Hope Valley
Climate Action

Technical Study on Energy and Renewables in Hope Valley

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Hope Valley Climate Action Energy Group

"Focusing on the promotion of energy efficiency, sustainable building and green energy generation, essential elements in the drive to achieve the UK's goal of net-zero carbon emissions by 2050."

About the authors

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Dawn has a background in the design and implementation of renewable energy at an industrial, community and individual household level. She has also worked on reducing carbon through efficiency and the implementation of behavioural change. She has a BSc in Mechanical Engineering, an MSc in Renewable Energy Systems Technology and a Doctorate in Renewable Energy Marine Structures

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Contents

Executive summary

1. Introduction

This report was undertaken by the Hope Valley Climate Action Energy Group, to understand why and by how much our domestic electricity demand is likely to change in the years leading to 2050, and how local renewable energy might contribute towards this demand.

2. Study area today

Our study area is defined by S33 and S32 postcodes as well as the northern properties within the SK17 postcode. This extends from Ladybower in the North to Tideswell in the South and from Edale in the West to Ringinglow in the East.

The current annual domestic base electricity demand for this study area is around 23,000 MWh. The total current annual domestic total energy demand is around 154,000 MWh, which releases over 32,000 tonnes of CO_2 emissions, with heating responsible for 55% of the total.

3. Future energy scenarios

Three future energy scenarios have been used to predict domestic electricity demand: a best-case scenario based on the National Grid's Consumer Transformation scenario called scenario A; a likely mid-way scenario, called scenario B and a little change scenario based on the National Grid's Steady Progress scenario, called scenario 'C'.

4. Energy and electricity predictions

Annual values are predicted for 2030, 2040 and 2050. However, it should be noted that there is an unavoidable and unpredictable level of uncertainty within all the results presented.

Results given for ‘total energy’, is the domestic energy required to heat, electrify, and run private vehicles, with the different energy fuel sources all converted to MWh. We predict that by 2050 the annual demand under scenario A would be around 65,000 MWh, increasing to nearly 90,000 MWh under scenario B and over 130,000 MWh under scenario C.

Results for the ‘total electricity’, refers to just the domestic electricity needs of the study area. Under all three scenarios we predict an increase in the base electricity demand in Hope Valley of more than double the current requirement, rising from 23,000 MWh to between 50,000 – 60,000 MWh by 2050.

5. Main findings from energy demand predictions

Our main finding is that the electricity requirements within Hope Valley will rise, at least doubling, by 2050. Under all future energy scenarios, we will see an increase in electricity demand within the Hope Valley as we electrify our vehicles and home heating sources.

By 2050 the increased demand could be met from a combination of renewable energy installations, stored energy such as large or domestic scale battery banks, hydro storage systems and electric cars along with flexible generation such as biogas. This would require smart technological advances to control it.

6. Community energy

Community energy has a strong part to play, both at a local and national level, in the push towards a net zero carbon emission future, by reducing emissions utilising local low carbon, grid connected, electricity generation.

Hope Valley and the Peak District National Park are classed as sensitive landscapes, but with the increased electricity demands that will arise as we electrify our homes, larger scale local renewable generation proposals should be assessed on an individual basis so that some sustainable energy sources could be seen as appropriate in certain areas.

7. Grid connections

For community energy generation projects, the connection of any proposed renewable generation technology onto the grid will usually be a major factor influencing their technical and financial viability. The strength of the distribution network is weak leaving less flexibility and more issues for connecting local generation within the Hope Valley. This is partially due to the fact that the electricity supply is from the ends of two different networks, Northern Powergrid at Hope substation and Western Power at Eyam substation.

8. Renewable generation options

Three main families were chosen for further investigation - solar, wind and hydro - as these were deemed to be the most appropriate renewable generation options within the study area, when the main consideration is technical.

9. Large scale solar photovoltaics

To achieve maximum efficiency from a specific solar array, the orientation and angle of the solar panels can be adjusted throughout the day and/or seasons to match the sun's movement and relative height in the sky. A 5 MW single access array would require around 20 acres and could provide over 6000 MWh annually. However, the maximum generation occurs in the summer, whereas more electricity is required during the winter months. Within Hope Valley there could be potential for both land based and floating solar arrays.

10. Solar PV on roofs

Solar PV on the roofs of buildings, whether domestic, public or industrial has a real benefit, as electricity can be generated without the need to convert land from other uses.

An average domestic 4 kW system could provide around 3400 kWh annually in the UK, which is equivalent to the current electricity demand of the average 3-bed domestic household. If 1 out of every 3 houses were to incorporate a 4 kW solar array on their roof, over 7,000 MWh of electricity could be generated within the community. This could provide the annual electricity needs of around 1000 homes in 2050.

11. Wind turbines

The annual generation from wind turbines can vary quite drastically due to weather conditions and wind speeds. Nevertheless, the average capacity factor for England is 30.5%, which will increase as more modern machines displace older installations coming to the end of their lifetime.

A 4.5 MW turbine could produce 10,000 MWh annually, with more generation being likely, during times of maximum demand, in the winter months.

12. Micro-hydro

Although the generation of an individual micro-hydro site may be low, they have a much higher efficiency of up to 90% and like most forms of waterpower including tidal and wave, they are quite predictable.

Calver Mill on the River Derwent has been identified as having a potential continuous capacity of 125 kW, which could generate around 500 MWh annually. The site is also close to the residential areas of Calver and Curbar and is less than a 100 m to a grid connection point.

13. Renewable technology comparisons

Costs and hence the lifetime £/MWh of electricity generated are very dependent on the individual site, grid connection and scale of a specific renewable power plant. However, large-scale solar and onshore wind have now been identified as the cheapest forms of electricity, across both renewable and non-renewable technologies, within the UK

14. Storage and smart control

Some storage at household level, in the form of batteries incorporated into solar installations or electric vehicles, could be either switched off from charging when demand is high, or the flow could be reversed so that they are putting electricity back onto the grid to help DNOs balance the fluctuating demand. Such control methods should enable overall peaks in demand to be lowered, reducing the need for some of the extra generation capacity.

