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Decarbonising Off Grid Homes: A Rapid Evidence Review

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Knowledge Applied

Decarbonising Off Grid Homes: A Rapid Evidence Review

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Executive Summary

Overview and methodology (Chapter 1)

Currently, there are circa 2,000 properties across the UK that are 'off-grid', meaning they are without access to both electricity and gas mains / grid connections. A further 4.3 million UK domestic properties are off the mains gas grid (BEIS, 2022d). A range of socio-economic challenges are faced by people living 'off-grid', including being at greater risk of fuel poverty, and struggling to adequately heat their homes.

This evidence review forms part of a wider research project about the realities and practicalities of decarbonising off grid properties. It aims to understand what is currently known about approaches to decarbonising (or improving the energy performance of) homes that are completely or partially off grid. We were interested in understanding what the existing literature around decarbonising off grid homes tells us about the following questions.

Drivers

- What are the **drivers and barriers** of off grid decarbonisation?
- What are the main **policies and regulations** determining whether and at what pace off grid decarbonisation should happen? What are the relevant regulatory frameworks relevant to off grid decarbonisation? What are the policy drivers of off grid decarbonisation?

Challenges

- What are the **issues that need to be considered** in relation to decarbonising or improving the energy efficiency of off grid properties? What does the literature tell us about the **priorities for occupants – how they might respond and what they might prefer** in terms of decarbonisation solutions?
- What are the financial, social, cultural and practical **impacts** of decarbonising off grid homes for **households**?
- What are the **impacts** of decarbonising off grid homes on **energy infrastructure**?

Solutions and policy support

- What **approaches to decarbonising** off grid properties are featured in the literature and are there any lessons about **pros and cons** of these approaches?
- What is effective in terms of **policy and regulatory interventions** in relation to improving energy performance of off grid homes?
- What works in relation to **different off grid scenarios** (for example, totally off grid, partially, remote rural, agricultural, historic homes, homes in national parks etc.)?
- What works for **particular groups of occupants** living off grid (for example, older people, farmers, families, low-income households etc.)?

- Which **agencies** are involved in off grid decarbonisation or are crucial to it? Who is trusted in this context?

The evidence review took the form of a Rapid Evidence Assessment (REA). Criteria were developed to assess the studies for inclusion in the review, in relation to types of studies (published peer-reviewed outputs, grey literature, and online book chapters), date range (2015 and onwards), study design (all types included), population (off-grid or partially off-grid communities in the UK), phenomena of interest (decarbonisation), context (off-grid or partially off-grid communities or households), and language (English).

The final full search string was: (“off grid” OR “off-grid” OR “off gas” OR “off-gas”) AND (“communit*” OR “home*” OR “propert*” OR “house*” OR “occupant*”) AND (“decarbonis*” OR “energy efficiency” OR “energy performance” OR “low carbon heating” OR “alternatives to oil heating”).

Overall, 44 sources were included in the review.

Policy context (Chapter 2)

- The evolution of decarbonisation policies in the UK has been marked by a series of initiatives aimed at transitioning towards cleaner energy sources and reducing carbon emissions. Beginning with the Clean Growth Strategy in 2017, the UK government committed to phasing out high-carbon fossil fuel heating in off-grid homes, setting the stage for subsequent frameworks like the Future Framework for Heat in Buildings. This framework emphasised the role of industry leadership in driving the transition, with electrification and improved energy efficiency identified as primary pathways for decarbonisation.
- The Heat and Buildings Strategy introduced in 2021 further outlined plans to prioritise energy-efficient buildings and phase out fossil fuel boilers by 2035, with a specific focus on off-gas grid properties starting from 2026. The government proposed a 'heat pump first' approach, promoting air source heat pumps as lead technologies for decarbonisation, while also considering alternative low-carbon heating solutions where applicable.
- In parallel, government initiatives such as the Home Upgrade Grant Phase 2 (HUG 2) aims to improve energy efficiency in off-grid homes, particularly targeting low-income households. However, concerns are raised regarding the effectiveness of using Energy Performance Certificates (EPCs) as a measure of energy efficiency, potentially incentivising the use of high-carbon fuels.
- Broader initiatives like the Social Housing Decarbonisation Fund and Energy Company Obligation (ECO4) seek to address energy efficiency and decarbonisation across various housing sectors, including off-grid properties. However, challenges remain in effectively implementing these schemes, with reports indicating issues with meeting retrofitting targets.
- In Scotland and Wales, regional governments have also developed strategies to promote heat decarbonisation, emphasising community-led projects and tailored approaches to address regional nuances. These initiatives include funding support for renewable energy projects and energy efficiency improvements.

Demographics of off-grid households in the UK (Chapter 3)

- As of 2021, the UK has approximately 4.3 million domestic properties off the mains gas grid, constituting around 15% of all residences, with England alone accounting for roughly 3.6 million off-grid homes. This number has increased since 2015.
- Around 2,000 properties are completely off-grid, lacking both electricity and gas supply.

- Rural areas have a significantly higher incidence of being off the gas grid compared to urban areas, largely due to geographical factors.
- Off-grid properties, especially rural ones, are more likely to use heating oil or coal, presenting opportunities for emission reductions.
- Fuel poverty rates are notably higher among off-grid households, with a fuel poverty gap more than three times that of on-grid households. Rates vary across nations and regions, with rural areas generally experiencing higher fuel poverty rates. Cold climates, higher living costs, limited job opportunities, aging demographics, and a lack of affordable housing contribute to fuel poverty among off-grid households.

Living off-grid: challenges and coping strategies (Chapter 4)

- Households in the UK choose off-grid living for various reasons, including sustainability, environmental concerns, and a preference for renewable energy. However, a lack of alternative options in remote areas mean this choice is often limited.
- Rural and detached properties often rely on oil-fired heating or LPG, with approximately one million off-grid properties using oil as their main fuel source. Solid fuel and LPG are also common alternatives. Flats off the gas grid typically rely solely on electricity, particularly single-person households. Traditional heating and cooking methods, such as range cookers, contribute to energy inefficiency in rural lifestyles. Yet, transitioning to more efficient systems is challenging, especially for older properties or those in conservation areas.
- Affordability is a critical concern, with fuel costs varying and often volatile for off-grid households. Higher prices for alternative fuels disproportionately affect lower-income households, exacerbating fuel poverty.
- Health implications arise from inferior quality fuels and traditional heating methods, impacting vulnerable groups.
- Security of supply is another challenge, with households resorting to multiple fuel strategies to mitigate shortages. Household energy adaptations include diversifying energy sources and adopting energy-saving practices, yet economic and logistical barriers persist, particularly in rural areas.

Decarbonisation approaches and implications (Chapter 5)

- Studies suggest a shift away from natural gas towards electrical systems, especially with the increasing adoption of technologies like air source heat pumps (ASHPs). However, while ASHPs are regarded as efficient, they come with high upfront costs and may not be feasible for lower-income households. Ground Source Heat Pumps (GSHPs) offer high efficiency but require ample outdoor space.
- Case studies like the Isle of Eigg in Scotland demonstrate successful off-grid renewable energy systems, showcasing the potential of community-driven initiatives. Community involvement is highlighted as crucial for sharing knowledge and experiences during the transition to new energy systems.
- The evidence reviewed in this chapter highlighted the complexity and multifaceted nature of the transition to sustainable energy systems for off-grid homes, requiring a nuanced approach that considers regional variations and occupant preferences.
- Various decarbonisation pathways, including electrification, mixed technology switches, and the use of BioLPG boilers, are being explored. Yet, barriers such as affordability, housing tenure, and community involvement need to be addressed to ensure the widespread adoption of low-carbon solutions.

- Understanding the potential consumer experience with different technologies in off-grid decarbonisation transitions is a crucial but currently under-researched area.

Conclusions (Chapter 6)

- The evidence review examined approaches to decarbonising off-grid homes, exploring key considerations, challenges, and drivers.
- Drivers include government policies, cost savings, and community initiatives, while barriers include infrastructure limitations and high capital costs.
- The review identifies knowledge gaps, particularly regarding occupant preferences and responses, and the impacts of decarbonisation on energy infrastructure and households.
- Solutions must be diverse, tailored to different scenarios and occupant groups, and involve various stakeholders like governments, local councils, and consumer advocacy organisations.
- Trust in the energy sector is highlighted as crucial, with ongoing evaluation and adaptation of policies essential for success.
- Addressing concerns around equity, affordability, and inclusivity is vital for effective policy interventions, ensuring widespread adoption of sustainable solutions for off-grid decarbonisation.

1 Introduction

1.1. Overview of the project

This evidence review forms part of a wider research project about the realities and practicalities of decarbonising off grid properties. Currently, there are circa 2,000 properties across the UK that are 'off-grid', meaning they are without access to both electricity and gas mains/ grid connections. A further 4.3 million UK domestic properties are off the mains gas grid (BEIS, 2022d). A range of socio-economic challenges are faced by people living 'off-grid', including being at greater risk of fuel poverty, and struggling to adequately heat their homes. Therefore, there is a need for Distribution Network Operators (DNOs) and Gas Distributions Networks (GDNs) to understand the realities and practicalities of decarbonising off-grid properties and the likely impacts on occupants.

