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Campaign to Protect Rural England
Standing up for your countryside

WARM AND GREEN

Achieving affordable, low carbon energy while reducing impacts on the countryside

Cambridge Architectural Research and Anglia Ruskin University, for the Campaign to Protect Rural England

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Great Bow Yard, Somerset: a low carbon housing project

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FOREWORD

Shaun Spiers
CPRE Chief Executive

CPRE's vision for 2026, our centenary year, is that England's countryside will make a significant contribution to reducing greenhouse gas emissions. But this is not simply a question of supplying more renewable energy.

Indeed, if we continue to think largely in terms of supply, taking energy demand as a given, we will only be able to meet our carbon reduction commitments by handing over huge areas of the countryside to wind turbines, solar panels and biomass, with disastrous consequences for landscape character.

Political debate, including within the green movement, fixates on the supply of energy – for or against wind turbines, solar energy, fracking. We need much more focus on conservation and demand management. Using less energy should come first. It makes sense for the landscape and climate, and it also makes strong social and economic sense.

This report fills an important gap in knowledge by exploring the current realities of greening homes and community buildings in rural areas. It shows that rural communities, which often face the highest heating costs, are too often bypassed in initiatives to cut energy use. It is shocking that rural areas, home to nearly a fifth of England's population, receive only 1p for every pound the Government invests in energy efficiency.

If we are to tackle climate change, protect our wonderful landscapes and address fuel poverty, we need – among many other things – a major programme to improve our buildings. This should include insulation, renewable heat and small-scale renewable electricity generation. It should also incorporate principles of good design, to ensure that both new development and retrofitting are attractive.

The report gives examples of just what can be achieved, but progress should not depend on the extraordinary efforts of committed individuals and community groups, welcome though they are. Much more must be done to address the barriers rural communities face, and to ensure that the sort of initiatives we now regard as exemplary become commonplace.

We need much greater political ambition and a far stronger commitment to improving the energy efficiency of our buildings, particularly in rural areas. Based on the evidence of our research, this report sets out proposals to meet our future climate change commitments while protecting our countryside. We hope politicians of all parties, as well as other stakeholders, read this report and act with urgency upon it.

Shaun Spiers

EXECUTIVE SUMMARY

It is clear that there are major problems with England's energy system. Falling North Sea oil and gas production and ageing power stations are combining with increasing energy demands from a growing population and a desire for more comfortable homes. The gap between the action needed to prevent catastrophic climate change and what policy makers have put in place is not narrowing quickly enough. This is happening against the background of a dramatic rise in energy costs since 2003, and increasing pressure on land from energy production.

All of this raises serious questions about the way we use energy now and the system we need in the future. This report, and the research underpinning it, sheds new light on the scale of the energy problems we face and the solutions needed to tackle them. It explores the current realities of greening rural homes and community buildings. This report also considers how we can make the necessary cuts in carbon from housing and what this might mean for the countryside.

The Campaign to Protect Rural England (CPRE) commissioned Cambridge Architectural Research and Anglia Ruskin University to conduct research to fill a key gap in knowledge. The research explores what is stopping people adopting low carbon technologies and what our policy makers need to do to support the major increase in improvements needed. It considers this particularly with regard to rural communities, which face higher than average energy costs and lower than average energy efficiency associated with older buildings. It also lays out the implications of the major reduction in carbon dioxide emissions from homes that is needed by 2050, including landscape and land-use impacts.

New insight into energy problems and solutions

This report explores the motivations for, and barriers to, making energy improvements to homes and community buildings in rural areas, using real examples in three locations around England – East Anglia, Derbyshire and Somerset. Although the number of examples involved is fairly small, they nevertheless reveal a consistent narrative that illustrates the wider problems faced by rural households trying to reduce their carbon emissions and energy bills.

We use a set of case studies to highlight exemplary low carbon buildings and present new modelling, which projects forward from the 1990 baseline of carbon emissions caused by English homes, to identify the reduction needed by 2050 to achieve our national 80% reduction target set out in the Climate Change Act. This includes an estimate of the level of energy demand required from both rural and urban homes

Key findings

- Our in-depth interviews with householders and those responsible for community buildings revealed committed individuals motivated by factors such as rising fuel costs, and a desire to increase comfort and protect the environment.
- The interviews revealed extremely good examples of low energy and low carbon improvements to buildings, as well as new build projects.
- There is no clear national policy framework or comprehensive package of support to back those who choose to take action to save energy and reduce carbon. There are still too many barriers to action, including the upfront cost, the difficulty of finding skilled installers and the payback time.
- Our modelling suggests we could cut carbon emissions from homes by 44% (53 million tonnes of carbon dioxide a year) by 2050 by upgrading homes. This is based on an ambitious rate of retrofits, and reducing the carbon emitted per unit of electricity generated.
- However, we must go further if we are to meet the national target and save a further 38 million tonnes of carbon dioxide a year. This figure will need to be even higher if part of the anticipated savings is lost as a result of people being able to afford more comfortable temperatures in their homes. It will also increase if other sectors, such as non-domestic buildings or transport, make emissions reductions of less than the 80% target.
- If we rely solely on energy supply to cut carbon further, a possible scenario could involve planting half of England with biomass crops, erecting almost 3,500 new wind turbines (the majority offshore), and creating 8,000 hectares of additional solar panels. Such scenarios strengthen the case still more for the strongest possible action to reduce energy demand to avoid the most damaging landscape and land-use impacts. We need to be even more ambitious than the home retrofits assumed in our modelling.

once they have been improved to the ambitious level assumed in our modelling. We then use various scenarios to explore the possible landscape and land-use implications of meeting this residual energy demand through new low carbon generation.

Our research shows that even if we make the ambitious programme of 65,000 major retrofits to homes each year assumed in our modelling to reduce energy use and carbon emissions, we will still miss the 2050 carbon target for housing by a large margin unless we do more. Currently fewer than 1,000 such retrofits are completed each year. Committed individuals are making substantial energy improvements to their homes and community buildings, some of whom feature in our case studies. However, unless political ambition to reduce energy demand at least matches the ambition to build new energy infrastructure – and even if new generation is low carbon – the effects on the countryside and beyond will be devastating. It will mean a great deal of avoidable new infrastructure and increased energy bills, on top of the effects from climate change itself, such as more storms, floods and droughts.

By contrast, going further than the ambitious assumptions on low carbon solutions for homes that we use for our modelling would help further reduce householders' energy bills and carbon emissions, create more jobs and reduce the impacts of new energy infrastructure on the countryside.

This report highlights just how unsustainably we are living now, and the hard choices we face as a result. However, it also suggests solutions – informed by the experience of those we visited during the research – to enable us to live not only more sustainably but also more comfortably.

Our way forward

To make energy use in homes low carbon and affordable, as well as reducing impacts on the countryside, we recommend that the Government:

- Implements a bold and effective national programme to reduce energy and carbon emissions from homes and community buildings: this should be at least an equivalent priority to the commitment to reduce emissions from energy supply.
- Ensures that rural communities get their fair share of Green Deal, Energy Company Obligation and other sources of finance: if 18% of the population live in the countryside, they should get 18% of government support, not less than 1% as is currently the case.
- Publishes an authoritative, evidence-based comparison of the carbon savings and costs of different low carbon technologies – for both energy demand and energy supply.
- Implements higher standards for new homes to drive a clear pathway for energy and carbon savings.
- Re-frames expectations about savings: a large number of rural homes are currently under-heated, so savings are likely to be lower than predicted because people will be able to afford more comfortable temperatures in their homes.
- Ensures building regulations reflect the special requirements of traditional construction methods, such as natural insulation materials.
- Provides more support to the construction and retrofit industry to address the experience and skills deficit, such as through high quality training and reliable, impartial information.
- Drives innovation in solid wall insulation to reduce costs and improve the performance of thinner forms of this type of insulation.
- Ensures retrofit initiatives build trust with local communities by working with trusted organisations and individuals, such as someone who is well known and has successfully carried out energy improvements to buildings in the community.
- Ensures policies and initiatives target key points in the life of a building to encourage energy improvements, such as moving house or renovating.

This report also makes recommendations for action by industry, householders and those responsible for community buildings, but the focus is on the Government as it needs to drive behaviour change.

SECTION 1

Introduction and methods

Mark's house, Derbyshire

SECTION 1

Introduction and methods

1.0 Introduction and methods

Climate change is probably the biggest threat facing civilisation today. It will affect rural and urban areas across the globe. The full impact is hard to predict, but in England it will very likely mean increased storminess, milder, wetter winters and hotter, drier summers, along with increased flooding from surface water, rivers and the sea[1].

The Climate Change Act[2] commits the UK to reducing greenhouse gas emissions, including carbon dioxide, by 80% by 2050 in order to limit the likelihood of runaway climate change.

However, reducing greenhouse gas emissions is not the only major energy challenge. Developing secure supplies, meeting demands without prices becoming unaffordable, and protecting the environment – including the local environment – are together sometimes called the ‘energy trilemma’.

This research project came out of a roundtable event the Campaign to Protect Rural England (CPRE) organised in November 2014. Participants in the event came mainly from a wide range of national organisations, but there was also representation from CPRE’s local groups. CPRE subsequently appointed Cambridge Architectural Research (CAR) and Anglia Ruskin University to explore how to cut emissions from rural buildings by improving energy efficiency and using low carbon technologies. CPRE wishes to develop a realistic picture of how we can tackle the full range of energy challenges without sacrificing the countryside. The work therefore set out to throw light on four inter-linked issues:

- First, the problem of higher than average energy costs facing households in rural areas, especially those not served by the gas grid, and lower than average energy efficiency of rural homes. This is all the more pressing given the steep energy price rises since 2003[3].
- Second, it aimed to unpick the barriers to making improvements to buildings in rural areas, particularly in terms of energy efficiency and renewable energy – due to different building characteristics, greater distance from suppliers and installers, and reduced access to financial support for improvements in rural areas.
- Third, it sought to find out more about the capital cost of many low carbon technologies, and to what extent real projects have managed to make savings and recoup the initial outlay.
- And fourth, to assess the possible visual and land-use impacts on our countryside that would result from adopting more sustainable energy in rural areas. Land-use issues include the possible reduction in the area used for growing food and other crops, and potentially degrading the protection currently assigned to many areas of countryside.

The research team undertook primary research, based on interviews, in three locations around England – the flatlands of East Anglia, the upland areas in Derbyshire, and coastal areas in Somerset. We interviewed householders who had already upgraded their homes to save energy and reduce carbon emissions. To learn more about the barriers to action, we also interviewed householders who had considered upgrades but decided not to implement them. In addition, we interviewed people running community buildings to find out how they can be improved to save energy and reduce carbon emissions.

We carried out modelling, using the model CAR built for the Government: the Cambridge Housing Model. The modelling focused on what savings in energy use and carbon emissions are possible from upgrading English homes, and how far these upgrades can take us towards the national target to reduce greenhouse gas emissions by 80%. It also examined what more needs to happen for housing to achieve this reduction.

Ideally, upgrading energy efficiency and installing low carbon technologies in homes will happen first, before embarking on new energy generation infrastructure, because these have a less pronounced visual impact on the countryside, and in some cases are invisible. This is an area where CPRE’s local branches are very active[4,5]. However, successive governments have failed to put sufficient emphasis on this approach to date.

We have used the modelling to evaluate the impact on England’s countryside of different ways of meeting the 80% target. For example, should there be more emphasis on solar energy, or on increasing England’s forestry to grow more biomass fuel for heating?