15. Battery storage

At domestic level, an AC battery storage system utilises an additional battery charger to connect to the AC side of the solar inverter, making it possible to charge a battery from the grid as well as from the solar PV system. This could then be discharged directly into the home as electricity is required or back onto the grid to level out peaks in demand.

Community level storage would operate in the same way as a home system, with an automatic energy management system that can be controlled by the relevant DNO. These storage systems will also be able to either be connected to a renewable generation power plant or be stand-alone systems housed close to consumers.

16. Pumped storage hydro systems

Within the Hope Valley, disused quarries could be used to provide stored energy for electricity generation utilizing high density fluid hydro systems such as that proposed by RheEnergise. This system requires much smaller head heights from around 75 m.

17. Discussion

Under all future energy scenarios presented, we see an increase in the predicted domestic electricity requirements within the Hope Valley, at least double the current demand.

Hope Valley's total domestic, industrial and non-domestic vehicle demand could be as high as 350 GWh annually, by 2050.

The extra electricity demand both nationally and locally will require grid infrastructure reinforcing, as well as implementing more sophisticated flexible smart energy management systems along with mass battery storage plants.

For Hope Valley, the grid capacity is reduced by the nature of the networks, as it is on the periphery of both Northern Powergrid's and Western Power's distribution networks.

As home heating moves towards electricity as the main energy source, the thermal properties of homes will need to significantly improve, both to provide sufficient warmth and to prevent further fuel poverty and the knock-on effects that this has on people's quality of life and wellbeing.

Hope Valley could provide for its own domestic electricity demand in 2050 if 1 in every 3 homes incorporated a 4 kW solar PV array plus two 5 MW solar arrays along with three 4.5 MW wind turbines were installed locally.

Is there a place for larger scale renewable local generation within Hope Valley? If so, what type of renewable installations are most appropriate and where should they be sited, recognising the importance of landscape sensitivity in the national park?

18. Conclusions

Under all future energy scenarios, we will see an increase in the base electricity requirements within the Hope Valley, at least double the current requirement, as both vehicles and heating sources move towards electricity, generated from lower carbon emission renewable sources.

If we continue, as we currently are, with small steps as outlined within scenario C, then the emissions from our domestic energy requirements can be expected to be practically the same by 2050 as they are today. However, through electrification provided by renewable generation, domestic energy emissions could reduce by at least 55% by 2050.

Some of the necessary measures required to achieve this rely upon individual homeowner behavioural changes, which would also require adequate and easily accessible financial aid at governmental level.

To ensure that the increased electrification comes from renewable sources, local authorities and stakeholders need to work with the community, and local climate groups, to look towards how they can support renewable generation in their areas as outlined within the Government's recent paper 'Net Zero Strategy: Building Back Greener.

1. Introduction

Climate change, mainly occurring due to increased emissions from human activity, has driven a rise in global warming of over 1 °C in the last 50 years (Figure 1.1) [1]. This temperature rise has in turn impacted our weather patterns leading to increases flooding, fires, desertification and food shortage.

Scientists have predicted that if the global average temperature rises above 1.5 degrees Celsius (compared to the pre-industrial level), then we will have reached a tipping point that will result in rising sea levels, floods, heatwaves, wildfires and droughts that will make many places uninhabitable and threaten the food supplies of all of us.

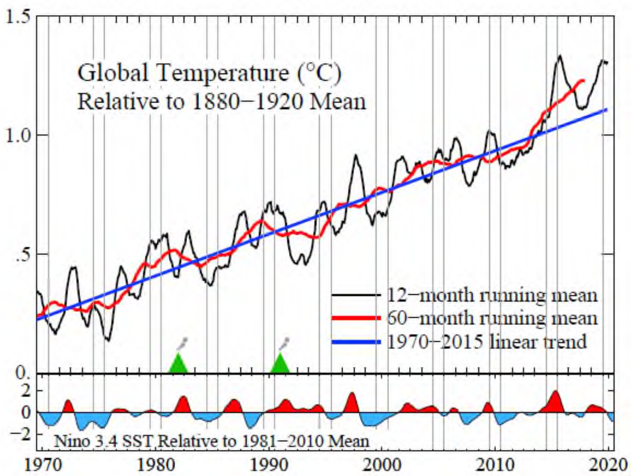


Figure 1.1 Global temperatures up to November 2020 [1]

Therefore, it is imperative that decisive measures, such as drastically reducing our use of fossil fuels, are taken immediately, to halt and then decrease the global average annual temperature.

Due to the imminent threat from the climate crisis, the UK has committed to a target of net-zero greenhouse gases by 2050 as well as to reduce economy-wide greenhouse gas emissions by at least 68% by 2030, compared to 1990 levels (Paris Agreement) - and then by 78% by 2035 (Sixth Carbon Budget). Some progress has been made and in 2019 UK greenhouse gas emissions were 40% less than those in 1990. However, even if the Government's recent 'Net Zero Strategy: Build Back Greener' [2], is realised, it is unlikely that we will meet these targets.

Net-zero emissions, also sometimes referred to as ‘carbon (or climate) neutrality’, is a target to reduce the emissions from greenhouse gases that cause global warming to net-zero. Most future energy scenarios achieve this by balancing the amount of CO_2 released with the amount captured and stored, usually referred to as Carbon Capture and Storage (CCAS). However, to achieve this, a large reduction in the amount released must be achieved.

The power of community involvement in helping to achieve all the emissions targets has been recognised in the Government's ‘Net Zero Strategy', with a renewed drive to install more onshore wind and solar generation in the UK.

‘Communities are especially well placed to help raise awareness and engage people in adopting net zero behaviours. For example, community ownership of renewables ….. can be an important driver of reducing local emissions.’