Despite representing a small population collectively, off-grid properties must be decarbonised to enable the attainment of net zero targets. This is also essential to avoid these households representing 'stranded assets' that are still dependent on highly expensive fossil fuels, once much of the rest of the country has transitioned to low carbon sources.

The focus of the wider project is on homes that are completely or partially 'off grid' in the North of England, which fall under the jurisdiction of Northern Powergrid and Northern Gas Network.

The scope of work consists of analysis, modelling, and occupant engagement to inform the development of decarbonisation solutions for off-grid communities which are technically, financially, socially, and culturally viable and replicable across other off-grid communities within the UK. The objectives of the wider project are to:

- Identify the current and likely future policy and regulatory frameworks within which decisions about the decarbonisation of off-grid communities will be made.
- Fully understand the nature of the identified case study off-grid communities from a physical, social, cultural, and infrastructural perspective.
- Engage with ~30 households living off grid in the case study locations (prioritising vulnerable households) to understand the full range of energy demands associated with current and likely future lifestyles and to gain their feedback on the acceptability, practicability and affordability of the identified decarbonisation solutions.
- Identify and assess the main decarbonisation solutions for the case study communities, considering technical, financial, social, cultural, and geographical barriers.

- Engage with key stakeholders with excellent knowledge of off grid communities and energy transitions to inform a final assessment of the most viable and replicable options and develop recommendations.
- Consider full system decarbonisation options, for example, how do we link connections to the requirements for Electric Vehicle (EV) / Hydrogen (H2) / delivery vehicles.
- Explore whether there are assets within the case study communities which could be harnessed for decarbonisation and future energy provision options.

1.2. Aims of the evidence review

The main aim of this evidence review is to understand what is currently known about approaches to decarbonising (or improving the energy performance of) homes that are completely or partially off grid. In particular, it explores evidence on the key considerations, challenges, barriers and enablers of decarbonisation – both practically and in terms of occupants' views and experiences. We were particularly interested in understanding what the existing literature around decarbonising off grid homes tells us about the following questions:

Drivers

- What are the **drivers and barriers** of off grid decarbonisation?
- What are the main **policies and regulations** determining whether and at what pace off grid decarbonisation should happen? What are the relevant regulatory frameworks relevant to off grid decarbonisation? What are the policy drivers of off grid decarbonisation?

Challenges

- What are the **issues that need to be considered** in relation to decarbonising or improving the energy efficiency of off grid properties? What does the literature tell us about the **priorities for occupants - how they might respond and what they might prefer** in terms of decarbonisation solutions?
- What are the financial, social, cultural and practical **impacts** of decarbonising off grid homes for **households**?
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Solutions and policy support

- What **approaches to decarbonising** off grid properties are featured in the literature and are there any lessons about **pros and cons** of these approaches?
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- What works in relation to **different off grid scenarios** (for example, totally off grid, partially, remote rural, agricultural, historic homes, homes in national parks etc.)?
- What works for **particular groups of occupants** living off grid (for example, older people, farmers, families, low-income households etc.)?
- Which **agencies** are involved in off grid decarbonisation or are crucial to it? Who is trusted in this context?

1.3. Review methodology

This evidence review took the form of a Rapid Evidence Assessment (REA). An REA is a systematic and transparent method of reviewing existing literature and knowledge, while also being particularly useful when synthesising the evidence base in an efficient and timely manner. The REA framework used in this review was adapted from previously developed frameworks, and consisted of protocol development, literature review, screening and study selection, data extraction, knowledge synthesis and output production. The protocol development stage involved the development of a clear and detailed plan for the review, including setting out the context, rationale and research questions and objectives. The protocol further set out the search strategy for the review, the inclusion criteria, what information will be extracted from included sources, and how we will synthesise the data. In the reporting of this review, we follow PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021).

Search strategy and inclusion criteria

Criteria were developed to assess the studies for inclusion in the review; these criteria are listed in Table 1.

Table 1: Inclusion criteria for the Rapid Evidence Assessment

Selection criteria	Inclusion criteria
Types of studies	Published peer-reviewed outputs, grey literature (in the form of reports or briefings), and online book chapters.
Date	Articles/reports published since 2015. 2015 was chosen due to the resources available for the study, and timeliness and relevance to policy frameworks. Exceptions were made where studies were particularly relevant to the research questions.
Study designs	All study designs included.
Population	Sources focusing on off-grid (or partially off-grid) communities in the UK, due to relative comparative policy frameworks, legislative environments and geographical/climatic contexts.
Phenomena of interest	Decarbonisation.
Context	Off-grid (or partially off-grid) communities and households.
Language	English.

Search terms were developed based on the research question(s) and on the expertise of the research team. Two search strings were developed. The first string focused on the context and population; this included the keywords of “off grid” OR “off-grid” OR “off gas” OR “off-gas” AND “communit*” OR “home*” OR “propert*” OR “house*” OR “occupant*”. The second search string was developed to focus on the phenomena of interest, i.e., decarbonisation; this included key words such as “decarbonis*” OR “energy efficiency” OR “energy performance”. These search strings were then combined using Boolean phrasing and piloted to test the reach and relevance of the search. The final full search string was: (“off grid” OR “off-grid” OR “off gas” OR “off-gas”) AND (“communit*” OR “home*” OR “propert*” OR “house*” OR “occupant*”) AND (“decarbonis*” OR “energy efficiency” OR “energy performance” OR “low carbon heating” OR “alternatives to oil heating”). The Boolean phrasing was modified for each database.

Search methods

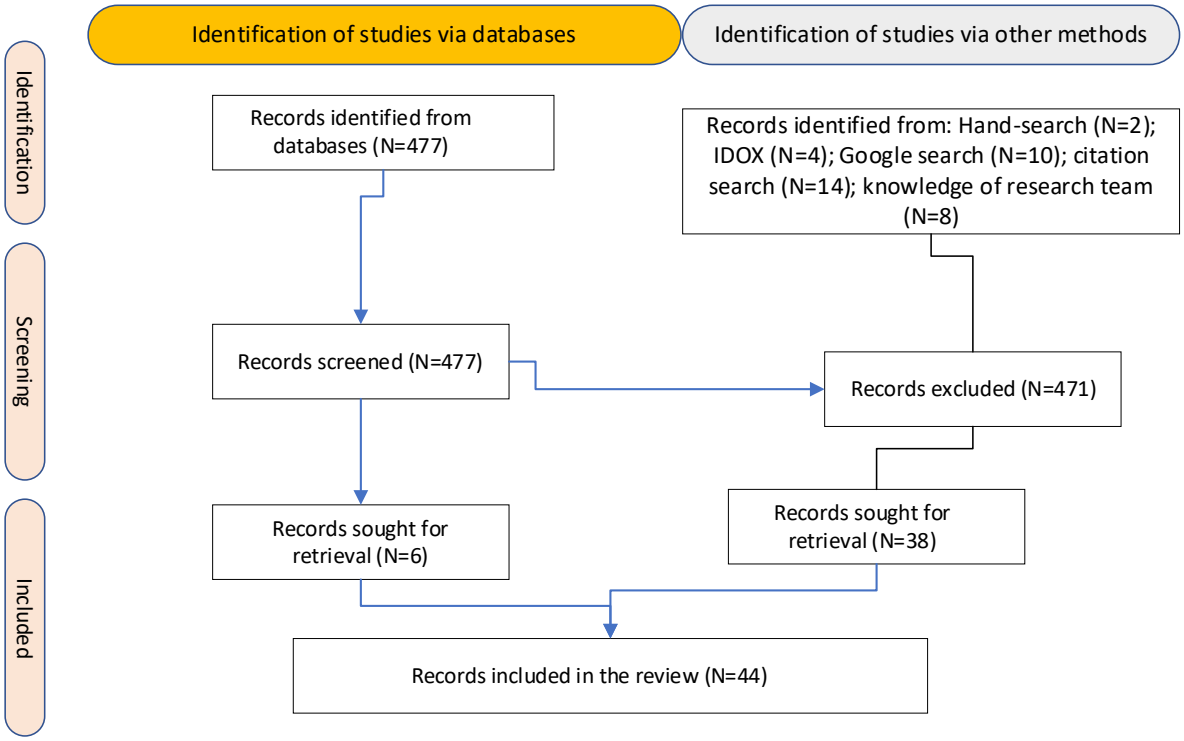
Figure 1: Search tools

Scopus and Web of Science, the two largest bibliographic databases, were used for the search. A hand search of relevant journals identified by the research team was conducted. These journals included Energy Policy, Energy Research and Social Science, Consumption and Society, Nature Energy, Sustainability, Local Environment, and Energy and Buildings. A Google search limited to the top 50 returns was undertaken, as well as a hand search of reference lists. A search for grey literature sources was used to supplement the academic database searches. This included a search conducted through the IDOX service. The team reviewed sources for relevance based on the title and abstract/executive summary.

Included studies

Overall, 44 sources were included in the review. In the PRISMA flowchart in Figure 2, at each stage of the search process, the number of records identified are displayed.