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[1] Jenkins, G., Murphy, J., Sexton, D., Lowe, J., Jones, P. and Kilsby, C. (2009) UK Climate Projections: Briefing report: Met Office Hadley Centre: http://ukclimateprojections.metoffice.gov.uk/
[2] HM Government (2008) Climate Change Act 2008: http://www.legislation.gov.uk/ukpga/2008/27/contents
[3] Palmer, J., and Cooper, I. (2014) The UK Housing Energy Fact File: Department of Energy and Climate Change: https://www.gov.uk/government/statistics/united-kingdom-housing-energy-fact-file-2013
[4] CPRE Norfolk (2014) Green Buildings: The CPRE Norfolk initiative to promote reduced energy use in buildings: http://www.cprenorfolk.org.uk/campaigns/green-buildings/
[5] See: http://www.cprehampshire.org.uk/press/pr_282.html

‘We need to make the right choices now to address our energy challenges while making sure we protect the countryside we treasure’

As a nation, we face some very hard choices about how to meet England’s demand for energy over the next few decades. There is a real risk that our countryside will suffer – not only from new energy generation infrastructure, but also from how that energy is transmitted to where it is used. Avoiding a decision is not an option, for this would bring the risk of runaway climate change, or put an end to any confidence that the lights will stay on long term. We need to make the right choices now to address our energy challenges, while making sure we protect the countryside we treasure.

This report shows how some householders and people responsible for community buildings in rural areas have already upgraded these buildings to reduce their carbon footprints. They are examples to us all, and some are showcased here as case studies of exemplary low carbon homes and community buildings. We chose the four case studies to represent different perspectives: different motivations, barriers, upgrades or building types.

The report presents hard evidence of what can be achieved without sacrificing the countryside. For the difficult choices, it also shows graphically what these could mean – for example, how much new forestry we might need, and how much new electricity generation from solar or wind.

Clay Field eco-homes, Suffolk

1.1 Who was interviewed?
As part of this research, we interviewed 19 people, representing 130 homes and community buildings in rural areas. We selected mainly properties that had already had energy efficiency upgrades (such as insulation or improvements to windows) and/or renewable energy (such as solar electricity or a ground-source heat pump), although we also included two that had not been improved to find out more about the barriers to action. In fact, those who had carried out improvements also provided information about barriers, and they were able to describe how they had overcome barriers, and what barriers they faced to doing more.

The table on pages 9 and 10 gives a summary of the properties included in the research.

What is rural?

The Government's Office for National Statistics defines a 'rural' area as one with a population of fewer than 10,000 people. This is a high threshold, and population alone is not a perfect way to distinguish between rural and urban communities[6]. However, by this measure 9.3 million people live in rural areas in England (18%).

In this research we have concentrated on villages, hamlets and isolated dwellings.

Rural households are much more likely to be off the gas grid. Just over a third of rural households in England use oil heating, and 13% of them use electric heating[7]. Both oil and electricity are significantly more expensive than mains gas. Research[8] suggests that rural households need to spend 10% to 20% more on everyday expenses, on average, than households in urban areas – partly because of higher energy bills.

Gamlingay Eco Hub, Cambridgeshire

[6] Sellick, J. (2014) So just how do we define 'rural'? Rural Services Network online article: http://www.rsnonline.org.uk/analysis/how-do-we-define-rural
[7] Baker, W. (2011) Off-gas consumers: Information on households without mains gas heating: www.consumerfocus.org.uk/files/2011/10/Off-gas-consumers.pdf
[8] Smith, N. et al. (2010) A minimum income standard for rural households: Joseph Rowntree Foundation: http://www.jrf.org.uk/publications/minimum-income-rural-households

‘As a nation, we face some very hard choices about how to meet England’s demand for energy over the next few decades’

Table 1. Summary of in-depth interviews

Participant*/ building (location)	Upgrades	Reasons for acting	Sources of help	Barriers
Homes				
Andy (Derbyshire)	Insulation and underfloor heating fitted as part of a major renovation	Fuel costs (gas) and taking the opportunity of the renovation	Advice from friends in the building trade	None
Bill (Derbyshire)	Ground source heat pump in house with oversize radiators. Air source heat pump with underfloor heating and insulation in workshop	Wanting to be warmer. Being climate change friendly	£1,500 subsidy	Hard to find supplier interested in an old house (1750)
Carol (Cambridgeshire)	PV panels, solid wall insulation, double glazed windows and doors, and MVHR	Future proofing energy costs. ‘Saving the planet’	Local PV initiative	Cost
Duncan (Cambridgeshire)	Gas boiler, secondary glazing and stove	Fuel costs (gas). ‘Right thing to do’	Local environmental group and district council	Finding skilled local tradesmen, planners (for historic buildings). Finding information
Helen (Derbyshire)	Insulation, biomass boiler with accumulator and PV panels	Fuel cost (oil). The logical next step after making their farm organic	Feed-in Tariffs and now Renewable Heat Incentive	Lack of experience. Difficulty finding good advice
James and Sue (Norfolk)	Double glazing, secondary glazing, cavity and loft insulation, temporary wooden conservatory for winter use, solar thermal, solar PV and wind turbine	Concerned about climate change and everyone else’s inaction. Want to be more comfortable	Lots of government grants used	Ineffectiveness of emerging technology (e.g. broken wind turbine) and inadequate skills of professionals (e.g. PV salesmen)
John (Derbyshire)	Air-to-air heat pumps and solar water heaters	Fuel cost (LPG)	Example of village hall	None
Laura (Cambridgeshire)	Wood stove as main heating, PV panels with water heater	Environmental outlook	Her own past experience	Cost
Mark (Derbyshire)	Pellet boiler	Fuel cost (oil)	Renewable Heat Incentive premium payment	None
Matthew (Somerset)	PV panels, wood stoves and top-up loft insulation	‘Right thing to do.’ Minimise outgoings	Grant (source unknown)	Cost. Lack of confidence in new technologies
Mary (Somerset)	None	Not applicable	Not applicable	Cost. Old age
Pat (Derbyshire)	None, but considering insulation	Fuel cost (gas). ‘Right thing to do’	None	Cost of breathable insulation. Hassle. Loss of period features
Penny (Somerset)	None	Fuel cost	Not applicable	Concern about reliability of heating, air quality and mould, and appearance of house. Don’t plan to live there long enough for payback

Participant*/ building (location)	Upgrades	Reasons for acting	Sources of help	Barriers
Reepham Community Programme (Norfolk)	Solar thermal, PV panels, wind turbine, insulation and glazing (mainly for community buildings), and an insulation programme for homes (100 Reepham homes took this up)	Fuel poverty	Community pooling knowledge and resources. Local community groups encouraging upgrades. Government financial support	Cost
Tye Green Wimbish Passive House development (Essex)	14 new Passive House-certified homes with external polystyrene insulation, MVHR, and solar thermal coupled with gas boiler for hot water and one radiator	Housing association mainly for rural fuel poverty. Inadequate housing supply in the village	Nothing other than the 'normal' channels	Additional cost. Industry struggle to build airtight. Lack of understanding of MVHR (occupants and professionals)
Community buildings				
Combs Village Hall (Derbyshire)	Air-to-air heat pumps, solar hot water panels and increased insulation	Fuel cost (electricity)	None	Cost
Dunster Lodge (Somerset)	Biomass boiler	Prefers to use a low carbon fuel	Installer. Energy fair	Financial. Unobtrusive location
Gamlingay Eco Hub (Cambridgeshire)	Ground source heat pump, solar water heaters, PV panels and 'sun-pipes' for daylight	'The right thing to do'	Local environmental group	Concerns about maintenance and sources of fuel (for biomass)
Rest & Be Thankful Inn (Somerset)	PV panels and solar water heaters	Prefer renewable energy. Fuel cost. 'Right thing to do'	Grant from Exmoor National Park Authority	Cost

PV = photovoltaics; MVHR = mechanical ventilation with heat recovery; LPG = liquid petroleum gas.
Note: *names of participants have been changed to provide anonymity.

SECTION 2

Improvements to rural buildings

Matthew's house, Somerset

SECTION 2

Improvements to rural buildings

2.0 What have rural householders and others done?

Table 2 shows the most common types of measures installed by people we interviewed for this research. Most of them had installed more than one measure. There are two types of measure: reducing heat loss (such as adding insulation, improving windows and fixing draughts) and renewable energy (such as heat pumps, biomass boilers and solar panels). Both types of measure are important and are included in Section 3, National upgrades, where we have used scenarios to assess the potential for savings from upgrading homes.

Table 2. Measures installed in properties in the research

Measure	Number of examples
Airtightness	11
Solar water heating	8
Solar electricity (PV)	8
Insulation	7
Double/secondary glazing	5
Heat pumps	4
Biomass	3
Mechanical ventilation with heat recovery (MVHR)	2

2.01 Air tightness

Fixing draughts is essential to reduce heat loss and keep homes comfortable. Most existing properties have draughts around windows and doors, between floorboards, around loft hatches and other places that are simple to fix using draught-stripping. Ventilation is important in older homes to manage moisture, especially in stone constructions with no damp course, but uncontrolled draughts are an unnecessary and expensive source of heat loss.

2.02 Solar electricity panels

Solar panels for electricity ('photovoltaics', or 'PV') are currently the most popular form of renewable energy because Feed-in Tariffs make them a reliable investment. Feed-in Tariffs are payments from the energy company for generating power. Solar electricity does not actually contribute to heating though, unless you use spare electricity to heat your hot water, as Laura does. And, even then, it contributes little during the winter months.

2.03 Solar hot water

Solar hot water (or solar thermal) panels bring excellent savings when there is significant need for hot water in the summer time – such as at Gamlingay Eco Hub, where the showers are in heavy demand after sports activities, and make sense for many homes too. For example, John used to use an immersion heater during the summer when he shut down his liquid petroleum gas (LPG) boiler, but now he gets his summer-time hot water from solar water heaters. These now qualify for the Renewable Heat Incentive – cash payments for generating low carbon heat – a new Government incentive for installing more sustainable heating. Supplementary heating for hot water is needed in the winter months.

2.04 Insulation

Better loft insulation is the simplest, and often the cheapest, way to make a property more energy-efficient, but many rural properties do not have as much as they should. In 2012, an audit of 401 homes across five villages by National Energy Action[9] found 14% of homes needed loft insulation and another 32% would benefit from a top-up. The study also found that around half the homes would benefit from solid wall insulation, often more important for detached homes. Before and after comparisons of 830 cases of solid wall insulation in the National Energy Efficiency Data Framework show average savings of 14%[10]. Excellent insulation is a feature of Passive House constructions such as Tye Green Wimbish, included in this study, but retrofitting it into existing properties can be a big job, best combined with other work.

'The builder said I might as well because there wouldn't be another opportunity like this'

Carol put in external wall insulation along with new triple-glazed windows, with the windows set into the insulation layer for even better performance. Andy installed insulation on the inside of his new home as part of a complete fit out and re-plaster before moving in: 'The builder said I might as well because there wouldn't be another opportunity like this.'

2.05 Double or secondary glazing

Double or even triple glazing is the norm for new build, and double-glazed windows are about two-and-a-half times better than single glazing at retaining heat. Double glazing with wooden frames is unobtrusive in most existing properties, such as Pat's limestone terraced house. It can even be fitted into sash windows, although it does mean

[9] NEA (2012) Future of Rural Energy in Europe (FREE), England, Year 2 Report Village: Energy Audits, CALOR, NEA and ACRE: http://www.cumbriaaction.org.uk/Portals/0/Other%20Publications/Calor%20FREE%20Year%202%20England%20Report%20-%20Vilage%20Energy%20Audits.pdf
[10] DECC (2014) Summary of analysis using the National Energy Efficiency Data-Framework (NEED): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/323939/National_Energy_Efficiency_Data-Framework_2014.pdf

adjusting the sash counterbalance weights. For listed buildings such as Duncan's house, where double glazing is not usually allowed, secondary glazing is an effective option – and it also helps to cut down on road noise, which was important to Duncan since he fronts directly onto a main road.