It also recognised that local climate action groups (such as Hope Valley Climate Action) can help people to understand climate change and help them to adopt sustainable behaviour changes:

‘most people want to play their part in achieving net zero, the strategy emphasises nudging/empowering people towards making low carbon choices by ensuring they are easier, affordable and well understood.’

This report, undertaken by the Hope Valley Climate Action Energy Group, aims to inform the community living with the Hope Valley and the surrounding area and the relevant stakeholders firstly about our domestic energy and base electricity needs up to 2050, then how Community Energy could play a part in providing some of this energy. It also provides information on grid connections and the likely issues that connecting renewable generation locally could face. The final and main body of this report gives information on different renewable energy technologies that could play a valuable role in the fight against climate change and identifies a few possible sites within the Hope Valley area.

It is, however, recognized that it will not be possible for Hope Valley to become fully self-sufficient in electricity. However, there is a real need for local renewable generation everywhere and the question is how much of our electricity demand can we offset locally, thereby helping to reduce the CO_2 emissions from electricity nationally, and how much we will realistically continue to need to import.

1.1 Hope Valley Climate Action

Hope Valley Climate Action was set up two years ago to take action on climate change, by raising awareness, taking practical action, research and advocacy. We are a Charitable Incorporated Organisation with six hundred supporters. We have three main action groups: travel, energy and land. A key part of what we do is to carry out practical projects to demonstrate what realistic solutions to the climate crisis could look like. This allows us to advocate for change at a national level.

Alongside home energy efficiency, renewable energy is one of our main themes of HVCA's Energy Group, the authors of this report. Its areas of interest are energy efficiency, sustainable building, and green energy generation, all elements essential in the drive to achieve the UK's goal of net-zero carbon emissions by 2050.

"Together let's take action on climate change"

1.2 What we believe

We believe the science and what committees such as the IPCC and the UK's CCC say in their reports because they draw on wide-ranging, empirical research from a variety of sources world-wide.

We accept the reality of global warming and fear the threats it poses to our planet.

We believe that we need to reach net-zero CO_2 emissions much sooner than the UK government's goal of 2050 and hope that the events and activities we organise will contribute in some small way to achieving this.

We are focusing on the promotion of energy efficiency, sustainable building and green energy generation, all three of which we view as essential elements in the drive to achieve the UK's goal of net-zero carbon emissions by 2050.

2. Study area

2.1 Hope Valley

Hope Valley, the area covered by this report, is all within the Peak District National Park. The area is known for its stunning vistas and is much loved by residents and the many visitors.

Figure 2.1 Hope Valley in winter looking west from Surprise View [3]

It is often associated with the open and exposed moorland, seen by many as ancient and untouched. However, much of the landscape and habitat is a product of human activity.

2.2 Household numbers

Our study area extends from Ladybower in the North to Tideswell in the South and from Edale in the West to Ringinglow in the East. This consists of the areas defined by the S33 and S32 postcodes as well as the northern properties within the SK17 postcode, including Tideswell. It consists of around 6300 domestic buildings and a permanent population of around 13000. A proportion of the domestic buildings identified are used solely for visitors throughout the year.

Figure 2.2 Hope Valley highlighting the approximate area covered within this study [4]

2.3 Energy vs. Electricity

Within this report, ‘total (domestic) energy’, is defined as the energy required by households to run domestic vehicles and to heat and electrify homes in the study area. The sources of this energy may be primary sources such as natural gas, oil and petroleum as well as electricity which is generated from both primary sources and renewables and nuclear.

The term ‘base electricity’ refers to the consumption over a period of time, such as a day or a year. This electricity is however not used at a constant rate and therefore there are times during a day and season when the demand will be very high, usually referred to as the ‘peak’ demand.

The term ‘total (domestic) electricity’ refers to the electricity needs of a household and will include space heating and vehicles.

As we approach 2050, the difference between ‘total domestic energy’ and ‘total domestic electricity’ will reduce as homes become more electrified and less electricity is generated from fossil fuels as more renewable energy is connected to the grid.

Energy consumption is given in megawatt hours (MWh). A megawatt hour is used to measure electric output and is equivalent to 1,000 kilowatts (kW) of electricity consumed per hour.

Currently, the average UK household uses around 10 kWh of electricity per day. Therefore 1 MWh would run 100 houses for one day, and one house uses around 3.6 MWh per year.

2.4 Current domestic energy use and emissions

To estimate the total annual domestic energy demand, energy consumption was considered under three headings: electricity consumption (used for lighting, laundry, refrigeration, cooking, other electrical goods and current electric heating), space heating (gas, solid fuel, oil, low pressure gas (LPG)), and private vehicles (electric and fossil fuel).

Our current annual base electricity demand is around 23,000 MWh. This was derived from data provided by the future energy scenarios (FES) from the two local distribution network operators (DNOs), Northern Powergrid and Western Power [5] [6]. It includes the electricity used by households heating their homes with electric storage heaters (which account for approximately 6% of homes [7]).

Mains gas as a heating source is estimated to be used by 80% of homes within Hope Valley, a lower percentage than the national average (85%) accounted for by its rural location. Oil and LPG off grid heating is estimated to be used in approximately 12% of homes, electric storage heaters by 6% and with the remaining 2% using other sources such as biomass or air source heat pumps (ASHP) [7] [8].

It is estimated that there are around 7100 private vehicles [9] within Hope Valley with an average annual milage of 8000 miles, 17% above the UK average, again due to the rural setting [10][11]. Of these, the majority are powered by fossil fuels with electric vehicles accounting for just 3%.