Figure 2: PRISMA flowchart of search process



Data extraction and synthesis

All selected records were read by a member of the research team. The extracted data were then synthesised using a narrative synthesis approach, which involved the development of a descriptive summary of the key findings across the selected studies. This data synthesis approach was guided by the research questions and the objectives set out in the introduction. This approach enabled the identification of patterns and trends in the literature, allowing for the exploration of approaches to decarbonising homes that are off grid, and the key considerations, challenges, barriers and enablers of decarbonisation.

Evidence review limitations

As an REA, this approach does impose some limits on the search and inclusion criteria due to the timeframes involved. This may mean that this study does not capture as broad an evidence base in comparison to a full systematic review. Despite this, the present study covers a suitable timeframe (post-2015) and grey literature was included to broaden the evidence reviewed. The study only included English language records and focused on the experiences within the UK. While incorporating other languages was out of the scope of this study, a further study that incorporates other languages and the experiences within the global south would be advantageous to identify further evidence on this important topic.

1.4. Structure of the report

The remainder of this report is structured as follows: Chapter 2 sets out the policy and regulatory frameworks involved in shaping the direction of off-grid decarbonisation agendas; Chapter 3 explores the demographics of off-grid households in the UK; Chapter 4 examines the motivations, challenges, and coping strategies of living off-grid; Chapter 5 considers a range of decarbonisation solutions and scenarios for off-grid households, and their implications; and Chapter 6 summarises findings under the review's research questions.

2 Policy context

2.1. Policy evolution in the UK

This chapter traces the chronological progression of UK decarbonisation policy, starting from the Clean Growth Strategy (BEIS, 2017) and extending to contemporary initiatives and funding schemes. The chapter focuses on policies directly relevant to off-grid properties as well as broader decarbonisation initiatives, which, while not specifically designed for off-grid properties, still carry implications for them.

Clean Growth Strategy to Future Framework for Heat in Buildings

The UK's approach to off-grid properties is rooted in the Clean Growth Strategy (BEIS, 2017), which committed to phasing out "the installation of high carbon forms of fossil fuel heating in new and existing homes currently off the gas grid during the 2020s, starting with new homes". As a subsequent step, the government launched 'A Future Framework for Heat in Buildings' (BEIS, 2018a), calling for evidence on strategies to realise the goals outlined in the Clean Growth Strategy. The framework aims to address the decarbonisation of heat in buildings by outlining a long-term plan to phase out high carbon fossil fuel heating, supporting industry in leading the delivery of the transition, exploring potential regulations, and assessing clean heating technologies for off-grid properties. As Qureshi (2022) remarks, the apparent aim of the government, in this document, was to establish a policy framework initially centred on encouraging the market to drive the transition; only then would the focus shift to assisting consumers and industry in adhering to regulations in the long term. In response to their call for evidence (BEIS, 2018b), the government identified electrification, coupled with enhancing building energy efficiency, as the primary opportunity for decarbonising the majority of off-grid buildings. A prominent message from the response emphasised the requirement for a government-established, clear, and long-term framework, enabling industry to actively contribute to the transition.

The Heat and Buildings Strategy

The UK government's Heat and Buildings Strategy (BEIS, 2021a) focuses on reducing carbon emissions from buildings, which account for a significant portion of the UK's carbon footprint. The strategy involves prioritising action on buildings with the lowest energy efficiency or those responsible for the highest carbon emissions. The overall goal is to ensure that buildings are energy efficient before transitioning to low-carbon heating sources on a larger scale ('fabric first'). Additionally, there is a focus on collaborating with network companies and industry to enhance capacity and build supply chains in preparation for a widespread shift to low-carbon heat sources. In the longer term, there is an ambition to phase out the installation of new fossil fuel boilers from 2035, contingent on cost reductions. This signals a commitment to a gradual transition away from traditional heating methods in favour of more sustainable alternatives. Notably, the strategy suggests initiating the shift to low-carbon heating with a primary focus on buildings not connected to the gas grid. For off-gas-grid buildings, the proposed phase out of new fossil fuel heating systems and the switch to

low-carbon alternatives is from 2026 (2035 for on-gas-grid buildings[1]). This sentiment is echoed by the Committee on Climate Change (2019), who state that deployment of low-carbon heat cannot wait until the 2030s and identify the opportunity to install heat pumps in homes that are off the gas grid.

Phasing Out the Installation of Fossil Fuel Heating in Homes Off the Gas Grid

In October 2021, alongside the Heat and Buildings Strategy, the UK government released an additional call for evidence. 'Phasing out the Installation of Fossil Fuel Heating in Homes Off the Gas Grid' (BEIS, 2021b) sets out the government's policy proposals on phasing out the installation of fossil fuel heating systems in homes off the gas grid and invites stakeholders' views on their approach. The proposals can be summarised as follows:

- **End to fossil fuel heating installation (2026):** The government proposes to cease the installation of new fossil fuel heating systems in off-gas grid homes starting from 2026. Recognising the need for targeted regulation to drive the transition to low-carbon heat, the proposal aims to balance the pace of change with industry and consumer considerations. The focus is on promoting air source heat pumps as the lead technology for decarbonising off-gas grid homes, with an ambition to reduce upfront costs by 25-50 per cent by 2025 and achieve cost parity with gas boilers by 2030. Financial support through schemes like the Boiler Upgrade Scheme is intended to facilitate the transition, which is eligible for specific properties/households (homeowners). However, this scheme still only provides a grant towards a fraction of the upfront cost of low carbon heating systems so is only accessible for households who are able to meet the rest of the costs.
- **'Heat pump first' approach (2026):** The government advocates a 'heat pump first' approach for replacing heating systems from 2026. Heat pumps are identified as a primary technology for decarbonising heat, with a proposal to set a high standard favouring low-temperature air source heat pumps. The goal is to make low-temperature air source heat pumps the lead replacement technology, supplemented by other high-performing low-carbon options. The proposal extends this approach to homes that can be made suitable for heat pumps through minor energy efficiency upgrades. The government intends to issue guidance on determining the practicality of installing a heat pump and seeks public input on the proposed approach. Qureshi (2022) sees this as too much of an 'all or nothing' approach, placing an unfair and disproportionate burden on off-grid households, and not offering consumers choice as to what heating technology they choose.
- **High performing replacement systems:** For homes where a low-temperature heat pump cannot reasonably be installed, the proposal suggests enabling alternative low-carbon heating solutions consistent with net zero objectives. Criteria for replacement systems include the use of fully renewable fuels or those on a clear trajectory to becoming so, with a focus on minimising pollutant emissions, considering sustainability, and ensuring a positive consumer experience. High-temperature heat pumps and solid biomass systems are initially identified as consistent with these criteria, providing room for industry innovation. The government is exploring the potential of alternative electric heating

[1] However, in a recent press release the Prime Minister committed to revising these plans and timescales. Under revised plans, the Government will delay the ban on installing oil and LPG boilers, and new coal heating, for off-gas-grid homes to 2035, instead of phasing them out from 2026 (https://www.gov.uk/government/news/pm-recommits-uk-to-net-zero-by-2050-and-pledges-a-fairer-path-to-achieving-target-to-ease-the-financial-burden-on-british-families).

appliances and net-zero consistent liquid biofuels as future options. Consultations on the detailed criteria and implementation options are planned.

2.2. Current government initiatives and grants

The **Home Upgrade Grant** (Phase 2) (HUG 2) is the main grant support for off-grid homes in England (BEIS, 2022a; BEIS, 2021b). HUG 2, to be delivered between April 2023 and March 2025, has two key objectives according to government guidance: 1) "to deliver progress towards the statutory fuel poverty target for England, by improving as many fuel-poor homes as reasonably practicable to a minimum energy efficiency rating of Band C by 2030, with the interim milestone of Band D by 2025"; 2) "to enable the delivery of the wider Net Zero programme to phase out high-carbon heating for homes off the mains gas grid, by growing supply chains and ensuring such policies do not act to the detriment of fuel-poor households".

HUG 2 is aimed at off-gas-grid homes of low-income households (defined as having an annual gross household income of less than £31,000) with an Energy Performance Certificate (EPC) between D and G, and in one of the local authority areas in receipt of the funding. At the current time, 45 local authorities have received funding under HUG 2. While individual HUG programmes are council-led, the funding available is often used for a range of energy efficiency measures, such as insulation, air source heat pumps, solar PV panels, and high heat retention storage heaters. The evidence review did not identify any formal evaluations of the HUG scheme at this early stage. While some acknowledge that HUG2 may be a step in the right direction for supporting low-income off-grid households (Qureshi, 2022), there are also a number of concerns raised about certain elements of the scheme. Qureshi (2022), for instance, notes the issues with regards to using the EPC system as a gauge for the energy efficiency of a domestic property. EPC methodology gives too much weight to the type of fuel used, in comparison to the fabric of the building. As a result, homes that are essentially the same but use different fuels can end up with different EPC ratings, with off-grid homes getting lower ratings. This has unintended consequences, especially for the government's efforts to improve energy efficiency through programmes like HUG2. Off-grid homeowners are encouraged to use high-carbon fuels to get a better EPC rating, which goes against the goal of making homes more energy efficient. The feasibility of different decarbonisation solutions for off-grid properties are considered in further depth in Chapter 5.

Additionally, there are various government initiatives aimed at decarbonising in a broader sense, not specifically tailored to off-grid properties.