Loosely related to glazing are 'sun-pipes', which can help to bring daylight to rooms located away from the perimeter of a building. These were used at the Gamlingay Eco Hub, reflecting light from the sky along a mirrored tube to help light a dark spot in the building.

2.06 Mechanical ventilation with heat recovery

Mechanical ventilation with heat recovery (MVHR) is the most effective way to cut down heat loss through ventilation. It captures the heat from stale, humid air going out to pre-warm fresh air coming in. You need to fix draughts first, but then MVHR can make a big difference. Carol said: 'We don't need to open windows any more and the house feels better ventilated… before, it was cold and draughty.' Whole house MVHR requires an air inlet or outlet in each room with air ducts between – often between the floor joists. The heat savings easily outweigh the extra electricity needed for the fans, provided the building is sufficiently air-tight first.

'We don't need to open windows any more and the house feels better ventilated… before, it was cold and draughty'

2.07 Heat pumps

Heat pumps are a way of heating efficiently by using electricity. A heat pump works in the same way as a refrigerator, except instead of taking heat from inside the fridge and pushing it into the room, it takes heat from outside and pulls it into your house or hot water tank. You should be able to get an average efficiency through the year of at least 2.5 – meaning you get 2.5 units of heat from 1 unit of electricity.

You cannot use heat pumps in the same way as a conventional boiler because they do not heat to high temperatures efficiently. They work better with big radiators or underfloor heating, but are not suited to delivering a burst of heat as soon as they are switched on, so you normally run them more or less constantly, albeit slowly. Some people find this hard to get used to, and heat pumps may not be suitable for properties that are used intermittently. However, there are other advantages. Bill said: 'It's just transformational – the oil central heating was never satisfactory but now we're warm all day,' – and they still saved £1000 a year on fuel bills.

'It's just transformational – the oil central heating was never satisfactory but now we're warm all day'

Heat pumps can take heat from the ground ('ground-source') or from the air ('air-source'). A ground collector is usually laid in a trench, covering a wide area. Air-source heat pumps are less efficient because the air can get much colder than the ground. However, they are also less expensive to install. The outside half of an air-source system is rather ugly – Bill lives in a National Park and the planners required his to be hidden behind a stone wall.

The domestic Renewable Heat Incentive covers ground-source and air-source heat pumps, but not air-to-air systems (with no radiators). This is because air-to-air heat pumps are usually reversible and can supply cooling as well as heating. The non-domestic Renewable Heat Incentive only supports ground-source heat pumps.

2.08 Biomass heating

Biomass heating uses fuel from wood or waste plant material. It isn't quite carbon neutral during operation, however, because some fossil fuels are currently used in transportation and for drying and processing. The Renewable Heat Incentive requires that biomass used meets sustainability criteria related to both carbon emissions and land use. It also only supports biomass boilers used as a main heating system. Biomass boilers usually handle wood chips or pellets, or sometimes logs.

'It's just like oil, only with a clear conscience'

Large biomass boilers using wood pellets can be fed automatically using a blower system. Helen fitted one for their large 120 kilowatt (kW) boiler system when they converted to using pellets. Previously they used logs, but manual loading was a lot of work. Now Helen says 'it's just like oil, only with a clear conscience'. They used to rely on a range that ran all day and consumed more than half their oil, though it only heated a couple of rooms properly. Now they run the new system just a few hours a day on a timer. Looking back, Helen says they were under-heated before, but now they are warm and feel they are in control.

Mark did not opt for an automatic feed for his boiler, but he only has to load up the hopper with a couple of bags every two or three days, even in winter. Apart from that, the boiler runs exactly like a conventional boiler, with a timer and thermostats on the radiators.

2.1 CASE STUDIES

2.11 Mark's home – biomass boiler

Mark and Diane live in a remote two-bedroom cottage in Derbyshire. Worried about the rising price of oil, and needing to replace their boiler as it was getting old, they decided to look at alternatives to oil central heating. They went to a local agricultural show where there were a variety of vendors. They chose a biomass pellet boiler as most suitable, because they have a high heat demand. This sort of boiler functions as a direct replacement for a conventional boiler – so they could have used the same radiators as before, although in fact they chose to upgrade most of them with smaller, fan assisted radiators to save wall space.

Elegance and warmth
One full year on they are delighted with their choice. The new 22 kW boiler is elegant – they opened up an old fireplace in the dining room to house it – and they are now as warm as they like, even while saving £300 a year on fuel. They don't need to use the wood stove in the lounge any more.

Hard when a delivery comes but very little trouble
Mark says the boiler is very little trouble to run. It runs off a timer like the old boiler, and works with radiator thermostat valves. They get pellets in 10 kg bags, a tonne at a time a few times a year, and stack them in their porch. Mark loads the hopper in the boiler with a couple of bags (every two to three days when the weather is cold) and empties the ash pan once a week. Mark strongly recommends the boiler to his friends and to clients of the supply company.

2.12 Mary's home – minimum upgrades

Mary lives on her own in a semi-detached two-bedroom house in a coastal village in Somerset. The house was originally part of the stables for a large estate. It has 450 mm-thick stone walls with 150 mm of internal insulation. Mary bought the property 15 years ago along with the adjoining house, and it had already been converted from stables into holiday accommodation for tourists.

The accommodation was refurbished to rent to tourists, and refurbished again when she moved in for her retirement a year ago and sold the adjoining house. It had to have internal insulation at this point to meet building regulations, although Mary was reluctant because she 'lost six inches from all outside walls'. Double-glazed windows were installed throughout seven years ago. There is no gas in the village, so there is an oil-fired boiler, installed a year ago along with a new oil tank.

Barriers to acting

Mary has not given much thought to other energy improvements, but she does not think it is worth investing much more in upgrades because she does not have the capital, and she may not live long enough to see the benefit. She is just about to build a ground-floor extension so that she could live only on the ground floor if her mobility deteriorates. 'Space is more important to me than energy saving,' she said.

The only other improvement Mary thought about seriously was having a wood stove. However, unlike one of her neighbours who has access to a free source of wood, she cannot get free wood. She is also unsure how long she will be fit enough to light and maintain a stove. She also says that if she were younger she would see improvements differently: 'If I were 40 I'd do everything.'

2.13 Combs Village Hall – heat pumps, solar thermal and extra insulation

Combs Village Hall in Derbyshire consists of two linked buildings – the old chapel (built in 1864) and the new hall, added in 1998. It is managed by the Combs Village Hall Trust. On weekdays both buildings are used as a primary school, and in the evenings and at weekends they are used by community groups.

Bills higher than the rent

When the school moved in, heating was mainly from electric night storage heaters, with infra-red heaters for top-up when necessary. Even though both the hall and chapel are well insulated (the chapel was given double glazing and internal wall insulation when the new hall was built), the heating bills were much higher than expected and the Trust was running at a loss. They could not increase the rent from the school, so they had to reduce costs.

Air-to-air heat pumps: low cost and low risk

The chairman of the Trust, Mike, was a retired engineer and he researched the problem thoroughly, picking up skills in building surveying and heat-loss analysis along the way. He was also fortunate to find a family connection to a renewable energy equipment company who provided advice. Mike selected air-to-air source heat pumps because they could be installed at low cost and needed little maintenance compared with biomass systems. Also, unlike a wet radiator system, they could be turned off over the holidays without fear of freezing and leakage. Initially, they installed a single test unit and when this was successful installed two further units, with a total capacity of 24 kW. They also installed a large hot water tank and solar hot water panels, and topped up the roof insulation in the chapel.

Low voltage in the electricity supply blew the control boards

The first problem they had was caused by low voltage in the electricity supply, which blew the heat pump control board – along with several more control boards in the village, on conventional heating systems. The supply company accepted responsibility and paid for the repairs. Since then, one of the pumps sometimes glitches when there is a power cut and has to be reset manually.

The cheapest installer was 200 miles away

The budget for the heating system was just £4,000 (in 2009). Mike shopped around to get a good deal both for the equipment (through his family connection) and installation. Local contractors were expensive or not interested, but eventually he found one in Dorset.

New controls ensure the heating goes off overnight

Some of the building users forgot to turn the heating off at the end of the day, and often turned the thermostat very high (to 28°C), increasing costs. The system now runs on a fixed setting and time schedule, but with a button to override the timer and give heat for a few extra hours when necessary.

Electricity use cut in half

The combination of new heating system, new controls, solar water heating and a little further insulation reduced the electricity use from about 42,000 kilowatt-hour (kWh) a year to 22,000 kWh a year.

Other residents in the village followed suit

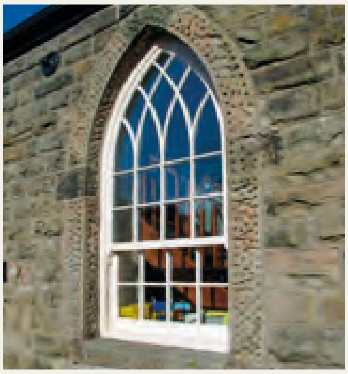
Following the example of the village hall, another five residents in the village have installed air-to-air source heat pumps as controllable secondary heating systems. Some homes have also had solar water heating installed. Mike used the skills he had learned to help other people in the village make savings on their energy bills. His recommendations are based on a simple building survey and heat loss analysis, and infra-red pictures. He also ran a workshop with Derbyshire County Council, using the village hall as an example to encourage take-up of local insulation grants. This led to another 8 to 10

TIMELINE OF IMPROVEMENTS AT COMBS VILLAGE HALL

- **JUN 2007** Energy usage reaches 42,000 kWh/year
- **JAN 2008**
- **SEP 2008** Planning application
- **JAN 2009**
- **JUN 2009** Solar hot water and initial air-source heat pump (ASHP)
- **OCT 2009** Chapel windows upgraded
- **JAN 2010**

homes being insulated, and two further workshops where Mike has trained volunteers in his survey method.

Mike's support was so effective because he was known and trusted in the community. He was also able to apply his engineering skills to model each building's performance and translate his findings into recommendations that the residents could understand. At the time, insulation was installed through a 'Warmstreets' project funded by the energy companies. Unfortunately, the current Energy Company Obligation is more difficult for community projects to navigate, so it is much harder for someone like Mike to support residents all the way through to funding and installation.



JUL 2010
Electrical mains supply problems

AUG 2010
Hall ASHP fitted

SEP 2010
Chapel heat pumps fitted

JAN 2011

MAR 2011
Loft insulation increased in chapel

JAN 2012

JAN 2013

APR 2013
Newer timer units fitted to hall ASHP

JAN 2014

EARLY 2014
Energy use 22,000 kWh/year

2.14 Hastoe Housing Association – Tye Green Wimbish Passive House new build

Hastoe provides affordable housing in rural areas, and has become increasingly concerned about issues of fuel poverty that its tenants face. This led to Hastoe exploring ways to improve the energy efficiency of its housing, and trying to lower its tenants' energy costs. In 2011, Hastoe was the first developer to build an affordable, rural, Passive House-certified housing development in the UK, in the small Essex village of Tye Green Wimbish. These 14 new homes are a mixture of flats and two-bedroom and three-bedroom houses.