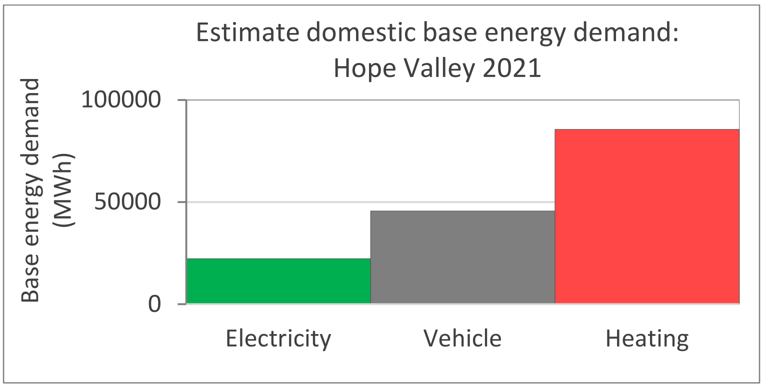
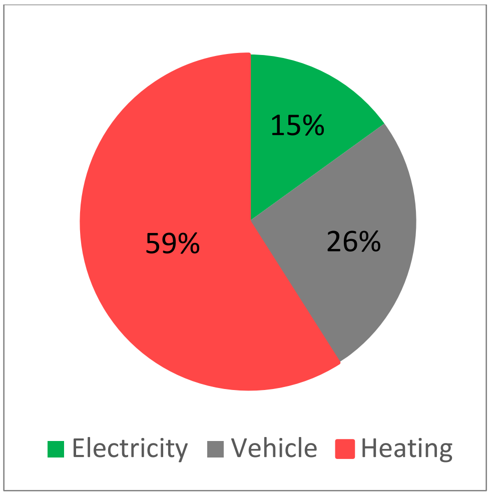


Figure 2.3 Estimate domestic energy demand of the study area in 2021

The total current domestic annual energy demand within the study area is 154,000 MWh which releases over 32,000 tonnes of CO_2 each year, with heating (excluding current electric storage heaters) responsible for 55% of the total [12]



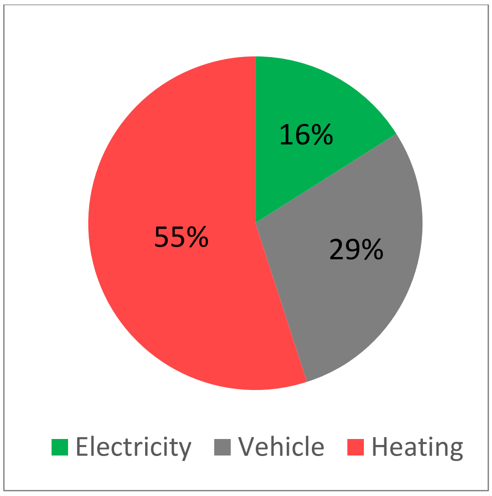


Figure 2.4. Current domestic energy demand (left) and current CO_2 emissions (right) by source in 2021

3. Future energy scenarios

Three FES have been used within this study to predict domestic and non-domestic electricity demand up to 2050: a best-case scenario based on the National Grid's (NG) and local DNOs 'Consumer Transformation' scenario, hereafter called scenario 'A' (Appendix B1) [13][14][15]; a likely mid-way scenario, hereafter called scenario 'B' (Appendix B2] and a little change scenario based on the National Grid's and local DNOs 'Steady Progress' scenario (Appendix B3), hereafter called scenario 'C' [13][14][15].

Scenario B is mainly based upon scenario A, but with some local adjustments taking account of the rural area and the additional complexities due to the style of older detached, more rural houses, which will be more difficult to make energy efficient and hence harder to heat with an ASHP alone. A Scottish study identified that for urban dwellings, just one out of every 100 homes is poorly insulated compared to 13 out of every 100 in more rural locations [16]. To account for the rural setting of some homes within Hope Valley, the following amendments have therefore been applied to this more localised scenario:

- Current gas boiler usage applicable to 80% of homes, rather than 85% in 2021
- LPG and Oil as heating sources increased to 12% from 8% in 2021
- Electric storage heaters used in 6% of homes in 2021
- Other heat sources, such as biomass, used by 2% in 2021
- Gas boilers still account for 30% of heating by 2050

Scenario C has the following adjustments:

- 25% of cars are still run-on fossil fuel by 2050

This adjustment to scenario C, when compared to the NG 'Steady Progress' scenario, has been made under the assumption that electric car adoption could be slower than predicted, if the ban on sales of new non-zero emission cars is delayed past 2035 and/or if the Government does not ban the use fossil fuel cars after that time [8].

Under each scenario we have predicted the energy use and emissions for: private vehicles (dependent upon the quantity within the study area, annual mileage, and fuel source); household heating (dependent upon the fuel source and standard of home insulation), and electricity demand (for lighting, home entertainment, refrigeration, laundry, and cooking). Under all scenarios, vehicle mileage has been increased from the national average by 17%, due to the rural nature of the study area [10] [11].

The main driving assumptions in terms of the percentage of vehicle type and heat pump and gas boilers for each scenario, up to 2050, are presented in Table 3.1.

Table 3.1 Main driving assumptions used for each scenario up to 2050.

Year	2020	2030			2040			2050		
Scenario		**A**	**B**	**C**	A	**B**	**C**	A	**B**	**C**
Electric cars (%)	**3**	**38**	**38**	**10**	**80**	**80**	**51**	**97**	**97**	**75**
Fossil fuel cars (%)	**97**	**62**	**62**	**90**	**20**	**20**	**49**	**3**	**3**	**25**
Heat Pumps (%)	**0.1**	**23**	**13**	**3**	**61**	**37**	**12**	**95**	**63**	**21**
Gas Boilers (%)	**85***	**66**	**70**	**83**	**32**	**49**	**77**	**2**	**30**	**69**

* For scenario B, the assumption is that currently 80% of homes are heated by gas boilers

4. Energy and electricity predictions

Results given for the 'total (domestic) energy', is for the energy required to heat and electrify homes, and run domestic vehicles, with the different energy sources all converted to MWh.

Results for the 'total (domestic) electricity', refers only to the electricity needs of a household and can include heating and vehicles.