The **Social Housing Decarbonisation Fund** (SHDF), created in 2020, "aims to deliver warm, energy-efficient homes, reduce carbon emissions and fuel bills, tackle fuel poverty, and support green jobs" (BEIS, 2022c: 13). The fund has an overall budget of £3.8 billion spread over ten years. However, the funding has been released in stages, with £62 million in 2020, £160 million in 2021, and up to £800 million in 2022. The projects funded by the SHDF are required to be completed in a short timeframe. As some have noted, the way the fund operates has led to ineffectiveness in establishing a lasting foundation for local projects to decarbonise social housing, with reports indicating that over half of the councils funded through the scheme had to return the money because they could not meet the retrofitting targets (Catapult, 2023).

Energy Company Obligation (ECO4) and the Great British Insulation Scheme are designed to run alongside existing support schemes, HUG and SHDF. ECO4, is expected to deliver energy efficiency measures to an estimated 450,000 low-income and vulnerable households. The Great British Insulation Scheme is intended to broaden the eligibility pool beyond low-income and vulnerable households to others who do not currently benefit from government support to upgrade their homes (DESNZ,

2023b). Previous iterations of ECO have been criticised as having limited benefits for off-gas rural homes in particular. Only two per cent of rural off-gas grid homes with heating oil or LPG received ECO measures according to data up to September 2015 (Calor Gas Ltd, 2016). Regarding the modifications implemented for ECO4, the 35 per cent increase in funding allocated to Scotland and Wales could potentially offer advantages to off-grid households in rural regions. This increase may facilitate installers in reaching homes requiring upgrades in those areas.

Referencing earlier iterations of ECO, Calor Gas Ltd (2016) responded to the Public Accounts Committee's inquiry on household energy efficiency schemes, focusing on off-gas-grid rural areas in Britain. They note that only two per cent of off-gas homes using oil or LPG received ECO measures. They highlight a number of issues with the first year of ECO, namely how definitions of 'rural' were inadequate, excluding smaller rural off-gas-grid communities; and how EPC methodology is unreliable in measuring energy efficiency in off-gas-grid areas. They emphasise the need for future policies to address these issues, ensuring equitable delivery and support for rural off-gas grid households.

Additionally, the **Solar Together Scheme**, first introduced in 2015, allows homeowners and private tenants (with permission from their landlord) in participating local authorities to group-purchase solar systems and battery storage at 30-35 per cent less than average market prices.[2] However, the scheme is not nationwide and is only active in a limited number of council areas.

2.3. Scotland

The Scottish Government has also formulated policies to promote heat decarbonisation, aligning with the country's 2032 goal of achieving 32 per cent of domestic heat from renewable sources. Outlined in the 2018 route map titled 'Energy Efficient Scotland' (Scottish Government, 2018), the government has established a 20-year programme aimed at delivering more environmentally friendly, energy-efficient homes by 2040.

A key focus has been placed on the significance of locally executed building retrofits, assigning local authorities a more proactive role in implementing energy efficiency measures and low-emission heating systems. This strategy acknowledges the regional nuances in building stock and household conditions, such as variations in fuel poverty rates, across the country. By leveraging the area-specific expertise of local authorities, this approach aims to set the stage for deploying a diverse range of low-carbon technologies tailored to the unique circumstances of each locality (Liquid Gas UK, 2019).

The Community and Renewable Energy Schemes (CARES), running from April 2021 to March 2025 focuses on supporting heat decarbonisation in community-led projects and helping to inform decisions for those participating in local energy projects (Scottish Government, 2021). Through this programme, up to £5.25 million was made available in the 2021 financial year to assist community groups in developing renewable energy projects. An additional £3 million is available to support decarbonisation of Scotland's most remote and rural off-grid communities by upgrading their energy systems, making them more energy resilient and sustainable for the future.

[2] https://solartogether.co.uk

2.4. Wales

In 2019, the Welsh Government introduced the "Prosperity for all: A low carbon Wales" (Welsh Government, 2019) vision document, outlining the country's policies and initiatives related to climate action. The plan reaffirms Wales' commitment to reducing emissions from buildings by 40 per cent by 2030, measured against 1990 levels. Various policy strategies have been devised to support emission reductions in buildings, encompassing funding for research and development in new builds,[3] retrofit,[4] energy efficiency grant schemes, and the tightening of building standards.

A notable aspect of the Welsh Government's strategy is its approach to energy planning, which involves mapping the most suitable sources of low-emission heat. This method acknowledges the intricacies of heat decarbonisation, recognising the diverse technological options available, all of which should be evaluated based on specific local circumstances (Liquid Gas UK, 2019).

One such scheme to help make homes warmer and more energy efficient is the Welsh Government Warm Homes Nest scheme, which offers free, impartial advice and a package of free, home energy efficiency improvements. This scheme will come to an end in April 2024, replaced by a new scheme with a greater focus on low carbon technologies (where it makes sense to do so).[5]

2.5. Summary

This chapter has explored the UK's strategy for off-grid properties, tracing its foundation in the Clean Growth Strategy and the subsequent 'A Future Framework for Heat in Buildings.' Emphasising the market-driven transition, the government aims to phase out high carbon fossil fuel heating, prioritising electrification and enhanced building efficiency. The chapter also examined current initiatives, such as the Home Upgrade Grant and broader decarbonisation efforts, including the Social Housing Decarbonisation Fund, ECO4, and the Great British Insulation Scheme. Criticisms and concerns about these programmes underscore the multifaceted challenges of transitioning off-grid properties to sustainable alternatives.

[3] Innovative housing programme | GOV.WALES
[4] https://www.gov.wales/optimised-retrofit-programme
[5] Home - Nest Wales - nest.gov.wales

3 Demographics of Off Grid Households in the UK

3.1. The extent of off-grid power in the UK

According to the most recent government estimates in 2021, approximately 4.3 million domestic properties are **off the mains gas grid** across Great Britain (BEIS, 2022d). This constitutes roughly 15 per cent of domestic properties in the UK. Specifically in England, approximately 3.6 million homes were estimated to be off the gas grid in 2021, accounting for around 15 per cent of residences in England (BEIS, 2022d). These figures have increased since 2015, at which point there was an estimated 4.1 million properties off the gas grid in the UK, and 3.3 million in England (BEIS, 2022d). The estimates are calculated by comparing the number of domestic properties with the number of domestic gas meters. They should therefore only be seen as approximate estimates.

Currently, there are circa 2,000 properties across the UK that are **completely 'off-grid'**, meaning they are without access to both an electricity and gas supply (EIC, 2023).

Based on data from the English Housing Survey, reports show that **rural properties** have a much higher incidence of being off the gas grid (56.8 per cent, compared to just 9 per cent of urban properties) (DESNZ, 2023a). Qureshi (2022) explains this further, attributing geography as the principal reason why many domestic and commercial properties will be off the gas grid, owing to their distance from the wider gas network. Attachment to home-places, and affordability, means that moving to a more connected property is not an option for many people (Roberts & Henwood, 2019). Properties off-gas also encompass **flats,** especially high-rise flats in urban areas (Catapult, 2023). According to Liquid Gas UK (2019), it is rural off-grid properties where the greatest emission reductions can be achieved, given their propensity to consume heating oil or coal. Flats are seen as less problematic given most heating demands are met by electric panel/storage heaters.

Among homes not connected to the gas grid, 20.1 per cent are **fuel poor**, compared to 12.3 per cent on the gas grid (DESNZ, 2023a). Gas grid homes have a higher percentage in energy efficiency bands A-C (48.4 per cent) compared to off-grid homes (31.3 per cent). The average fuel poverty gap for off-grid households is £804, more than three times that of on-grid households (£222) (DESNZ, 2023a).

Breaking down fuel poverty rates by nation, considering variations in definitions, in 2018, approximately 14 per cent of households in rural areas in Wales were identified as fuel poor, while urban areas had a lower rate of ten per cent. In England, fuel poverty rates remained consistent between rural and urban areas in 2020, both at 13.5 per cent, surpassing the semi-rural rate of 10.1 per cent. In 2019, Scotland reported that

about 43 per cent of households in remote rural areas met the Scottish definition of fuel poverty, notably higher than the overall rural rate of 29 per cent and the urban rate of 24 per cent. Gas grid connection had a minimal impact, with rates of 24 per cent for those on the grid and 27 per cent for those off it (Rough et al., 2022). There are a number of rural specific drivers of fuel poverty, which are likely to impact on the majority of households living off-grid, namely cold and wet climates, the higher cost of rural living, fewer employment and training opportunities and lower levels of pay, a shortage of affordable housing, ageing demographics, and limited access to support services (Changeworks, 2023a).

3.2. Summary

This chapter discussed the prevalence of off-grid properties in the UK, estimating around 4.3 million homes without mains gas access, constituting 15 per cent of residences. Rural areas, particularly, show a higher incidence of off-grid situations (56.8 per cent) compared to urban areas (nine per cent), mainly due to geographical factors (Qureshi, 2022). Fuel poverty rates vary, with 20.1 per cent for off-grid homes, higher than the 12.3 per cent on the gas grid. Gas-connected homes also exhibit better energy efficiency (48.4 per cent) compared to off-grid homes (31.3 per cent).