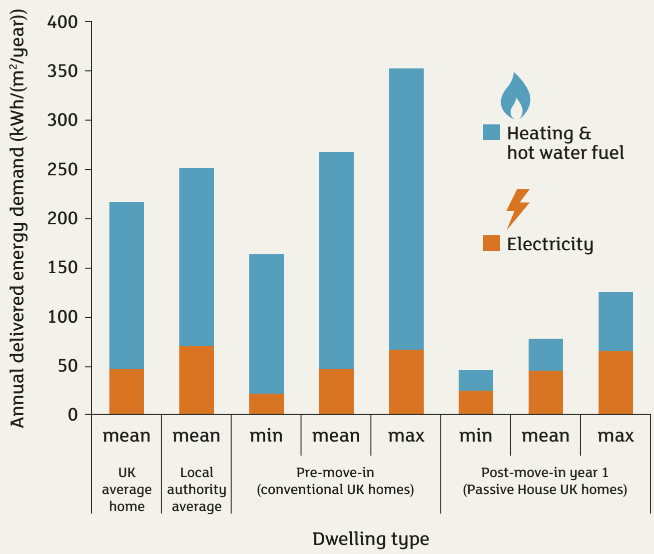
All homes met the Passive House energy efficiency standard and, as such, were super insulated and airtight. A mechanical ventilation with heat recovery (MVHR) system ensured they had fresh air, and heating and hot water was provided through solar thermal panels working in conjunction with a gas-fired boiler.

The overall construction cost was £1.7 million, or £1,444 per square metre. This was around 12% higher than equivalent homes built to Level 4 of Code for Sustainable Homes[11], which is much less ambitious for energy use. The project team believes that, since 2011, Passive House construction has become much less costly due to supply chains developing and the whole industry gaining more experience.

Heating and hot water energy was at least 85% lower

It is clear that the households now use far less gas for heating and hot water than they did in their previous, conventional, homes. They had previously used, on average, 219 kWh/m^2 per year, and they now consume an average of 32 kWh/m^2 per year (85% less). Even though lowering gas bills was a key message to tenants before they moved in, almost every household was very surprised how much they saved. However, as anticipated, electricity use in the new homes was very similar to their previous homes, mainly because they used very similar appliances and now had mechanical ventilation running too.

Figure 1. Energy demand for UK Passive House homes compared with other property types



What is the 'Code for Sustainable Homes'?

The Code for Sustainable Homes was launched in 2006 as a voluntary assessment method for rating the environmental performance of new homes. The code gave ratings (Level 1 to Level 6) based on nine sets of sustainability criteria: energy and carbon dioxide (CO_2) emissions, water, materials, surface water run-off, waste, pollution, health and well-being, management, and ecology.

The Energy and CO_2 requirements for each level also acted as a useful pathway for future changes to the building regulations, en route to all new buildings being 'zero carbon' from 2016 onwards. However, the term 'zero carbon' has been re-defined and watered down several times, such as energy use by electrical appliances being excluded, then small housing sites being excluded. In March 2014, the Government announced that the code would be withdrawn, with its performance criteria being integrated into the building regulations instead.

The code inherently prioritises carbon emissions, so higher ratings can often be achieved by installing renewable energy measures. In contrast, the more demanding German Passive House standard prioritises energy efficiency, meaning an emphasis on insulation and airtightness. It does not address other aspects of sustainability. As such, some Passive House-certified developments, which may consume around 80% less heating fuel than conventional buildings, have ended up with only a Level 3 rating under the code.

[11] See: https://www.gov.uk/government/policies/improving-the-energy-efficiency-of-buildings-and-using-planning-to-protect-the-environment/supporting-pages/code-for-sustainable-homes

A comfortable environment at a low cost
All householders talked very positively about living in these Passive House homes, with some saying that they could never imagine not living in one. The main benefit seemed to be achieving thermal comfort at an affordable cost. For example, most were very surprised that there were no draughts near doors and windows, and that they didn't need to wear a jumper indoors during the winter. And all of this was possible with much lower bills too. Several parents talked about how these lower energy bills meant that they could, for instance, spend more on their children's Christmas presents.

'No radiators – but how will I keep warm?'
The homes only had one radiator, and that was a heated towel rail for the bathroom. So, as far as many of the households saw it, there was a genuine concern that these homes would struggle to keep them warm because warmth provided through radiators was what most were familiar with. However, after a few months of living there, they soon realised that this was not a problem. They also ended up seeing no radiators as a positive feature of their home because that meant that they could now put their furniture anywhere that they wanted.

It's a learning experience for everyone involved
Since this was the first Passive House development that any of the project team had been involved in, they agreed that improvements could be made in the technical design, construction and commissioning of future Passive House homes. The support given to residents during handover and beyond could also be improved. Knowledge comes with experience, and so it makes sense the completion date was delayed slightly a couple of times, and that contractors would not always be able to fix faults first time because they had not encountered the Passive House systems before.

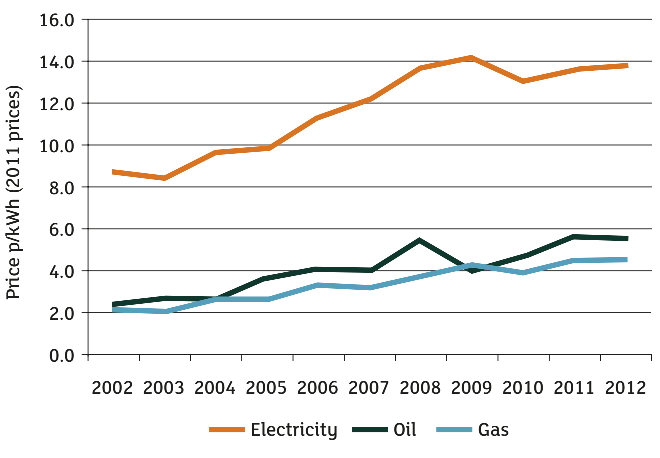
2.2 Why did they act?

2.21 Concern about fuel costs

Rising fuel costs were worrying for the majority of interviewees, and this drove more people to change their heating than anything else. Even though mains gas prices have doubled over the past decade, oil prices have almost always been significantly higher and electricity higher still, as shown in the graph below. Thirty-four per cent of rural homes are off the gas grid, and forced to use these more expensive fuels[12]. Interviewees were also concerned about uncertainty in future energy prices, so reducing fuel needs in the long term was seen as a way of 'future proofing' their homes.

For homes with electric heating, installing a heat pump should reduce their heating bills by around 17%[13], including the effect of off-peak electricity prices. The price of biomass pellets varies from one place to another and also depends on quantity and delivery method. Currently, it is similar to the price of oil[14]. It is hard to predict how this will change in the future, but production costs are largely unrelated to the cost of fossil fuels since the most energy intensive parts of production, drying and pelleting, can also be fuelled by biomass[15].

Figure 2. Fuel prices 2002 to 2012



Data from the UK Housing Energy Fact File 2013[16]. kWh = kilowatt-hour

Fuel poverty is a closely-related issue. Fuel poverty is now defined as a combination of higher than average heating costs and low income. As well as being more likely to be without mains gas, rural homes tend to be larger, are more often detached (45%) and are more likely to have solid walls that are difficult to insulate (25%)[17]. All this adds up to many rural homes being more expensive to heat than the national average. The Reepham Community Programme we investigated was driven primarily by concern for fuel poverty and 100 homes were insulated as a result. Several social housing projects have installed heat pumps to reduce fuel costs for residents, with some success. For example, eight homes in Bedfordshire were upgraded mainly from electric storage heating to air-source heat pumps[18]. As a result, 60% of the residents were very satisfied with the running costs of the new system, compared with none before.

2.22 Comfort

Five of 18 interviewees mentioned comfort as a concern in relation to costs – in particular, not being warm because they were worried about fuel bills. Cold can contribute to a range of health problems, including respiratory and circulatory conditions, and cardiovascular disease. Rural homes are often exposed to colder weather than in cities[19]. Our interviewees were almost all warmer than before they carried out improvements and they are not alone. The Bedfordshire study showed that 60% of the residents who converted to a heat pump were very satisfied with the level of warmth provided compared with none when they had electric storage heating[18].

2.23 Protecting the environment

Ten interviewees mentioned 'saving the planet' or 'being climate friendly' as a reason for installing their carbon saving measures; almost as many as the 13 who mentioned cost. Reducing fuel bills reduces carbon emissions too. Currently, all fuels have a fossil fuel component – even biomass – because of transportation. Electric heat pumps present a carbon saving over oil as long as the energy use is

[12] English Housing Survey analysis tool: https://www.gov.uk/government/statistics/cambridge-housing-energy-tool-guidance-note??
[13] Energy Saving Trust (2013) The Heat is On: Heat pump field trials Phase 2: http://www.energysavingtrust.org.uk/sites/default/files/reports/TheHeatisOnweb%281%29.pdf
[14] Nottinghamshire Energy Partnership (2015) Energy Cost Comparison: http://www.nottenergy.com/energy_cost_comparison
[15] Wood Pellet Information Resource (2012) Wood pellet supply, demand and prices: http://www.woodpelletsupplies.com/content/wood-pellet-supply-demand-and-prices-future-prospects
[16] Palmer, J. and Cooper, I. (2014) Housing Energy Fact File 2013, Department of Energy and Climate Change: https://www.gov.uk/government/statistics/united-kingdom-housing-energy-fact-file-2013
[17] English Housing Survey analysis tool: https://www.gov.uk/government/statistics/cambridge-housing-energy-tool-guidance-note??
[18] NEA (2014) Heat Pump Trials in a range of Bedfordshire "off gas" properties: http://www.nea.org.uk/Resources/NEA/Publications/2013/Aragon%20Final%20Report%20%28V12%29_06-03-2014.pdf
[19] Public Health England (2014) Fuel poverty and cold home-related health problems: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/357409/Review7_Fuel_poverty_health_inequalities.pdf

'The biggest barrier cited by interviewees to upgrading their homes is the cost'

reduced by at least 50%. Carbon emissions for biomass vary according to production methods, but can be generally assumed to be 10% that of oil[20].

2.24 Part of a refurbishment
Five interviewees took opportunities to install measures when other work was also needed. In one case insulation was installed as part of a general refurbishment, and in another the boiler needed replacing and a new heating system was installed instead. Taking opportunities like this is a good way to reduce the effective cost. For example, Bill indicated that his new heat pump system cost less as part of other refurbishment work than if it had been installed on its own. Research by the Tyndall Centre[21] shows that energy efficiency measures are usually combined with other renovation work, and government incentives should support this to have the greatest effect.

Table 3. Why did interviewees act?

Reasons for acting	Number of examples
Fuel costs	13
Environmental protection	10
Comfort	5
Part of refurbishment, including replacing heating	5
To avoid waste	1

2.3 What are the barriers?

Perhaps unsurprisingly, the biggest barrier cited by interviewees to upgrading their homes is the cost. More than half of those we interviewed said that the cost of energy improvements either delayed the work they wanted to carry out, or prevented them from doing more. Households that had made no improvements also said that cost was a major factor in preventing them from doing work on their homes. However, other barriers were also mentioned, and in many cases there was a combination of impediments to going ahead with improvements.

2.31 Upfront cost
Ten of the 18 interviewees said that the high capital cost of improving their home was the main hurdle to energy efficiency or renewables. The perceived high cost was specifically mentioned in relation to solid wall insulation, photovoltaics, solar water heaters and biomass heating. Some interviewees also said that current government schemes were unhelpful in overcoming the cost barrier. The Green Deal was perceived as an expensive loan, and some interviewees had found other, cheaper ways to raise the money needed.

One interviewee also said that funding available from utilities for low-income households, through the Energy Company Obligation (ECO), is difficult to access for individuals who want to carry out upgrades. Another factor was uncertainty about payback times for energy upgrades: would improvements pay for themselves within the lifetime of the upgrade? And can they trust figures from suppliers about actual savings or income from improvements?

Allocating a fair share of the ECO to rural households may help to overcome financial hurdles, particularly for poorer households. Given that 18% of people live in rural areas, this would be a reasonable target, although up to the end of June 2014 only 0.11% of total ECO measures installed were in rural households[22].

2.32 Payback time longer than time expecting to live in the home
Two interviewees said that they were unsure how much longer they would continue living in their homes, which prevented them from carrying out upgrades. Neither of them intended to move out imminently, and Penny said that she would continue to live in her home as long as she was able to, but she was entering old age, and she 'might not live to see the benefit'.