Annual values are predicted for 2030, 2040 and 2050, considering the different assumptions outlined in Section 3 for each scenario presented. However, there is an unavoidable and unpredictable level of uncertainty within all the results presented.

4.1 Household numbers to 2050

The Office for National Statistics projections for household growth in the High Peak and 2011 census data were used to estimate the change in households through to 2050 as shown in Table 4.1 [17] [18] [19], with a predicted rise of approximately 650 houses within the Hope Valley area by 2050.

Given Hope Valley is within the Peak District National Park, this increase may not happen. However, it is important that we anticipate the potential growth, and hence an increase in 650 households has been used for all scenarios.

Table 4.1 Household projections in the study area up to 2050

Year	2021	2030	2040	2050
Household numbers	6295	6645	6960	6960

4.2 Domestic private vehicles to 2050

An increase in electric vehicle take-up has a direct impact on the base electricity demand. Under scenarios A and B, 97% of privately owned vehicles will be electric, whilst, under scenario C, electric vehicles account for just 75% by 2050.

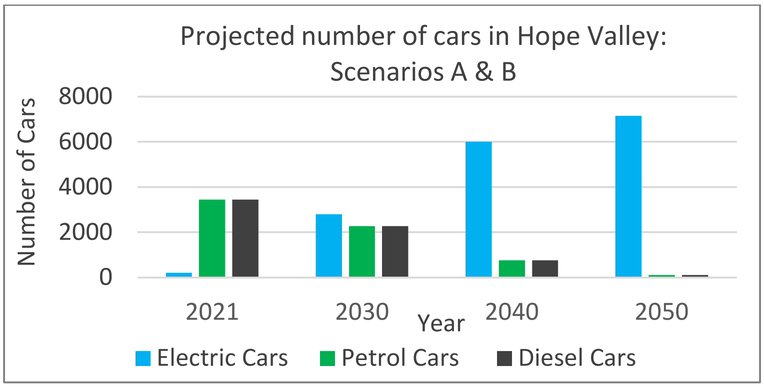


Figure 4.1 Projected annual number of vehicles under scenarios A and B

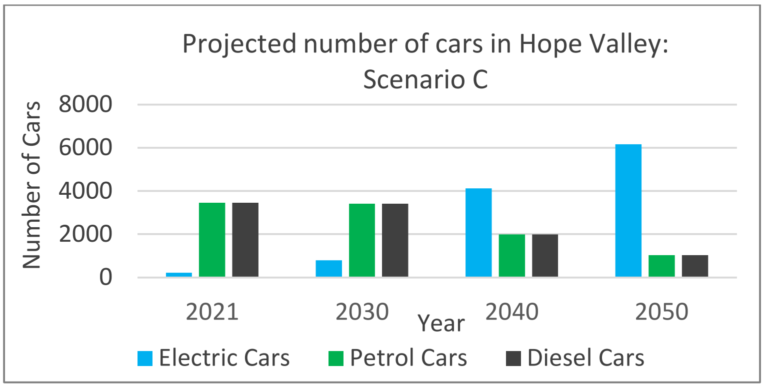


Figure 4.2 Projected annual number of vehicles under scenario C

The average mileage per vehicle has been set at just under 8000 miles annually in 2021, falling by around 5% by 2050 [10]. 2021 costs, emission and energy comparisons between vehicle types, shown in Figure 4.3, highlight the advantages of moving towards electric vehicles in the push towards net-zero greenhouse gases by 2050 [12][20][21]. All vehicle types are based on a similar mid-size family car and fossil fuel mileage per litre has remained the same as 2021 estimates [22][23][24]. Fuel costs and emissions are also based on 2021 values. The cost of fossil fuels is expected to rise at a faster rate than electricity, just as the emissions from electricity will drop further as more renewable sources come on to the grid, thus widening the gaps between fossil fuel powered cars and electric vehicles still further, making electric vehicles even more attractive over time.

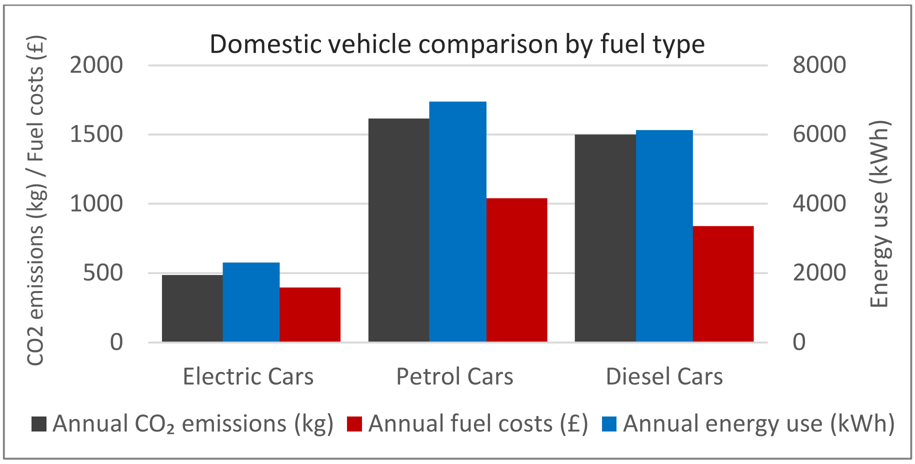


Figure 4.3 Annual individual vehicle emissions, fuel costs and energy use based on 2021 data

The projected annual energy demand for private vehicles under scenarios A and B, (Figure 4.3) derived from the predicted numbers of each type presented in Figure 4.1, is around 17,000 MWh, by 2050 and under scenario C, from the predicted numbers presented in Figure 4.2, demand is estimated to be around 26,000 MWh, by 2050.