4

Living Off Grid: challenges and coping strategies

4.1. Fuel sources

Certain households might opt for off-grid living due to a preference for sustainable lifestyles, environmental concerns, a decision to prioritise renewable energy over traditional fuel sources, or wanting a closer relationship with the natural environment (Qureshi, 2022; Hope et al, 2018). Nevertheless, research indicates that the extent of this 'choice' is significantly influenced by the existing energy infrastructure, revealing that households in more remote areas of the UK often have limited options regarding their fuel sources (Golubchikov & O'Sullivan, 2020). Rural and detached properties are likely to rely on oil fired heating or LPG. It is estimated that approximately one million off-grid properties in the UK use oil as their main fuel source (Catapult, 2023). Around 198,000 homes use solid fuel as their main heating source, and 187,000 homes use LPG (Citizens Advice Scotland, 2018). Flats off the gas grid tend to rely on electricity alone (Catapult, 2023). Single person households are also more likely to have electric heating than other household types (Citizens Advice Scotland, 2018).

Golubchikov and O'Sullivan (2020) establish a connection between (inefficient) cooking and heating systems and the rustic allure or charm of rural lifestyles. They illustrate this with the instance of range cookers, such as Agas and Rayburns, which operate continuously on slow-burning fuel, consuming 30 times more energy for cooking compared to the UK average. The ability to switch to alternative or more efficient cooking and heating systems for households off-grid is extremely limited, however.

Not specifically limited to fuel sources, studies also show how households switch electrical appliances to ones that can be operated manually, such as cool boxes instead of fridges, and relying on more traditional food sourcing and preparation methods (Hope et al, 2018).

4.2. Building fabric

As demonstrated in Chapter 3, homes without access to the gas grid exhibit a greater likelihood of experiencing fuel poverty compared to those that are connected. Coupled with the high price of alternative fuels, the structural fabric of the building is likely to play a role in shaping this outcome. As recognised in decarbonisation initiatives' 'fabric first' approach (BEIS, 2021a), the building envelope is often considered the most important aspect of achieving a high-performance energy efficient building.

Off-grid homes, the majority of which are in rural areas, are more likely to be "leaky" pre-1900 solid stonewall builds which are particularly difficult to keep warm and

insulate (Golubchikov & O'Sullivan, 2020). Over 25 per cent of oil-heated properties featured in Liquid Gas UK's (2019) study were built before 1918. Transitioning to low carbon energy sources is therefore likely to be restricted to those with agency over the building and with the finance to improve the fabric, i.e. wealthier homeowners (Golubchikov & O'Sullivan, 2020). This challenge intensifies when these residences are located in conservation areas or National Parks, where measures are enforced to safeguard the traditional character of the area, further complicating the implementation of deep retrofitting measures such as external cladding. Occupants of older properties – or indeed, properties in rural areas – may be less willing to make any retrofitting measures that change the aesthetic appearance of their homes. In Roberts and Henwood (2019), for example, one off-gas household were keen to retain as much of their cottage's history as possible.

4.3. Affordability

It is important to acknowledge that affordability is partly contingent on household income and main fuel type used. Data from Citizens Advice Scotland (2018) show that households using heating oil are more likely to be on higher income bands. Those using oil or solid fuels for heating are more able to shop around for the best price. However, research has shown huge price volatility for heating oil and solid fuel supplies, making it difficult for households to properly budget for their fuel costs (Jewell et al., 2017). LPG customers usually enter into a contract with one supplier for a fixed period of time, and prices are capped during this timeframe (Jewell et al., 2017). Many suppliers also require customers to buy in bulk, posing a challenge for those on lower incomes (Jewell et al., 2017).

Evidence relays the difficulties faced in managing fuel costs for households living off-grid – not all of whom are on high incomes or have had the ability to 'shop around' – exacerbated by the continuous rise in fuel prices. Alternative off-grid power comes with additional economic costs, limiting access for lower-income households (Yadoo et al., 2011). Participants living off-gas in rural Wales, in Roberts' (2020) study, acknowledged the higher price for thermal comfort due to geographical factors and distance from the mains gas grid. Those relying on heating oil or cylinder LPG faced significant expenses, particularly in peripheral areas. One study participant noted a more than doubling of bottled gas prices, reaching about £150 from an initial £46 for a large cylinder. This increase of around 220 per cent translated to an additional £200-£300 per year in terms of consumption, and was on average twice the price of mains gas. The increasing price of bottled gas prompted this participant to re-consider how he heats his home; in this case, the only alternative was to rely more on the wood burner. This finding highlights the significance of affordability as a catalyst for change and emphasises the necessity for policies that guarantee a variety of affordable decarbonisation solutions for off-grid households.

4.4. Health implications

A number of sources highlight the health implications of living off-grid. Households, mainly in rural areas, lacking access to electricity often rely on inferior quality fuels such as candles, kerosene or gas lamps which can be detrimental to health and eyesight (Yadoo et al., 2011). Domestic wood and coal burning account for 38 per cent of primary particulate matter (PM) in the UK, the single largest contributor to national PM emissions in the UK (NAEI, 2018). PM is associated with a range of short- and long-term health impacts with effects more severe in vulnerable groups (older people, pregnant women, young children and people with existing lung and heart conditions). The UK Government's Clean Air Strategy 2019 (DEFRA, 2019) partly aims to raise awareness of the breadth of everyday activities that contribute to air pollution, acknowledging that public debate on air pollution has tended to primarily concentrate

on outdoor sources. Different fuels and heating methods produce different levels of pollution, with coal and wet wood considered the dirtiest fuel types and solid fuel open fires and stoves the most polluting heating method (DEFRA, 2019). Although local councils can now designate 'smoke control areas', in which only authorised fuels and appliances can be used, evidence suggests that awareness and compliance is low, and people still struggle to make the link between domestic burning and air pollution (DEFRA, 2019).

A number of studies note the physical labour involved in managing alternative energy supplies (gathering firewood, lifting LPG cylinders, for instance) and participants' concerns about sustaining these practices as they aged (Roberts, 2020; Forde, 2017). Similar concerns were raised about ageing in off-grid homes that were cold and difficult to heat, potentially pushing residents into energy vulnerability (Roberts & Henwood, 2019).

Households using unmetered fuels are also excluded from various consumer protections, including the guaranteed supply afforded to older or vulnerable customers. Gas and electricity providers operating on mains are obligated by Ofgem to maintain a Priority Services Register (PSR), which comprises households with older residents or individuals with vulnerabilities, such as chronic health conditions. Suppliers are prohibited from disconnecting the heating during winter for PSR-listed households, even if bills are outstanding. Jewell et al. (2017) notes how this protective measure is unavailable to households relying on unmetered fuels for heating. Consequently, older or vulnerable off-gas consumers must depend on friends, family, and neighbours in the absence of a fuel delivery, or, in some cases, endure the absence of fuel for heating their home, food, or water.

4.5. Security of supply

Security of supply has been noted as a significant risk for non-mains energy. Off-grid households relying on oil must regularly monitor their consumption and order replenishments in good time. However, this can be put at risk by factors such as adverse weather conditions affecting fuel deliveries (Golubchikov & O'Sullivan, 2020). For rural households off the mains gas network, relying purely on an electricity supply can also be risky. Physically poor electricity infrastructure in the peripheral locations in Golubchikov and O'Sullivan's (2020) study meant that in winter months when temperatures fell to -4˚C, communities were entirely cut off and had to rely on supplies brought in by helicopter.

In Roberts' study (2020), individuals not connected to the gas grid were required to store solid fuels in bulk on their premises, frequently outside their property, making it susceptible to theft. The occurrence of recent wood theft incidents in the community raised substantial concerns among participants, particularly those facing more precarious financial circumstances.

As other studies have found, households are likely to resort to multiple fuel strategies, often including using traditional polluting fuels, when they are uncertain about security of supply (Hope et al., 2018). As noted in Section 4.4, without consumer protections afforded to older or vulnerable customers, there are no safety nets if supplies run out or if households cannot pay for their energy (Jewell et al., 2017). Although trade associations for unmetered fuels have voluntary documents which set out minimum standards of service for consumers, mystery shopping by Citizens Advice found that none of the suppliers across the UK made any specific reference to provisions they have for vulnerable consumers, suggesting they are not aware of their obligations (in this case, under the Federation of Petroleum Suppliers Customer Charter and UKLPG's Vulnerable Persons' Protocol) (Jewell et al., 2017).

4.6. Household energy adaptations and practices

Studies show that households living off-grid adopt various energy coping strategies in response to the constraints posed by their current energy systems.

In research with households who were to a greater or lesser extent reliant upon decentralised off-grid energy, Hope et al (2018) found that participants took an active role in energy management. Their most significant finding was that people both fully and partially off-grid adapted to limited energy supplies by diversifying their energy sources. Traditional polluting fuels such as wood, coal and oil were used in combination with cleaner options like solar and air source heat pumps. Households in the study spoke of being motivated to diversify because of a perceived vulnerability to shortages in energy supply. Hope et al (2018) conclude that decarbonisation strategies should consider this behaviour and guarantee the availability of a variety of cleaner, more sustainable options for households to choose from in response to scarcity. Similar findings have emerged in other studies, with off-grid households keeping fuel costs down by relying on a mix of heating solutions. Participants living off-gas in Roberts (2020), for instance, relied on wood burning stoves and open fires as supplementary sources of heat (often providing localised warmth to a single room) due to the affordability of heating oil and cylinder LPG. In obtaining their energy from a range of sources, off-grid energy users in Forde (2017) rarely went without energy. They planned for such contingencies and if one component of their overall energy mix was unavailable, they drew on others.