Mary and her husband had no immediate plans to move either, but they too are approaching retirement, and their children have left home. They expect to live in their large home for around another 10 years before moving somewhere smaller. They said: 'if they had surplus money they might feel differently', but uncertainty about how long they will stay puts them off investing beyond usual maintenance costs.

> Penny said that she would continue to live in her home as long as she was able to, but she was entering old age, and she 'might not live to see the benefit'

Wendy Wrapson and Patrick Devine-Wright found similar barriers in their interviews of 17 older households (60 to 89

[20] SAP 2009 The Government's Standard Assessment Procedure for Energy Rating of Dwellings (revised 2010)
[21] Wilson, C., Chryssochoidis, G. and Pettifor, H. (2014) Understanding Homeowners' Renovation Decisions: Findings of the VERD Project: http://tyndall.ac.uk/sites/default/files/verd_summary_report_oct13.pdf
[22] NEA and Calor (2014) Energy and Equity One Year On: Access to Government programmes for rural and off-gas households in England: National Energy Action

years old) with no gas supply[23]. Many were concerned about dipping into savings because they were cautious about spending money when they did not know what might lie ahead. For example, Bella said: 'I'm just really wary of spending too much money in case I need it because that much is quite a significant amount [to invest in energy efficiency or renewables]. If I need a new hip and I can't get it done on the NHS for example – and I've got a dodgy hip – I could use that money.'

2.33 Solid wall insulation can mean loss of space and period features
It is usually better and less disruptive to insulate walls on the outside, where this is practical. However, this almost always changes the external appearance and covers up period features such as window sills and lintels. To be effective, insulation has to be continuous. If there are gaps then this can encourage condensation and mould inside. Internal insulation is an option, but even here features like timber lintels mean that it can bring unwanted change in appearance.

Also, the insulation is usually at least 100 mm thick to reach the standard required by modern building regulations, and this means losing some space in the room. When more than one wall has to be insulated this can be significant. These issues discouraged several of our interviewees from considering insulation. Clearly there is a trade-off. There are innovative materials such as 'Aerogel' (trade names include 'Thermoblok' and 'Spacetherm'), which can be effective in thinner layers, but these are much more expensive.

Increasing the thickness of walls around windows through insulation reduces the light entering the room. One way to alleviate this problem is to line the window reveals with mirrors, as Mark did around some of his small windows (see photo). This maximises the light and makes the window look bigger.

2.34 Concern about air quality, damp and mould
Insulation and draught proofing improves air tightness but some fresh air is essential. Insufficient ventilation can lead to poor air quality, including high levels of humidity and sometimes toxic gases. The solution is to ensure there is adequate ventilation – for example, by installing trickle vents in windows and extractor fans in kitchens and bathrooms. However, fresh air remains very important to some people and Penny mentioned this as a concern.

Window mirrors at Mark's house, Derbyshire

Older homes with traditional construction, in particular some kinds of stone and masonry, are permeable to moisture whereas most modern insulation materials are not. This incompatibility changes the way moisture is carried through walls and away from the building. Building Regulations do not specify any special treatment in these cases, but English Heritage advises differently. It recommends that external insulation materials must be permeable and ideally internal insulation materials should be too. It recommends materials such as wood fibre insulation and lime plaster[24].

Yougen (which offers practical advice on energy efficiency and renewables) also recommends breathable insulation such as wool, hemp or cellulose for stone walls[25]. This was a concern for Pat, whose home has limestone walls with random stone infill, and no damp course. On English Heritage's recommendation, she selected corkboard insulation, but this turned out to be twice the cost of 'Kingspan' (one of the most common makes of insulation) – more than she could afford.

2.35 Concern about reliability
One of the reasons Penny cited for not installing new heating was concern about reliability. Her friends and family had reported various problems with new condensing boilers, and poorly installed cavity wall insulation. However, interviewees who had gone ahead with improvements had relatively little trouble. Helen found local contractors did not have much experience with their type of biomass boiler, and on one occasion the maintenance engineer damaged the boiler, which had to be repaired. Also Bill had some teething

[23] Wrapson, W., and Devine-Wright, P. (2014) 'Domesticating' low carbon thermal technologies: diversity, multiplicity and variability in older person, off grid households: Energy Policy, 67, pp 807-817
[24] English Heritage (2012) Energy Efficiency and Historic Buildings Insulating solid walls: https://content.historicengland.org.uk/images-books/publications/eehb-insulating-solid-walls/eehb-insulating-solid-walls.pdf/
[25] Yougen (2014) Insulation: http://www.yougen.co.uk/energy-saving/Insulation/

'It is usually better and less disruptive to insulate solid walls on the outside, where this is practical'

problems with his ground-source heat pump due to air trapped in the ground collector. Once this was fixed it was very effective.

Wrapson and Devine-Wright's work, mentioned above, also found that some older households were not keen to face the challenge of new and possibly complicated technology. One said: 'I don't think it would have occurred to me to investigate a heat pump. I mean I'm getting to the time of life I want to simplify.'

2.36 Finding skilled tradesmen and installers
Interviewees reported very different experiences in selecting tradesmen to make improvements. Duncan found it hard to find anyone skilled in handling traditional building materials for his listed home. 'Local tradesmen are terrible because there is no competition,' he said. In desperation, he went so far as researching and developing his own mix for traditional lime render. Mike from Combs Village Hall found local contractors were very expensive compared with specialists from further afield recommended by his supplier. However, Pat would only consider using local people because they were familiar with the limestone construction in the area. Pat and Carol used contractors they had worked with before, while Andy and Mark found tradesmen recommended by friends and colleagues.

2.4 What did they save?

A total of 15 of the 16 projects we examined that had made some improvements reported saving energy, although not all of them were able to put figures to the savings. Those who could put figures to the energy they used before and after improvements are shown in the tables below. There is some uncertainty in the figures – especially the stated savings for oil because these are estimated based on how many times they refilled oil tanks – and we were not able to adjust the heating figures for yearly variations in the weather, or

Table 4. Barriers cited by interviewees

Stated barriers	Number of examples
Cost	10
Finding skilled tradesman	4
Reliability	2
Time in house	2
Worry about mould	2
Concern about fuel source	1
Hard to get good advice	1
Hassle	1
Maintenance	1
Period features	1
Planning restrictions	1
Small rooms	1

changing energy prices. There may also be some 'optimism bias' in the stated savings because most of the interviewees had become enthusiasts for the improvements they had chosen, and so may have exaggerated reported savings.

The average carbon saving for community buildings was 26 tonnes of CO_2 a year – about the same as five average homes – although there was a wide range of achieved savings. The average cost saving for these buildings was £4,100 a year (against an average capital cost of £37,000).

The average carbon saving from these homes was just over four tonnes of CO_2 a year, although again there was a wide range: from 260 kg up to 9 tonnes a year. As for cost savings, the householders who had access to these figures reported average savings of just over £700 a year, compared with average capital costs of around £14,000.

Table 5. Summary of savings from improved community buildings

Building	Upgrades	Yearly saving	Annual CO_2 saved	Annual cost saving	Percentage saving
Combs Village Hall	Air-to-air heat pumps and solar water heating	21,000 kWh	11,000 kg	£3,300	50% of heating cost 50%
Dunster Lodge	Biomass boiler	£7,000 of oil	60,000 kg	£7,000	50% of heating cost 50%
Rest and Be Thankful Inn	Solar PV, solar water heating	£1,000 electricity + £1,000 oil	8,200 kg	£2,000	10% of electricity and 15% of oil (quantity saved) 10% 15%

PV = photovoltaic; kWh = kilowatt-hour.

Almost every interviewee who had made changes reported other important benefits apart from simple cost savings and feeling good about reducing their carbon footprints. In most cases they said that they were more comfortable in the buildings. Those with new heating systems often said that the new system was more controllable than the old one – although many of those with biomass boilers also reported some teething problems when the system was first installed. Indeed, nearly everyone with a biomass boiler recognised that they needed more care and maintenance than a simple oil-fired boiler. One retained the old oil heating system as a backup in case there was ever a problem with the biomass boiler.

In nearly every case, carrying out improvements also helped to make interviewees more aware of their energy use, carbon emissions and energy costs. This sometimes meant they found other opportunities to save energy that they probably would not have done, but for the improvements.

Table 6. Summary of savings from improved homes

Homeowner's name	Upgrades	Yearly saving	Annual CO_2 saved	Annual cost saving	Percentage quantity saved		
Bill	GSHP in house with oversize radiators. ASHP with underfloor heating and insulation for workshop	£1,000 for oil	4,500 kg	£1,000	33% of oil		33%
Carol	Solar PV, wall insulation, insulated doors and windows, and MVHR	300 litres of oil	at least 780 kg	at least £174	15% of oil		15%
John	Air-to-air heat pumps and solar hot water panels	Two 47 kg bottles	260 kg	£80	15% of LPG		15%
Laura	Wood stove and solar PV with water heater	1,200 kWh of electricity and £1,600 of oil	7,700 kg	£1,800	23% of electricity and 100% of oil	23%	100%
Mark	Biomass boiler	£300 in heating costs	9,000 kg	£300	100% of oil		100%
Matthew	Solar PV, thermodynamic water heating, wood stoves and top-up loft insulation	£400 oil and 3000 kWh electricity	3,400 kg	£1,050	70% of electricity and 40% of oil	70%	40%

GSHP = ground-source heat pump; ASHP = air-source heat pump; PV = photovoltaic;
MVHR = mechanical ventilation with heat recovery; LPG = liquid petroleum gas; kWh = kilowatt-hour.

SECTION 3

National upgrades

SECTION 3

National upgrades

3.0 What if we rolled out upgrades nationally?

The home improvement projects we examined showed impressive carbon savings: from 15% to close to 100% of heating emissions, and from 23% to 70% of emissions from electricity use. This prompts interesting questions about the savings that could be achieved if we improved as many homes as possible in England:

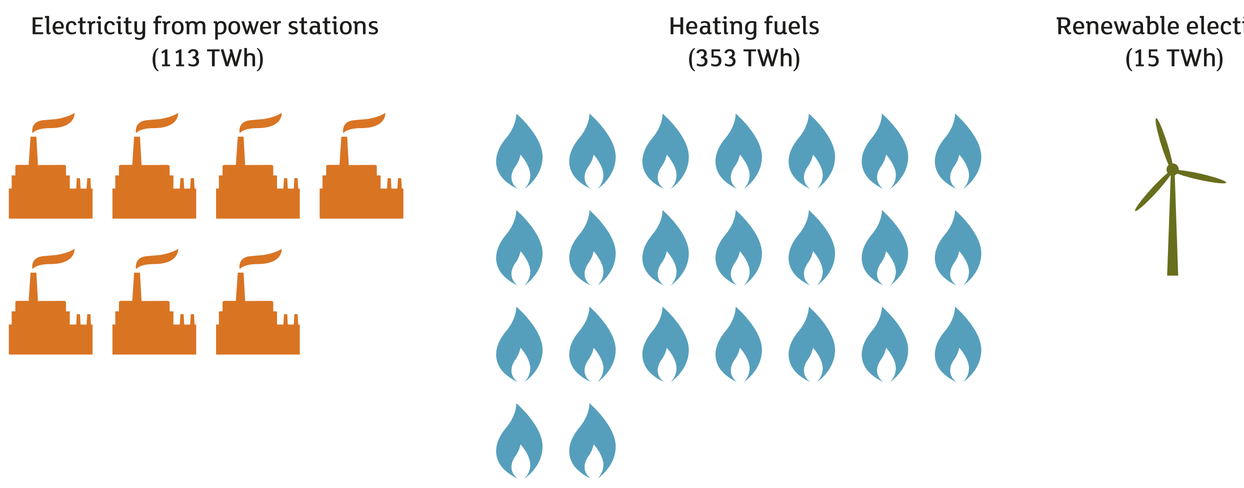
- Could we meet our greenhouse gas reduction commitments by improving buildings alone? Or would we still need more low carbon energy generation to replace existing high carbon generation?
- Would improving buildings result in a lower visual impact on the countryside than building more energy generation alone?