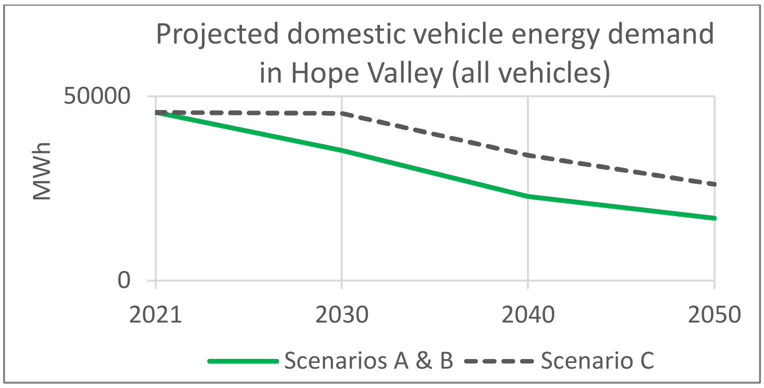


Figure 4.4 Annual domestic vehicle energy demand uto 2050 within the study area

In 2021, CO_2 emissions from private cars within our study area were around 11,000 tonnes. Under scenarios A and B, the annual projected CO_2 emissions from private vehicles is predicted to drop to around 3500 tonnes by 2050, and under scenario C to 6000 tonnes, hence a reduction to a third of the current emissions due to private vehicles could be achieved by us all changing to an electric car.

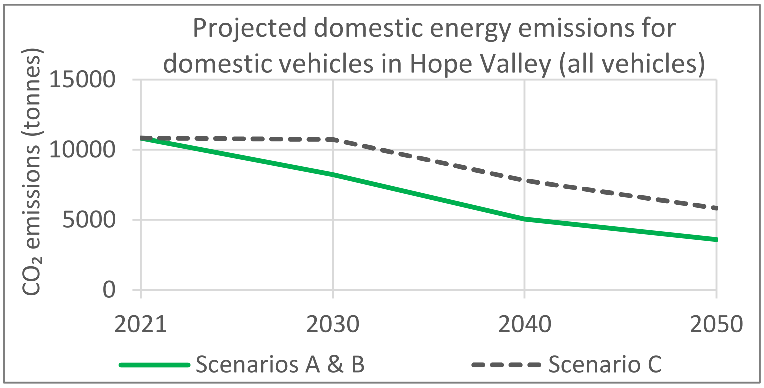


Figure 4.5 Projected CO_2 emissions from the annual domestic vehicle energy consumption within the study area

4.3 Domestic heating to 2050

Under scenario A, over 95% of homes would be heated by heat pumps by 2050 and those homes would also all be well insulated. Under scenario B around 60% of homes would be heated by heat pumps (twice as many as by mains gas) and again these homes would be well insulated. Under scenario C just 20% can be expected to be heated by heat pumps and these homes may also not be insulated to the degree where the heat pumps would be the most efficient, making the energy consumption higher to provide adequate heating.

The coefficient of performance (CoP), used for the heat pumps installed in each of the scenarios differs to reflect those assumptions made on home insulation and hence heat source efficiency and energy use. Scenarios A and B have heat pumps with a CoP of 4 (better efficiency and lower energy required) reflecting the assumption that homes will be very well insulated, hence making a heat pump more efficient. For scenario C heat pumps with a CoP of 2 has been applied, as homes may be more unlikely to have achieved the higher insulation needed for optimum efficiency.