In one way, energy sources are more visible for those living off-grid. For households in Hope et al's (2018) research, the visibility of solid fuels meant consumption could be gauged more easily. However, this also had the effect of daily practices being constrained around energy, "forc[ing] participants to recognise that energy was a valuable and limited resource" (pp.367). Participants carefully monitored, managed, and curtailed their energy use around available supplies. Forde (2017, pp.93) phrases this as people living off-grid "embody[ing] their own energy usage patterns". Hope et al (2018) underscore the significance of such practices for participants, highlighting that the failure to align supply and demand has more severe repercussions for off-grid households, such as the absence of light, warmth, and access to hot food. But this curtailing of energy to reduce costs is also identified as a welfare issue – not just for the participants in the study but for wider populations if cleaner energy options are to be rolled out. This is likely to have a disproportionate impact on lower-income households who already use less energy.

Roberts (2020) alludes to practices of energy foraging, in that off-gas households regularly collected free 'waste wood'. This was sourced from their own land or land that participants managed, off-cuts from friends and woodworking businesses, or by picking up fallen branches as they went on walks. This practice was positioned as a valued part of collective identity; it was something they did with family and related strongly to notions of agency and control. On the flip side of engaging in this practice, there was a potential risk of getting caught while taking firewood from private property, coupled with a lack of awareness that such an act technically constituted theft. Burning wet or waste wood also poses significant health risks (DEFRA, 2019).

A range of other coping strategies were also present in the literature. Concentrating on 'peripheral' regions, characterised by small settlements or sparsely populated areas in Wales with restricted access to services and employment opportunities, Golubchikov and O'Sullivan (2020) found that interviewees mitigated the excessive and concentrated heat produced by range cookers by opening windows and doors. Other strategies included those consistent with maintaining thermal comfort in homes that are difficult to heat, such as layering clothes, wrapping up in a blanket, confining to one room, and a resilience and stoicism to less-than-comfortable conditions

(Roberts & Henwood, 2019). On the latter point, one family claimed that their cottage was “warm enough”, suggesting as the authors write, that their “understanding of thermal comfort was intimately bound to the fabric of their home as it currently stands” (Roberts & Henwood, 2019, pp. 480). Other sources note the cultural distinctions between rural and urban communities which impact on energy consumption behaviours. Households who live in rural regions are more likely to consider themselves ‘hardy’ and ‘resilient’ to local climates but this may also come at the cost of being willing to seek help (Changeworks, 2023a).

4.7. Summary

In summary, this chapter has highlighted evidence that shows off-grid living presents a complex interplay of motivations, challenges, and coping strategies, encompassing economic, health, and cultural dimensions. Households adapt to limited energy resources, but inherent challenges necessitate comprehensive policy considerations for sustainable and inclusive solutions. A summary of key points from the evidence presented in this chapter are listed below:

- Limited options in remote UK areas influence the perceived 'choice' of off-grid living.
- Off-grid homes are often in older building stock posing challenges for retrofitting, especially when located in conservation areas or National Parks.
- Affordability is influenced by household income and main fuel type but challenges persist in terms of price volatility, budgeting and buying in bulk.
- Physical labour involved in managing alternative energy supplies poses concerns for aging residents.
- Off-grid households using inferior quality fuels face health risks.
- Unmetered fuel households lack consumer protections, risking fuel shortages and health consequences.
- Off-grid households actively manage energy use, adopting a mix of heating solutions to keep fuel costs down.
- Households engage in various coping strategies, including adapting to limited energy supplies and managing daily practices around available energy.

5 Decarbonisation approaches and implications

5.1. Low carbon transition options for off-grid homes

Connection to the grid or electrification

Given the national policy focus, it is likely that natural gas will play a shrinking role in future decarbonised energy systems, pushing gas boilers further out of the solution for off-grid households (Broad et al., 2020). Broad et al's (2020) modelling of future decarbonisation scenarios in the UK suggests that electrical systems will provide significant shares of future residential heat supply. This becomes more likely as efforts to address climate change increase, and more investments are made in technologies like air source heat pumps (ASHPs) and other electric heating systems. As Broad et al (2020) conclude, however, this strategy will not work on its own. Instead, they support a three-part strategy to reduce carbon emissions in residential heating: 1) using electricity for heating, 2) making heating systems more efficient, and 3) reducing the carbon intensity of electricity production. The study emphasises the importance of having a variety of technologies available for different regions to speed up the process of reducing carbon emissions from residential heating. Local conditions and preferences vary, and having diverse options can help avoid dependence on a single solution.

Heat pumps are regarded as the most efficient off-grid choice, with Ground Source Heat Pumps (GSHP) offering high efficiency. However, GSHPs necessitate ample outdoor space, while Air Source Heat Pumps (ASHP) require a clear external wall area for the fan unit. Up-front costs are high and likely to exclude lower-income households (installation costs for ASHP range from £9,000 to £15,000, and for GSHP, they range from £12,000 to £20,000). Often, concurrent improvements in building fabric energy efficiency are needed in advance of or alongside the installation of the new heating system (Qureshi, 2022).

Liquid Gas UK (2019) developed a range of scenarios to analyse the decarbonisation potential of the off-grid sector, against two different reduction targets: a reduction to 1.4 MtCO2e by 2050, reflecting the minimum fall in emissions to align with a net-zero target; and 87.5 per cent reduction on 1990 levels by 2050, informed by the Clean Growth Strategy. In their first scenario of 'electrification', homes currently using oil and coal for heating would switch to electric heat pumps when they replace their existing systems, and they suspect that those using LPG would switch to the more environmentally friendly version of biopropane. The overall emissions from this scenario are also predicted to decrease substantially, reaching a 75 per cent reduction by 2050. However, despite these improvements, the study suggests that this pathway alone is not sufficient to meet the emission reduction targets needed to address climate change by 2050. More efforts and additional measures are required to achieve the

necessary level of emission reduction, especially for homes not connected to the gas grid.

Myers et al. (2018), in a similar vein, consider the technical feasibility of installing electric heating systems in rural off-gas households, at both a dwelling level and at the level of the local electricity network. The results of their modelling show that the total number of houses suitable for any one type of electrical heating system is relatively high (86 per cent at existing insulation levels and 95 per cent if dwellings upgrade their loft and wall insulation). At a network level, modelling based on average peak winter day temperatures show that around 84 per cent of homes could be electrified at their current level of insulation. Whereas modelling for a 1-in-20 winter scenario shows that the current network could support around 64 per cent households with ground-source heat pumps and 41 per cent of homes with air-source heat pumps. The authors conclude that improving the energy efficiency and performance of heat pumps is required here to reduce demand on the network.

Other sources argue that those in rural locations may not have the electricity network capacity to install a heat pump at present (BEIS, 2022b). Qureshi (2022) recommends that government builds a programme of electricity infrastructure upgrade in rural areas into the roadmap to net zero.

Off-grid renewable energy systems

Case study: Isle of Eigg, Scotland (Yadoo et al., 2011; Chmiel & Bhattacharyya, 2015)

The Isle of Eigg, an inner Hebridean island, is entirely unconnected to the mainland grid. The community is proactive, having purchased the island in 1997 and developed a ten-year plan for its future. Eigg, with 37 households and five commercial properties, established an off-grid renewable energy system to overcome challenges of individual diesel generators. The system includes solar, hydro, wind, and battery storage, providing 90 per cent of electricity from renewable sources. The off-grid system, costing £1.66 million, proved more financially feasible than a £4-5 million mainland connection. Funding sources included Highlands and Islands Community Energy Company, European Regional Development Fund, and others. Eigg Electric Limited, a subsidiary of the Isle of Eigg Heritage Trust, owns and maintains the system. A four-person maintenance team ensures its consistent and safe operation. All islanders have 24-hour electricity, with a 5kW cap per household to reduce reliance on diesel generators. Smart meters monitor usage, and residents voluntarily reduce consumption based on a traffic light system. The system aims to be financially self-sufficient, with income from the Renewables Obligation Certificate scheme and a 20p per unit electricity tariff. A more recent assessment of the Isle of Eigg off-grid system revealed that residents on the island are enjoying a reliable supply of electricity that meets their energy needs, while having a significantly reduced carbon footprint (Chmiel & Bhattacharyya, 2015).

Yadoo et al. (2011) conclude that community involvement is crucial for the success of local renewable energy projects. For communities to gain full benefits from renewable energy (RE), they must be key instigators and drivers behind local RE development. The top-down centralised approach in the UK contrasts with the bottom-up nature of successful community projects like the Isle of Eigg's. As Yadoo et al. (2011) note, for such projects to work, more decision-making power should be devolved to regional planning authorities and local communities.