3.1 'All models are wrong, but some are useful' [26]
It would not be reasonable to attempt to extrapolate from the relatively small number of projects we examined to assess the total potential for savings across England. Every rural building is different, and we would not suggest that our 'sample' of projects is representative in terms of building type or savings achieved. However, we have used the Cambridge Housing Model[27], which CAR developed for the Government, and which is currently the most widely used and best tested model for estimating energy use and CO_2 emissions from housing. To date there is no equivalent, established model for non-domestic buildings, partly because the data available about other buildings is much more limited[28].

Figure 3 gives a simplified breakdown of current energy supply for homes in England, annually, based on Government statistics[29].

Our modelling estimates suggest that dramatic improvements to the energy efficiency of homes – from better insulation, more efficient gas or oil boilers, and improved airtightness – coupled with small-scale renewables on buildings – such as solar photovoltaics, heat pumps and solar water heating – could reduce average carbon emissions per home by nearly half. The assumptions behind this modelling are listed in the Appendix.

Figure 3. Current energy supply for English homes



One power station icon represents two power stations each with a capacity of 1.5 GW, a load factor of 52%, generating 6.8 TWh a year. One blue flame represents the same amount of thermal energy, and a turbine represents the same amount of renewable energy. Data is from the Digest of UK Energy Statistics 2014, the most up-to-date aggregate data available. TWh = terawatt-hours.

[26] G., E., P., Box (1976) Science and Statistics: Journal of the American Statistical Association, 71, No. 356 pp 791-799
[27] See: https://www.gov.uk/government/statistics/cambridge-housing-model-and-user-guide
[28] Armitage, P., Godoy-Shimizu, D. and Palmer, J. (2015) The Cambridge Non-Domestic Energy Model. Cambridge: Cambridge Architectural Research
[29] The Department of Energy and Climate Change (2014) Digest of UK Energy Statistics: Tables 1.1.5 and 6.4.3

Figure 4. Average CO_2 emissions per home

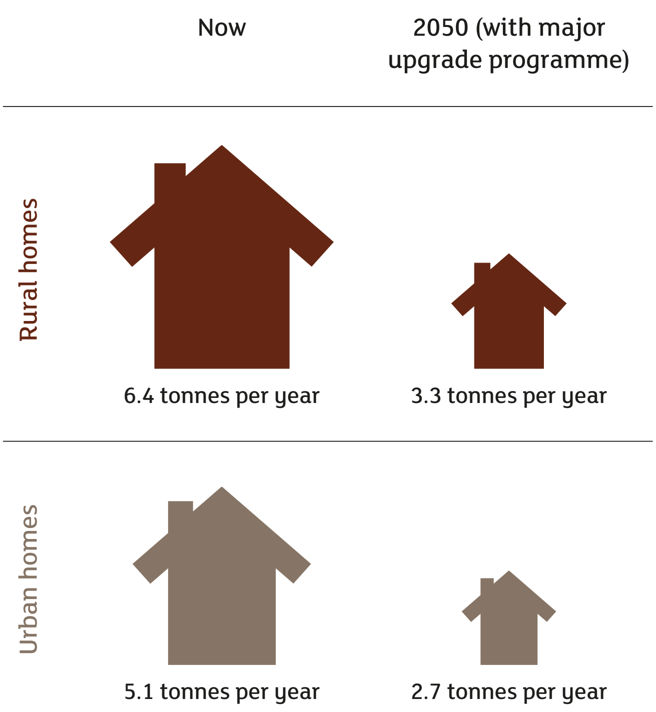


Figure 5. How many homes could we realistically improve by 2050? – urban and rural

One house icon represents 190,000 homes

3.2 Hard choices

Assuming that we do go ahead with a major programme of improving both rural and urban homes, new house building and supply side constraints on how many homes can be improved, along with physical limits on which homes can be improved, mean there will still be a large residual energy demand from homes (the 'energy gap' illustrated in Figure 6). If we are to achieve the legally binding commitment to reduce global warming gases by 80% by 2050, unless an even more radical energy demand reduction programme for homes is implemented, we will have to achieve most of this using new low carbon energy generation. This means proven technologies such as nuclear power, wind power, hydroelectricity, and solar electricity, and possibly technologies that are currently unproven at scale, such as tidal and wave power, and carbon capture and storage.

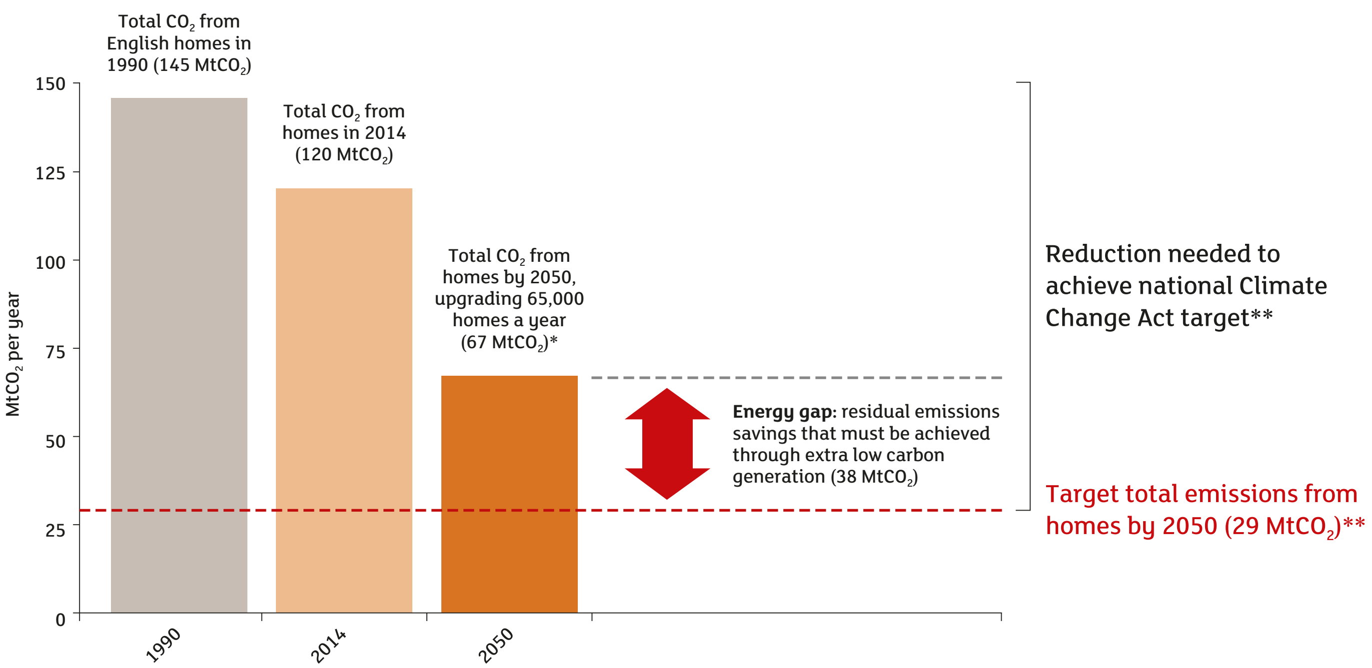
We have concentrated on household energy use because better data is available, but it is likely there are similar 'energy gaps' for other buildings and other sectors.

3.3 How can we meet the energy gap?

CPRE's position is that we should move towards a sustainable energy system without sacrificing the countryside, including aiming to minimise the local impacts of energy generation. This includes reducing the demand for energy before increasing energy supply, which means upgrading buildings and avoiding wasting energy. It also includes moving to low carbon sources of energy and becoming less dependent on fossil fuels.

If we assume that all of the practicable upgrades are carried out on all homes able to take the technologies by 2050, we will still need 83 terawatt hours (TWh) of electricity and 186 TWh of heating a year for housing. This includes the effect of new house building and demolitions. Figure 7 illustrates options for meeting this additional demand. These options are illustrative and many other mixed-technology options are possible, other than the wind-turbine-only scenario for renewable electricity and biomass-only scenario for renewable heat shown.

Figure 6. Meeting our 2050 target: the size of the 'energy gap' for homes in 2050



*This is optimistic because it does not allow for 'rebound effects' where part of the benefit of efficiency upgrades is taken back by households as improved thermal comfort or other lifestyle changes. In reality, the savings from 65,000 major retrofits will be less.

**The Climate Change Act target is expressed in greenhouse gas emissions, which include carbon and five other greenhouse gases. However, carbon dioxide (CO_2) is by far the most significant greenhouse gas from housing, so for purely housing questions the two are largely interchangeable. The reduction needed, and the energy gap for housing, will both rise if other sectors do not achieve the 80% target.

All emissions figures are per year; $MtCO_2$ = million tonnes of CO_2

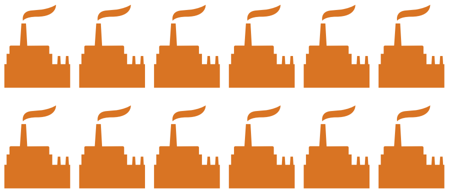
‘Even with a major programme of improving both rural and urban homes…there will still be a large residual energy demand’

Figure 7. Meeting our 2050 target: options for meeting household energy demand after all practical upgrades to homes

Electricity demand (83 TWh a year)*

Requiring

At least 12 large traditional power stations



OR

Renewable electricity**

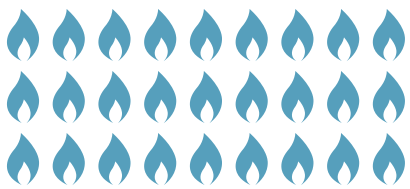
14,000 large wind turbines

Covering 0.3% of England

Heat demand (186 TWh a year)*

Requiring

Heat from gas



OR

Biomass heat***

Covering a third of England

These scenarios are illustrative and many other mixed-technology scenarios are possible, other than the wind-turbine-only and biomass-only scenarios illustrated.

*Assuming large power stations with a capacity of 1.5 GW, a load factor of 52%, generating 6.8 TWh a year. One blue flame represents the same amount of thermal energy.

**Assuming one onshore wind turbine with 50m blades, rated at 2.5MW, generates 6 GWh a year. In reality we could not use wind alone because of intermittency – when the wind drops so does the power. Larger turbines can be seen from some distance away, so the visual impact is larger than the area indicated.

***Using David Mackay’s central estimate of 4.4 m^2/kWh/year, from ‘Sustainable energy – without the hot air’.

TWh = terawatt-hours.

3.4 Landscape and land-use impacts on the countryside
The current UK energy generation mix includes a significant contribution from wind as a source of renewable electricity: four-fifths of renewable electricity comes from onshore or offshore wind turbines, see Figure 8. We have separated electricity from heat because of inefficiencies in converting heat to electricity, and because the demand for heat is concentrated in winter. This means most of the demand for heat could not be met by solar energy, which produces most power in the summer.

One low carbon scenario for meeting the residual energy demand for housing in 2050, after upgrades have been carried out is shown in Figure 10. This includes a mix of renewable energy technologies and power stations for electricity generation. CPRE is not advocating this scenario, but it is shown because it represents the middle scenario between two more extreme examples that were constructed for illustrative purposes. It is worth noting that nuclear is also low carbon.

CPRE advocates a higher proportion of roof-mounted and building-integrated photovoltaics than ground-mounted systems than is currently the case. CPRE also supports more community ownership of renewable energy and energy efficiency projects than current proportions, so rural households have a stake in their power generation.