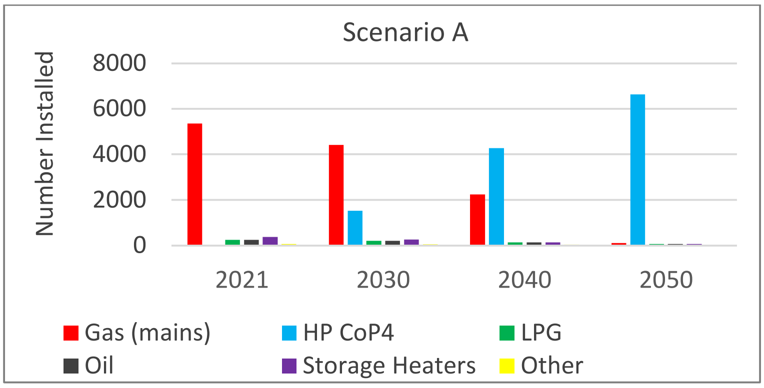


Figure 4.6 Projected source of heating within the study area under scenario A

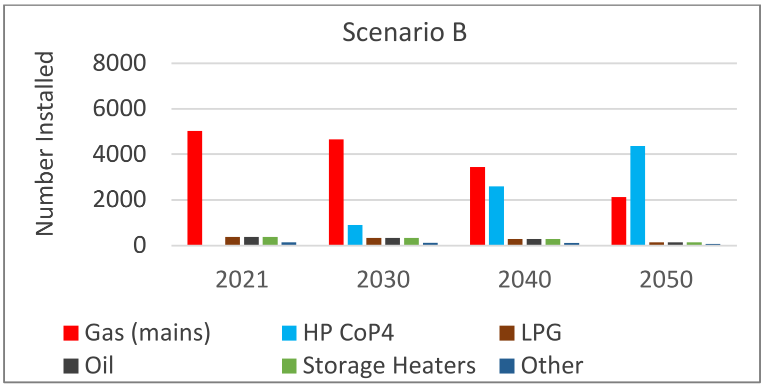


Figure 4.7 Projected source of heating within the study area under scenario B

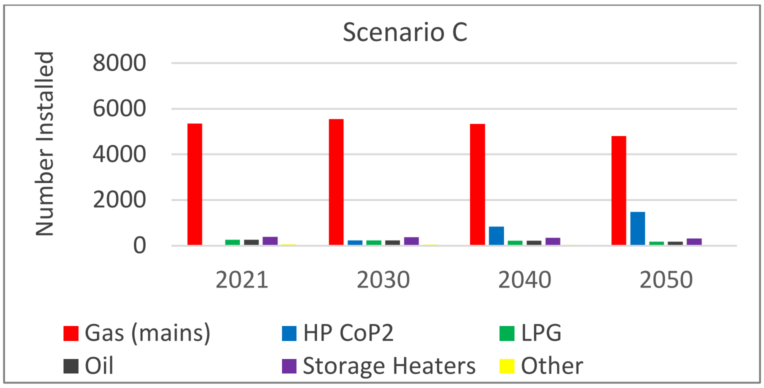


Figure 4.8 Projected source of heating within the study area under scenario C

Costs, emissions and comparisons between heating types highlight the advantages of moving towards heat pumps in terms of both energy and CO_2 emissions. All data is based on a mid-size 3-bed home. However, it is only in a very well insulated home that the annual running costs of heat pump are comparable to the cost of mains gas central heating. Fuel costs and emissions [12] are based on current (2021) values and the cost of fossil fuels and gas might realistically rise at a faster rate than electricity.

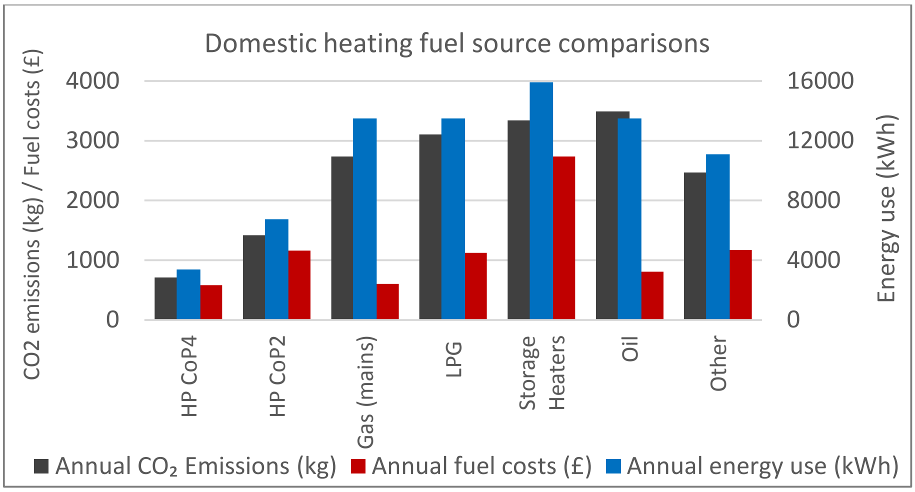


Figure 4.9 Annual heating emissions, costs and energy use based on 2021 data

Under scenario A the total annual domestic heating energy demand is predicted to be around 25,000 MWh by 2050. For scenario B the assumption that 30% of homes may still be heated by gas boilers (see Table 3.1) results in a doubling of the annual heating energy demand to around 50,000 MWh by 2050. Under scenario C, where around 70% of homes could still be utilizing gas boilers, the annual demand could be 85,000 MWh per annum by 2050.

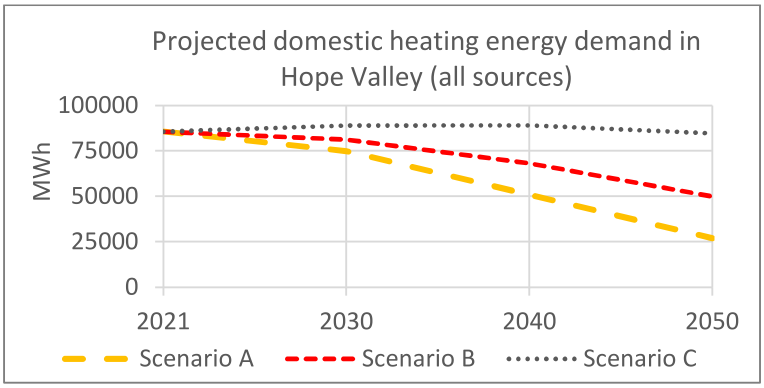


Figure 4.9. Annual domestic heating energy demand within the study area

Current heating emissions within our study area are around 18,000 tonnes. Under scenario A, the mass take-up of heat pumps with good home insulation could see heating emissions fall to 6000 tonnes of CO_2 eq by 2050 and for scenario B this would be reduced to around 10,000 tonnes. However, there is little change in emissions by 2050 under scenario C, because, although around a fifth of homes may be heated by air source heat pumps by 2050, without the required level of home installation, demand is double that of a heat pump installed in a well-insulated home.

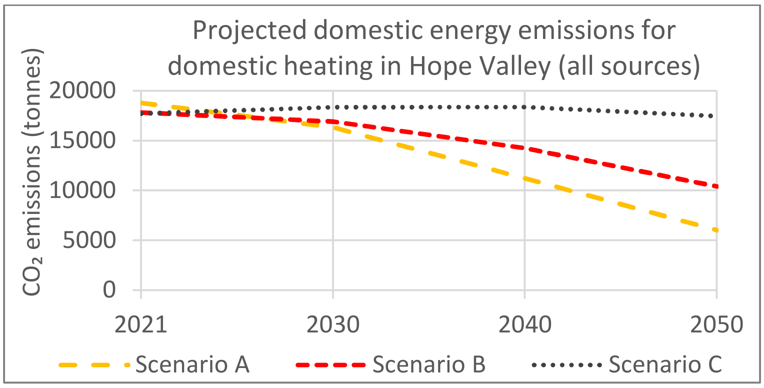


Figure 4.10 Projected CO_2 emissions from the annual domestic heating energy consumption within the study area

4.4 Total domestic demand to 2050

From the projections presented in Sections 4.2 and 4.3, the total annual domestic energy demand predictions for each scenario rise as the reliance on fossil fuel is increased. Hence, for scenario A the annual demand by 2050 is around 65,000 MWh, increasing to nearly 90,000 MWh under scenario B and over 130,000 MWh under scenario C, over double that required if nearly all vehicles and heating is electric and homes have high efficiency, as assumed in scenario A.

