provide sufficient heating and continuous supply

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- Least invasive
- Most cost effective
- Requires fuel storage
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Biomass Boiler → (**~£15,000** with grant , **~£20,000** without grant)

- Requires fuel storage
- Not an entirely 'clean' energy source, but potential to be CO_2 neutral, depending on fuel sourcing
- Estimated annual fuel cost of up to £575

Solar PV Heating System → (**~35,000**, no grants available)

- 3.5 kW solar PV array
- Would require installation of an immersion heater
- To ensure continuous heating and hot water supply a BESS (14 kW) system would be required

*Battery Energy Storage System (BESS)