Figure 8. Current renewable electricity generation

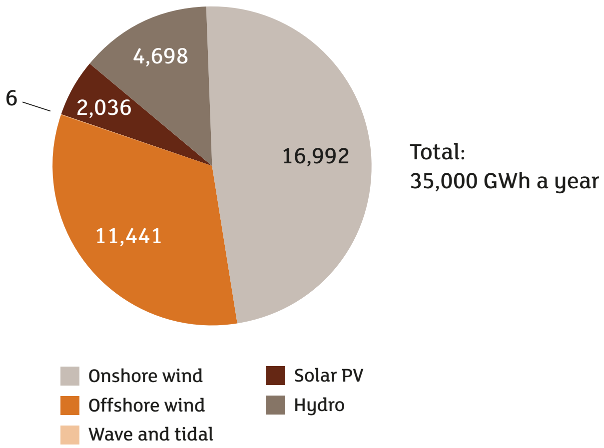
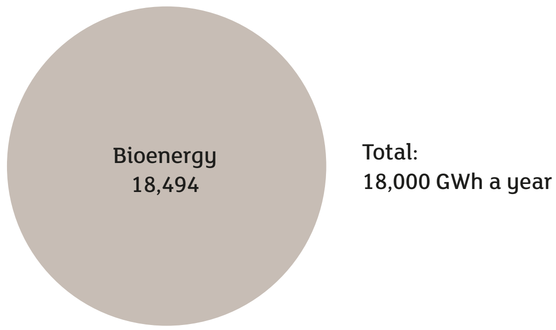


Figure 9. Current renewable heat generation



These figures are for all sectors of the economy, not just housing.
Data is from the Digest of UK Energy Statistics 2014[30], the most up-to-date aggregate data available. PV = photovoltaic; GWh = gigawatt-hours.

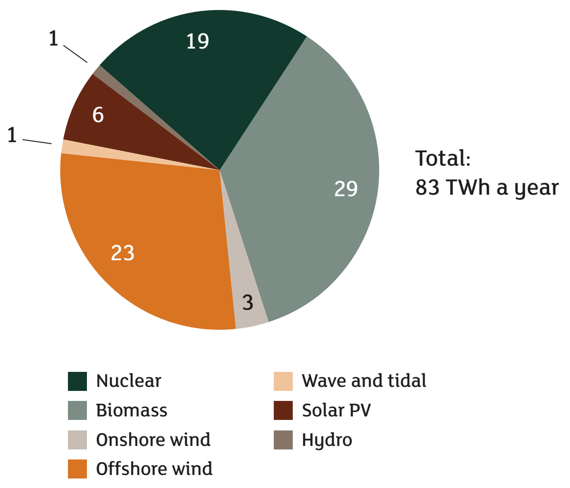
Assuming that the modelled 2050 demand for heat, apart from the demand that can be met through heat pumps, comes largely from timber and biomass, we would also need 186 TWh a year of extra energy for space and water heating.

The 2050 heat demand indicated by our modelling, combined with the low carbon electricity scenario shown in Figure 10, implies that approximately half of England's land area would be needed to grow biomass fuel, along with additional nuclear power stations, almost 3,500 wind turbines (the majority offshore), and a significant amount of new solar electricity – although its use can be maximised on and in buildings.

This is illustrated in Figure 11. As highlighted above, CPRE is not advocating a specific scenario, but it is being used for illustrative purposes.

The examples on these pages would clearly have significant impacts on our countryside, although for some choices such as solar electricity this could be partially mitigated by locating this on and in buildings as far as possible. We have chosen to illustrate it in this way to underline the energy gap and the urgent need for the strongest possible action to reduce energy demand from our homes.

Figure 10. Meeting our 2050 target: example scenario for electricity generation



If carbon capture and storage is shown to be effective and widely available it could replace some or all of the biomass or nuclear generation. In the original scenario, there was a small contribution from geothermal energy, but this is not shown on the pie chart because there are no readily available and robust published figures for geothermal. The scenario assumes that around 10% of electricity capacity will be met by standby gas turbines, 10% from international interconnection and 5% from pumped hydroelectric storage, to cope with peak demand. Different load factors for each generation technology mean that generation figures are quite different from installed capacity. In fact this scenario has equal capacity for solar PV and offshore wind, but offshore wind generates much more electricity over the course of the year because the load factor is higher.

PV = photovoltaic; TWh = terawatt-hours.

[30] Department of Energy and Climate Change (2014) Digest of UK Energy Statistics

'CPRE's position is that we should move towards a sustainable energy system without sacrificing the countryside'

Figure 11. Meeting our 2050 target: land-use implications of the biomass heat option plus electricity generation scenario

The power sources illustrated would be in addition to current power generation using these technologies.
*Using David Mackay's central estimate of 4.4 m^2/kWh a year, from 'Sustainable energy – without the hot air'.
**Assuming one 3.6 MW turbine generates 13.2 GWh a year, see http://www.ewea.org/wind-energy-basics/faq/
***Assuming one nuclear power station has a capacity of 2,000 MW and a capacity factor of 66%, generating 11,600 GWh a year.
****Assuming one onshore wind turbine with 50m blades, rated at 2.5MW, generates 6 GWh a year.
***** This area corresponds purely to the area of the panels. If a significant proportion of the panels were to be ground mounted, the area occupied would be much greater because space is required between the panels. The Government estimates that a further 250,000 ha of commercial roof space could be used for solar PV, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/302049/uk_solar_pv_strategy_part_2.pdf
PV = photovoltaic; GWh = gigawatt-hours; kWp = kilowatt-peak; MW = megawatts

Clay Field eco-homes, Suffolk

SECTION 4

Findings and recommendations

Carol's house, Cambridgeshire

SECTION 4

Findings and recommendations

4.0 Making energy use in homes low carbon and affordable

Our interviews with householders and those responsible for community buildings revealed committed individuals motivated by factors such as rising fuel costs, and a desire to increase comfort and protect the environment. The interviews also revealed some extremely good examples of low energy and low carbon improvements, and new build projects. However, those that choose to take action to save energy and reduce carbon are not backed by a clear national policy framework and a comprehensive package of support. There are still too many barriers to act, including the upfront cost, the difficulty of finding skilled installers and the payback time compared with the time people expect to stay in the same home.

Our modelling indicates that there is a clear and significant gap between how much carbon dioxide England's housing is likely to emit in 2050, and the reduction in emissions we need to achieve to meet the requirements of Climate Change Act. We need more effort to fill this energy gap, both in terms of reducing energy demand (better efficiency such as insulation), and decarbonising our energy supply (including low carbon technologies such as solar energy).

Our estimates are based on assuming 65,000 homes will have a major retrofit each year to reduce energy demand, which is fairly ambitious but still not enough. Currently fewer than 1,000 such retrofits are completed each year. Unless we go further, the impacts on the English countryside could be dramatic and require avoidable new energy infrastructure, on top of the effects of climate change itself such as more storms, floods and droughts.

Our modelling suggests we could cut carbon emissions from homes by 44% (53 million tonnes of carbon dioxide a year) by 2050 by upgrading homes. However, to meet the national target we must save another 38 million tonnes of carbon dioxide a year. This figure will need to be even higher if part of the anticipated savings is lost as a result of people being able to afford more comfortable temperatures in their homes. It will also increase if other sectors, such as non-domestic buildings or transport, make emissions reductions of less than the 80% target. If we save the extra carbon only by acting on energy supply, this might mean planting half of England with biomass crops, almost 3,500 new wind turbines (the majority offshore), and 8,000 hectares of solar panels. Envisioned like this, the need for further decisive action to reduce energy demand becomes overwhelming.

Not improving more homes would also add to the number of households in rural areas facing fuel poverty – families that cannot afford adequate heat or electricity to meet basic needs. By contrast, going further than the ambitious assumptions on low carbon solutions for homes that we use for our modelling would help to further reduce householders' energy bills and carbon emissions, create more jobs and reduce the impacts of new energy infrastructure on the countryside.

This report highlights just how unsustainably we're living now, and the hard choices we face as a result. However, it also suggests solutions – informed by the experience of those we visited during the research – to enable us to live not only more sustainably but also more comfortably.

We therefore put forward the following recommendations to make energy use in homes low carbon and affordable, as well as reducing impacts on the countryside.

Bags of biomass pellets, Dunster Lodge, Somerset

‘This report highlights just how unsustainably we’re living now, and the hard choices we face as a result’

Recommendations for Government

- **Implement a bold and effective national programme to reduce energy and carbon emissions from homes and community buildings: this should be a priority at least equal to the commitment to reduce emissions from energy supply.** An ambitious, community-led programme to retrofit energy efficiency measures focused on fuel-poor households should be at the heart of this national programme. Financial incentives to improve homes and community buildings must be easy to understand, accessible locally, and financially attractive. The Government’s Green Deal and Energy Company Obligation (ECO) do not pass these tests and should be reformed to ensure they do. It is early days, but the domestic Renewable Heat Incentive looks like a better initiative – though more needs to be done to help those in fuel poverty.
- **Ensure that rural communities get their fair share of Green Deal, ECO and other sources of finance.** If 18% of people live in the countryside, they should receive 18% of government support, not less than 1% as is currently the case. Legislation will probably be needed to make this happen.
- **Publish an authoritative, evidence-based comparison of the carbon savings and costs of different low carbon technologies – for both energy demand and energy supply.** There is currently no easy way to compare the potential carbon savings of different technologies. The published comparison should be used to prioritise technologies with the biggest carbon savings, and to restructure grants and subsidies so that financial support reflects the potential for savings.
- **Strengthen standards for new homes to drive a clear pathway for energy and carbon savings.** The Code for Sustainable Homes has been withdrawn and the zero carbon homes target has been watered down, and these move us in the wrong direction. Our research highlights the need to strengthen standards to reduce the energy gap, in line with the Zero Carbon Hub’s recommendations in 2014. Without more ambitious standards, innovation by developers will be stifled.
- **Re-frame expectations about savings: a large number of rural homes are currently under-heated, so savings are likely to be lower than predicted because people will be able to afford more comfortable temperatures in their homes.** This probably means that the ‘energy gap’ is even bigger than shown by our modelling. A big challenge then becomes bigger still.
- **Ensure building regulations reflect the special requirements of traditional construction methods.** In particular, if breathable construction in traditional buildings dictates that more expensive natural insulation materials are needed, grants should be offered, so people who own historic buildings are not disadvantaged.
- **Provide more support to the construction and retrofit industry.** The experience and skills deficit for the construction and retrofit industry is a barrier to the progress we urgently need. High quality, free or subsidised training, and access to reliable, impartial information on a website would help.
- **Drive innovation in solid wall insulation, to reduce costs and improve the performance of thinner forms of this type of insulation.** For example, ‘Aerogel’, developed by NASA to use for insulating spacecraft, is fragile and very expensive to use in buildings. Research and development, and manufacturing at scale, may help.
- **Ensure that retrofit initiatives build trust with local communities by working with trusted organisations and individuals.** This could be someone who is well-known and who has successfully carried out improvements in the community. Trust was a key factor in owners engaging with the idea of retrofits, let alone subsequently going ahead with work. Personal relationships are critical, and choosing the right person to engage householders and those responsible for community buildings is decisive.
- **Ensure that policies and initiatives target key points in the life of a building to encourage energy improvements.** Some householders are not just ‘hard to reach’, but cannot be persuaded to make energy improvements. Whatever the potential savings, or climate change impacts on the countryside, they have no inclination to change, and age is a factor. Moving house, renovating or replacing parts of a building (for example, heating systems, roofs and windows) are perfect opportunities for acting. There is no one-size-fits-all policy that works for every owner, but tapping into these key events can help even people who are not actively trying to reduce their energy use or carbon emissions. Providing information for builders and building supply firms can provide the right help at the right time.