Some evidence presents ‘radical off-grid living’ as one vision of a sustainable energy future (Bellamy et al, 2022). This may encompass decentralised smart grids between ‘energy islands’, a reliance on renewables, and a radical reduction in energy use. The Isle of Eigg is presented as a key example of radical off-grid living. Bellamy et al’s (2022) research with activist, innovator and consumer citizen groups scored the radical off-grid living vision across different criteria, including technical feasibility, carbon reduction, environmental impacts, economic efficiency, political practicality, public acceptability, and societal fairness. Concerns about the feasibility of off-grid systems were less about its technologies than they were about its niche appeal. Participants recognised its potential for carbon reduction but believed it would have a minimal environmental impact due to the suspected unsuitability for most communities. In terms of political practicality, it was also deemed too ‘radical’ and only compatible with very particular small, rural communities. It was also criticised from a societal fairness perspective, with participants envisioning it not engaging everyone, and leading to potential wealth inequalities between different communities.

As highlighted by Sherriff et al. (2022), the availability of renewable energy technologies is not uniform, primarily due to variations in access to capital, space, and control over living environments. They caution that if increasing numbers of affluent people are able to invest in renewables and move ‘off-grid’, those remaining may find themselves paying more for connection and services.

Bio LPG boilers

A report by Liquid Gas UK (no date) examines heating solutions for rural, off-grid homes in England, particularly focusing on a typical detached property in a rural village without gas grid connection. The report suggests BioLPG (liquefied petroleum gas) as a viable, low-carbon alternative to oil with lower environmental impact. BioLPG, a transitional fuel produced sustainably, offers the lowest upfront cost (£1,900) and ongoing affordability for 68 per cent of consumers. While other low-carbon alternatives exist, the report emphasises the economic accessibility and environmental benefits of LPG, especially BioLPG, for off-gas-grid homes. In the Heat and Buildings Strategy, government has acknowledged the potential of BioLPG as part of a hybrid heating system along with an air source heat pump. Qureshi (2022) supports a mixed technology approach where low carbon technologies and ‘drop-in’ fuels such as BioLPG play a part, acting as a stand-in for properties where heat pump technology is not a realistic option, for instance. For off-grid households currently using oil heating, the simplest approach may be to switch to a cleaner fuel than completely changing the heating system (Qureshi, 2022).

Through a comprehensive evidence review, Hopwood et al. (2019) suggest BioLPG is a promising drop-in fuel requiring no boiler modifications. They state that challenges and costs must not be underestimated, however, and further research is needed on costs, emissions, and supply chain constraints for introducing bioliquids in UK domestic heating.

Domestic hydrogen

Analysis by Gordon et al. (2023) provides insight into household acceptance of hydrogen homes. Primarily, enduring distrust of energy providers has undermined confidence in both the government and the energy sector, posing a significant obstacle to altering the existing state of affairs. Hydrogen homes were perceived as a potentially positive mechanism, in this case for industrial regeneration and local economic development. However, the authors conclude that existing trust deficits will need to be overcome, which would entail fulfilling a price promise on the cost of hydrogen appliances and energy bills.

Microgrids and heat networks

Microgrids facilitate the use of locally generated electricity which the national grid does not currently have the capacity to export. Changeworks (2023b) cites a number of examples of these solutions which are being successfully pioneered in Scottish islands due to grid capacity issues. In Lerwick, for instance, a large heat network provides low-cost heat to over a thousand homes.

Mixed technology switch (rapid replacement) pathway

Liquid Gas UK (2019) suggest the optimal decarbonisation pathway for off-grid properties is one which offers consumers a choice between several heating technologies: air source heat pumps, hybrid heat pumps, LPG boilers fuelled with biopropane, direct electric panel heaters, and biomass boilers. This scenario is modelled on a replacement rate of 19 per cent per annum. Energy usage decreases by 55 per cent from 2019 to 2050 in this situation, reaching a total of 17 TWh. At this point, approximately 586,000 homes that were originally heated with oil and coal would now be utilising biopropane, and around 2,700 homes would adopt hybrid heating systems, incorporating LPG boilers powered by biopropane along with heat pumps. Emissions reductions under this scenario are enough to meet both the net-zero target for total off-gas emissions and the more ambitious CGS target.

Carbon intensity standards

The Sustainable Energy Association (2022) go one step further and suggest introducing a carbon intensity standard, applying to fuel providers, heating system manufacturers, householder and installers. Fuel suppliers would need to have certification of the carbon intensities of the fuel they provide. Heating technologies would need to be tested to get an efficiency rating, and as part of Building Regulations, installers would need to assess the emissions intensity of the delivered heat.

5.2. Barriers and enablers of decarbonisation for off-grid households

Affordability

Monetary cost was seen as the dominant factor in achieving decarbonisation in Copeland et al's (2022) research with stakeholders in the North of Tyne. This extended to fairness and equity in relation to who pays and what costs relate to, and in ensuring that decarbonisation frameworks do not simply reward the wealthy.

While government grants off-set a proportion of costs for decarbonisation measures for some households, and while they may be cost-saving in the long-term, they are not financially possible for all households. Golubchikov and O'Sullivan (2020) give the example of renewable generation. This would reduce reliance on expensive sources such as oil and may in the long-term be cost-saving. However, they note that this mode of transition is restricted to those with the finance to change the building's energy system and pay upfront costs for the new technology. A consultation on proposals for a market-based mechanism for low-carbon heat (BEIS, 2022b), published alongside the Heat and Buildings Strategy, refers to the higher propensity of off-grid properties being occupied by elderly and retired consumers for whom low-carbon technologies such as heat pumps could be difficult to purchase. Energy efficiency retrofits may be expensive, especially if a lot of work is needed to bring the home up to standard. It is likely that a high percentage of off-grid homes will also fall through the gaps in government retrofitting schemes and grants. A reliance on area-based measures of deprivation makes rural deprivation more hidden and rural off-grid households overlooked (Golubchikov & O'Sullivan, 2020).

Research by Citizens Advice (2023) calculated distribution and transmission costs according to four different scenarios: 1) full electrification using air-source heat pumps; 2) mix of hydrogen boilers and air-source heat pumps; 3) mix of hybrid heat pumps and air-source heat pumps; and 4) mix of air-source heat pumps, hydrogen boilers and hybrid heat pumps. This was considered across 12 different archetypes (areas) across Great Britain, each with different characteristics (such as geographical location and dwelling density) that influence network costs. For 10 of the 12 archetypes, the lowest network cost option was found to be full electrification, with hydrogen having the lowest network costs across the other two archetypes. The research acknowledges that it did not consider all factors involved in the heat decarbonisation process (or the consumer experience of it). This includes the cost of buying, installing and maintaining new heating systems, for instance. Future fuel costs may also influence overall costs and mitigate higher network costs. However, the authors assert that based on the Climate Change Committee's expectations, it is likely that wholesale costs will be lower for electricity than hydrogen. The research underscores the importance of decision-making about decarbonising heat reflecting local network costs on an area-by-area basis. It also recommends that the UK Government rule out a GB-wide hydrogen-ready boiler mandate. Such mandates should instead be targeted at area where there is clear evidence that hydrogen is calculated to be the lowest cost option for decarbonising heat.

Current electricity network connection costs vary based on a number of factors, such as geographical location and whether an overhead or underground connection is required (Northern Powergrid, 2021). The average price (excluding VAT) for one standard domestic connection is £2,000.[6] This price may still be out of reach for some lower-income households. However, in National Parks where overhead connections cannot be used (to preserve natural beauty), the cost of an underground connection is estimated to be three times higher. A large, rural site where a distribution company needs to carry out a 60m road dig, for instance, could bring the cost up to approximately £10,000.[7]

Housing tenure

Golubchikov and O'Sullivan (2020) emphasise the positives of a number of government schemes being targeted toward more economically deprived households. However, restrictions in criteria around tenure prevent a large number of economically deprived households from accessing them. HUG2 and the Boiler Upgrade Scheme, for instance, are only available to homeowners. Privately rented household are seen as being least able to increase their home's energy efficiency due to overall power resting with the landlord (Golubchikov & O'Sullivan, 2020). Similarly, social housing tenants are reliant on local authority upgrade schemes which may take time to fully operationalise.

Community involvement

Golubchikov and O'Sullivan (2020) make the link between physical remoteness, feeling politically unrepresented and missing out on investments that could potentially improve declining local services and employment levels. Peripheral communities in their study expressed frustration that decisions about large-scale energy developments were made undemocratically and had no benefit for local residents.

Hope et al. (2018) highlight the importance of community for households living off-grid, in terms of sharing knowledge and experience. This observation similarly applies to

[6] National Grid - Our guide price tables
[7] New Electricity Supply Connection Cost in 2024? | Checkatrade

the process of transitioning to new energy systems. Focusing specifically on people moving off grid onto narrowboats, Hope et al. (2018) found that the initial steep learning curve was smoothed over by being part of a community with experience of managing energy and resources off grid.

5.3. Occupant preferences and impacts

As Citizens Advice (2023) state, the potential experience for consumers between different technologies must be better understood.