Recommendations for the construction and retrofit industry

- **Take opportunities to help cut carbon emissions from existing buildings and work on new low energy buildings, and invest time in making sure you have the right skills to ensure measures achieve the right level of energy efficiency and expected carbon savings.** These are real opportunities for growth, and it is better to get involved early. Low carbon solutions will probably be the only option in years to come, but in the meantime, low carbon solutions and the right level of associated skills can provide a business edge.
- **If you are new to delivering projects in this area, consider collaborating with other firms that already have relevant experience.** This can be a good way to enhance knowledge and skills in this emerging field.
- **Always include contingency planning in low carbon retrofit projects or new-builds.** Ideally allow extra time because some of the technologies involved are new, and inexperience across the supply chain can sometimes cause problems.
- **Look for opportunities to encourage your clients to increase insulation levels or make other improvements at the same time as other work.** This can bring savings for them and more work for you without having to find new clients.
- **Stay abreast of developments in materials and technologies related to energy efficiency and low carbon.** It is too easy to continue using the same equipment or materials as you did for the last job without evaluating new products, which might be better.

Recommendations for householders and those responsible for community buildings

- **Improve energy efficiency and install low carbon technologies to save money, energy and carbon, as well as making your building more comfortable.** This is especially important in rural areas, where properties often have low energy efficiency and gas is often not available, meaning more expensive fuels such as oil or electricity have to be used.
- **Look out for grants and subsidies to make low energy and low carbon improvements.** This is especially important if you are on benefits or have a low income, and the Energy Company Obligation (ECO) targets poorer households. Despite issues with some of the national programmes for reducing energy from homes, as highlighted above, there are still useful sources of financial support, including ECO and the Renewable Heat Incentive.
- **Ensure you ventilate your building properly after insulation and air-tightness work.** Poor ventilation of kitchens and bathrooms, or drying clothes inside without opening a window, can lead to humidity and mould.
- **If you haven't already, secure energy savings by doing the simple things** such as turning lights and appliances off when you don't need them, and installing cheap energy efficient lights.

APPENDIX

Tye Green Wimbish Passive Houses, Essex

APPENDIX

Appendix: detailed modelling and assumptions

The modelling for this report used an extended version of the Cambridge Housing Model, which Cambridge Architectural Research developed for the Department of Energy and Climate Change, estimated energy use and carbon dioxide (CO_2) emissions for:

1. The present situation, 'Base case'

2. 2030 and 2050 with all possible energy efficiency upgrades (insulation, air tightness, heating upgrades including condensing boilers and low energy lighting)

3. 2030 and 2050 with the same energy efficiency upgrades plus a renewables package (solar photovoltaic (PV) panels, solar water heating, ground-source and air-source heat pumps, and biomass boilers)

Table 7. Detailed modelling and assumptions

1. Base case	2015	
	Rural	Urban
Number of homes	3,233,459	19,520,681
Mean electricity/home (kWh)	4,868	4,179
Mean gas/home (kWh)	12,526	13,231
Mean oil/home (kWh)	3,464	546
Mean solid fuel/home (kWh)	1,627	474
Mean CO_2/home (kg)	6,446	5,096

2. Energy efficiency package*	2030		2050	
	Rural	Urban	Rural	Urban
Number of homes	3,467,981	20,936,513	3,780,678	22,824,290
Number of homes improved	141,065	851,619	323,287	1,951,713
Mean electricity/home (kWh)	4,525	3,899	4,136	3,582
Mean gas/home (kWh)	11,712	12,279	10,788	11,201
Mean oil/home (kWh)	3,046	480	2,575	406
Mean solid fuel/home (kWh)	1,432	417	1,212	353
Mean CO_2/home (kg)	4,741	3,698	3,736	2,905

3. Renewables package**	2030		2050	
	Rural	Urban	Rural	Urban
Number of homes	3,467,981	20,936,513	3,780,678	22,824,290
Number of homes improved	217,066	796,225	484,553	1,790,447
Mean electricity/home (kWh)	4,507	3,878	4,109	3,541
Mean gas/home (kWh)	10,927	11,862	9,190	10,352
Mean oil/home (kWh)	2,861	449	2,208	343
Mean solid fuel/home (kWh)	1,372	405	1,094	329
Mean CO_2/home (kg)	4,521	3,601	3,298	2,714

*Insulation, air tightness, heating upgrades (including condensing boilers) and low energy lighting.
**Solar PV, solar water heating, ground-source and air-source heat pumps, and biomass boilers.

Assumptions used in the modelling

1. All upgrades: all modelling was undertaken using an extended version of the Cambridge Housing Model (CHM), developed for the Department of Energy and Climate Change by Cambridge Architectural Research. This is used in national statistics on household energy use, and was used in domestic energy policy. Modelling assumes that all homes that can be upgraded are upgraded by 2050, subject to capacity constraints implied in BRE (2008) MAC Curves for the Domestic and Non-Domestic Building Sectors – Technical Documentation, prepared for the Committee on Climate Change.

2. Wall insulation: wall insulation covers cavity wall insulation, internal solid wall and external solid wall insulation. If the existing wall construction contains insulation, it is unchanged. If it is an unfilled cavity wall, it is changed to a filled cavity wall. Solid wall and system build walls are changed to external wall insulation. This uses the SAP standard wall constructions.

3. Roof insulation: roof insulation assumes that loft insulation for pitched and thatched roofs has been increased to around 300mm, using the SAP standard roof constructions. For flat roofs, improved insulation assumes that the 'U-value' (a measure of insulation performance) has been increased to 0.16 W/m^{2}K.

4. Floor insulation: if one of the non-insulated floor constructions is used, it is replaced with the equivalent insulated floor constructions with a U-value of 0.3 W/m^{2}K.

5. Biomass: if the main heating system is a wet system compatible with a biomass boiler, then it is replaced. It is assumed based on the SAP tables that a biomass boiler has a maximum efficiency of 70%. If the domestic hot water system is run off the main system, the DHW system efficiency is updated to reflect the biomass boiler. If an oil pump is included, this is removed.

6. Heating upgrade: the heating upgrade assumes the replacement of the heating system with an equivalent high efficiency system. If a dwelling has a low efficiency boiler system, it is replaced by a high efficiency gas boiler with an efficiency of 94.4%, reflecting the highest efficiencies reported in the existing stock. This assumes any oil boilers are replaced, so the oil pump is removed. If a warm air system is replaced, the heating efficiency is assumed to change to 85% – the efficiency of a modern condensing system with heat recovery. Heating controls are added if they are not already present: programmers, room thermostats, and thermostatic radiator valves. Any secondary heating systems are removed, and if the domestic hot water system is run off the main system, the domestic hot water system efficiency is updated to reflect the biomass boiler.

7. Improved glazing: single glazing is replaced by standard double glazing with a low-emissivity, soft coating. There is very little difference in SAP between double glazing and secondary glazing, and little to suggest where one is more appropriate than the other, so at this stage we are just modelling double glazing.

8. Improved doors: existing doors in the Cambridge Housing Model have a standard U-value of 3 W/m^{2}K. These are assumed to be replaced by doors with a U-value of 1.8 W/m^{2}K, reflecting the standard for replacement doors.

9. Draught proofing: the CHM currently includes a standard structural infiltration rate of 0.35 ach. This is improved to 0.175 ach, and it is assumed that draught stripping on doors and windows is increased to 100% where necessary.

10. Domestic hot water cylinder: where a cylinder is used for domestic hot water storage, the insulation level is assumed to be improved to a thickness of 150 mm. A cylinder thermostat and primary pipework insulation are also added where not already present.

11. Solar hot water: we assume a standard SHW target output of 3 kW, which requires a gross collector area of approximately 4.5 m^2. Therefore, solar hot water installations are limited to dwellings with a roof area of at least 9 m^2 (to account for pitch and shading), and which use a water cylinder to store hot water – the cylinder volume is increased to 250 litres.

12. Photovoltaic panels: we assume a standard domestic installation size of 4 kWp, which requires a roof area of approximately 28 m^2 (~7 m^2/kWp). The standard output for an array of this size is 2800 kWh/year, which is subtracted from the electricity requirement and added to the renewables total. Starting point of 380,000 installed PV panels, from 2013 Housing Energy Fact File.

13. Heat pump: the heating system is replaced by a ground-source heat pump, if one is not already present. This assumed the standard SAP Coefficient of Performance of 3.2. The model assumes that only detached houses will have the space required to install a ground-source heat pump.

14. Lighting upgrade: the lighting is upgraded to 100% low energy lighting, where this is not already the case.

15. Insulation package: this package includes all appropriate upgrades from: 2. Wall insulation, 3. Roof insulation, 4. Floor insulation and 9. Draught proofing.

16. Whole house improvement package: this package includes all appropriate upgrades from: 2. Wall insulation, 3. Roof insulation, 4. Floor insulation, 6. Heating upgrade, 7. Improved glazing; 8. Improved doors and 9. Draught proofing.

17. Carbon intensity of electricity: 0.517 $kgCO_2$/kWh for 2015, 0.286 $kgCO_2$/kWh for 2030 (after Pout, C. (2011) Proposed Carbon Emission Factors and Primary Energy Factors for SAP 2012: BRE.), 0.158 for 2050 (extrapolating forward from Pout, recognising the law of diminishing returns).

18. New homes: 20% increase by 2050, and linear interpolation for 2030 homes (8.6%). New build performance of 4,000 kWh/year gas and 1,000 kWh/year electricity, consistent with Passive House planning package and all-electric cooking.

19. Demolition rate: 20,000 dwellings demolished per year. This is in line with the average for 1996-2004 (from B. Boardman et al.'s 40% House), but totals less than 3% demolished between now and 2050.

20. Capacity constraints: 65,000 packages of upgrades assumed per year, consistent with BRE (2008) MAC Curves for the Domestic and Non-Domestic Building Sectors – Technical Documentation, prepared for the Committee on Climate Change: BRE. This is an oversimplification, because in reality there are different constraints for different upgrades. However, there are no reliable estimates of capacity constraints for all the upgrades included now – and future changes to capacity constraints are even more uncertain. Although we anticipate that parts of the construction industry installing upgrades will grow to 2050, this will be offset by increasing difficulty in upgrading harder-to-treat properties. We are also starting from a much lower base: fewer than 1,000 major retrofits a year.

21. Prioritising: we set up the model to prioritise homes for interventions where there was most potential to save carbon first. This means that the 'renewables' package preferentially selects homes suitable for installing a heat pump or biomass boiler.

Acknowledgements

CPRE would like to extend our sincere thanks to the Esmée Fairbairn Foundation for its support for this research and report, and our other energy work.

We would like to thank the householders and the people involved in running community buildings who took part in the research on which this report is based. We also wish to thank the local CPRE branches that supplied useful information, including to help with the case studies.

CPRE fights for a better future for England's unique, essential and precious countryside. From giving parish councils expert advice on planning issues to influencing national and European policies, we work to protect and enhance the countryside.

We believe a beautiful, thriving countryside is important for everyone, no matter where they live. We don't own land or represent any special interests. Our members are united in their love for England's landscapes and rural communities, and stand up for the countryside, so it can continue to sustain, enchant and inspire future generations.

Our objectives

We campaign for a sustainable future for the English countryside, a vital but undervalued environmental, economic and social asset to the nation. We highlight threats and promote positive solutions. Our in-depth research supports active campaigning, and we seek to influence public opinion and decision-makers at every level.

Our values

- We believe that a beautiful, tranquil, diverse and productive countryside is fundamental to people's quality of life, wherever they live
- We believe the countryside should be valued for its own sake
- We believe the planning system should protect and enhance the countryside in the public interest

Campaign to Protect Rural England
Standing up for your countryside

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