While it is difficult to know the impacts of decarbonisation on off-grid households due to a dearth of evidence, a number of studies raise important considerations based on analysis of current energy practices. In Hope et al. (2018), for instance, off-grid households curtailed their consumption when the fuel source was visible, a prospect which could risk sending some users into energy vulnerability. Likewise, households in the same study reverted to using other, more polluting fuel sources when more sustainable ones were in low supply. Low-carbon pathways must therefore ensure a consistent and reliable supply of energy, and potentially a mix of low-carbon options.

The existence of these knowledge gaps highlights the significance and timeliness of our wider research programme involving an exploration of the acceptability, feasibility and affordability of different decarbonisation solutions for off-grid households.

5.4. Summary

Overall, the evidence reviewed in this chapter underscores the complexity and multifaceted nature of the transition to sustainable energy systems for off-grid homes, requiring a nuanced approach that considers regional variations, community involvement, and occupant preferences. A summary of key points from the evidence presented in this chapter are listed below:

- Diverse technologies are essential due to regional variations and occupant preferences.
- While full electrification is deemed to offer the lowest network costs for the majority of area archetypes, rural electrification in certain areas (National Parks, for instance) faces challenges due to increased costs.
- Heat pumps are considered efficient off-grid decarbonisation options, but high up-front costs and usability must be considered.
- BioLPG is seen as an affordable and low-carbon (short-term) alternative for off-gas-grid homes, especially for those currently using oil heating.
- Affordability is a dominant factor, with monetary costs affecting fairness and equity in decarbonisation efforts.
- Community involvement is highlighted as crucial for sharing knowledge and experiences during the transition to new energy systems.
- Understanding the potential consumer experience with different technologies in off-grid decarbonisation transitions is a crucial but currently under-researched area.

6 Conclusions

This evidence review sought to understand what is currently known (and not known) about approaches to decarbonising (or improving the energy performance of) homes that are completely or partially off grid. It explored evidence on the key considerations, challenges, barriers and enablers of decarbonisation – both practically and in terms of occupants' views and experiences.

This concluding chapter revisits and summarises the key findings and knowledge gaps highlighted in the review in relation to the research questions posed at the outset of the report.

6.1. Drivers

What are the drivers and barriers of off grid decarbonisation?

The literature highlighted a number of drivers and barriers of off grid decarbonisation. Notable drivers included government policies and incentives, cost savings, and community initiatives. Contrastingly, a desire for energy independence motivates individuals to invest in off-grid solutions, reducing reliance on centralised energy grids. Barriers included infrastructure limitations, a lack of supportive policies, and high capital costs. It is likely that cultural and social norms and preferences may influence the acceptance or rejection of certain technologies within off-grid communities though such studies were absent in the evidence search. The connection between (inefficient) cooking and heating systems and the rustic allure or charm of rural lifestyles was highlighted in Golubchikov and O'Sullivan (2020), though this may have been driven by lack of choice more than anything else.

What are the main policies and regulations determining whether and at what pace off grid decarbonisation should happen? What are the relevant regulatory frameworks relevant to off grid decarbonisation? What are the policy drivers of off grid decarbonisation?

Chapter 2 examined current initiatives, such as the Home Upgrade Grant and broader decarbonisation efforts, including the Social Housing Decarbonisation Fund, ECO4, and the Great British Insulation Scheme. Criticisms and concerns about these programmes underscore the multifaceted challenges of transitioning off-grid properties to sustainable alternatives.

6.2. Challenges

What are the issues that need to be considered in relation to decarbonising or improving the energy efficiency of off grid properties? What does the literature tell us about the priorities for occupants - how they might respond and what they might prefer in terms of decarbonisation solutions?

Decarbonising and improving energy efficiency in off-grid properties present a set of intricate challenges that demand careful consideration. Affordability emerges as a primary concern, with high upfront costs for technologies like heat pumps and retrofitting older homes for energy efficiency. The choice of technology is crucial, weighing the suitability of options such as heat pumps and exploring alternative fuels like BioLPG or biodiesel.

Regional variations play a significant role, considering local climate, geography, and the capacity of the electricity grid. Community involvement becomes essential to address acceptance, preferences, and ensure that decarbonisation benefits all community members. Housing tenure and ownership dynamics introduce complexities, especially regarding access to government schemes and responsibilities of landlords.

Challenges related to grid connection in remote locations and associated costs add to the complexity. Understanding consumer behaviour and experiences is crucial to ensure proper use of new technologies and prevent a reversion to less sustainable options during shortages. Clear policy frameworks, incentives, and environmental considerations are vital components, promoting regulatory support and encouraging the adoption of energy-efficient solutions.

The review identified a particular knowledge gap around preferences and responses to decarbonisation solutions among off-grid households, an area which this research programme seeks to address.

What are the financial, social, cultural and practical impacts of decarbonising off grid homes for households?

Assessing the impacts of decarbonisation on off-grid households remains challenging due to a lack of available evidence. Studies indicating that off-grid households tended to reduce their energy consumption when the energy source was visible, and resorted to using more polluting fuel sources when sustainable options were scarce, suggests that low-carbon pathways must prioritise ensuring a consistent and reliable energy supply, incorporating a mix of different low-carbon options. Studies highlighting the health concerns of living off-grid suggests that impacts of decarbonisation would likely benefit this group if administered correctly. A number of studies note the physical labour involved in maintaining off-grid lifestyles (gathering firewood, lifting LPG cylinders, for instance) and participants' concerns about sustaining these practices as they aged. Findings from studies focusing on economic challenges for those currently living off-grid highlight the significance of affordability as a catalyst for change and emphasise the necessity for policies that guarantee a variety of affordable decarbonisation solutions for off-grid households.

What are the impacts of decarbonising off grid homes on energy infrastructure?

The diminishing role of natural gas in future decarbonised energy systems, especially for off-grid households, implies a reduced reliance on gas boilers. The focus shifts towards electrical systems, particularly emphasising technologies like air source heat pumps (ASHPs) and other electric heating systems. However, this shift poses challenges to existing energy infrastructure. Broad et al. (2020) advocate for a three-part strategy involving using electricity for heating, improving heating system efficiency,

and reducing the carbon intensity of electricity production. This strategy underscores the need for a diversified set of technologies to accommodate regional variations in conditions and preferences, avoiding dependence on a singular solution. Myers et al. (2018) evaluate the technical feasibility of electric heating systems in rural off-gas households, emphasising the importance of improving energy efficiency and performance of heat pumps to reduce demand on the network. Meanwhile, challenges related to electricity network capacity in rural areas are noted, suggesting a need for infrastructure upgrades (Qureshi, 2022). Other studies suggest the risk in relying solely on electricity in peripheral areas with poorer physical infrastructure, where adverse weather conditions can lead to communities being entirely cut off.

6.3. Solutions and policy support

What approaches to decarbonising off grid properties are featured in the literature and are there any lessons about pros and cons of these approaches?

Chapter 5 outlined various approaches to decarbonising off-grid properties, each offering distinct advantages and facing different challenges. Diversity in solutions is essential, acknowledging that there is no universal approach. A mix of technologies, coupled with strategic implementation and community engagement, is crucial for the successful decarbonisation of off-grid properties. Addressing challenges, such as high upfront costs, trust deficits, and regional variations, will be vital for achieving widespread adoption and positive environmental impact.

What is effective in terms of policy and regulatory interventions in relation to improving energy performance of off grid homes?

While policy interventions demonstrate a commitment to decarbonisation efforts, ongoing evaluation based on outcomes are crucial to ensure sustained effectiveness and to address emerging challenges. The evidence highlights that addressing concerns relating to equity, affordability and inclusivity will be key to the success of these interventions.

What works in relation to different off grid scenarios (for example, totally off grid, partially, remote rural, agricultural, historic homes, homes in national parks etc.)?

The evidence points to full electrification being the optimal solution for the majority of different area archetypes based on network costs but stresses that each scenario requires a tailored approach, considering geographical, climatic, and regulatory factors. Solutions in National Parks must prioritise measures that align with conservation goals and specific regulations. Implementing energy-efficient upgrades while preserving the historic character of the home is also crucial. This may involve using modern insulation materials that do not compromise the aesthetics, for it to be acceptable to the occupant. Further evidence is required in relation to other specific groups, such as people living on farms.

What works for particular groups of occupants living off grid (for example, older people, farmers, families, low-income households etc.)?

Tailoring off-grid decarbonisation solutions to specific groups of occupants involves considering their unique needs, preferences, and challenges. In terms of low-income households, the evidence shows that provision of grants is vital to cover both up-front and long-term energy costs and to make decarbonisation solutions accessible. Ensuring reliable power sources for medical equipment and incorporating climate control systems for health considerations is vital for older people and those with health conditions.

Which agencies are involved in off grid decarbonisation or are crucial to it? Who is trusted in this context?

While there is a dearth of literature exploring trust in relation to off-grid decarbonisation, a number of studies suggest areas where trust is somewhat lacking. In a study on hydrogen homes, enduring distrust of energy providers undermined confidence in both the government and the energy sector, posing a significant obstacle to altering the existing state of affairs (Gordon et al., 2023). Also crucial to the success of off grid decarbonisation are the UK Government in formulating and implementing effective policies; local councils in the implementation of government initiatives and grants; and consumer advocacy organisations in supporting consumers and contributing to a better understanding of consumer experiences.

7

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