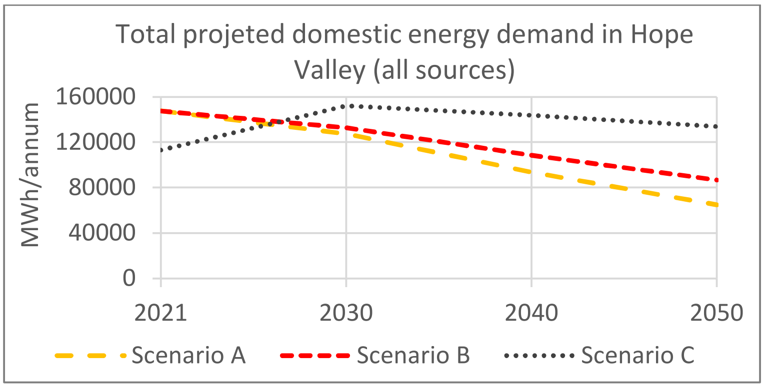


Figure 4.11 Total predicted annual domestic energy demand within the study area

Under all scenarios we predict an increase in electricity demand as we electrify of our homes to reduce emissions. Our current annual base electricity demand requirement is around 23,000 MWh, which we predict could rise to around 50,000–60,000 MWh, depending upon the uptake rate of both electric cars and air source heat pumps. If the uptake is slower then our electricity demand will still continue to rise past 2050, hence there will still be an increase in demand for domestic electricity generation, approaching three times our current annual usage.

Thus, a doubling or more in our domestic electricity demand by 2050.

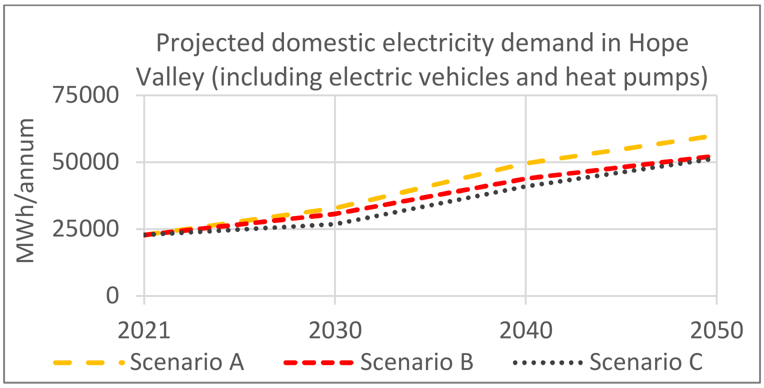


Figure 4.12 Projected domestic electricity demand up to 2050

4.5 Total domestic emissions to 2050

The current total annual CO_2 emissions from the 'total domestic energy' needs, within the study area, is around 30,000 tonnes (Figure 4.13). For any predicted of future emissions, both the original and new emissions from specific energy sources have been used, thus deriving estimated saving gained by switching to electricity. The value used for electricity in Table 4.2, was that provided for 2021, a year when 54% of electricity within the UK came from renewable sources of generation.

Table 4.2 UK greenhouse gas conversion factors 2021 [12]

	kg CO_2/kWh
Electricity UK	0.21016
LPG	0.22999
Natural Gas	0.20258
Oil	0.25849

CO_2 emissions due to our domestic energy requirements in 2050 are less than 50% of current emissions under scenario A, this is achieved just by electrifying our homes with current emission values. In reality the emissions savings will be much more than this as more electricity is produced from renewables and biogas allowing more fossil fuel power stations to close, but alone it will not reach net zero as there will always be some emissions in the manufacturing, maintenance and decommissioning processes, even if the generation plant is renewable. Future energy scenarios rely upon carbon capture and storage to achieve the net zero emission targets they achieve under different scenarios [8]. Emission calculations due to switching from fossil fuel vehicles utilized values provided by the vehicle manufacturers for petrol and diesel at 0.232 and 0.244 kg CO_2/kWh respectively [24].

For scenario B the reduction in emissions based on today's values could be 40% and for scenario C only a small decrease would be achieved.

This means that although our electricity demand is projected to at least double, our overall emissions would continue to fall as more electricity is produced from sources of renewable generation and other low carbon technologies [12].

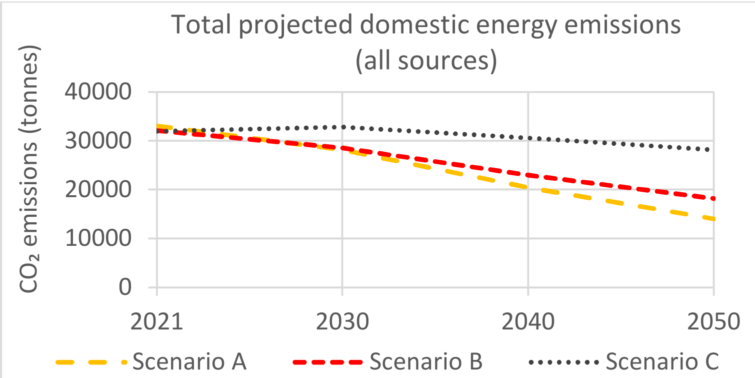


Figure 4.13 Projected CO_2 emissions from the total annual domestic energy consumption within the study area

4.6 Non-domestic electricity demand to 2050

Domestic energy and its electricity component are only a part of the picture within our study area. However, the task of defining the total energy use, including all non-domestic, is beyond the scope of this study, as all data on chemical, gas and liquid fuel used by industry and public buildings is not available. However, the UK Government's statistical analysis suggests that non-domestic electricity and non-domestic gas consumption are almost equal, with a slightly higher use of gas, when considering all non-domestic use including non-building-based sites, such as quarries [25]. The non-domestic electricity base demand within our study area, provided by the same supply network from local substations as the domestic demand is presented in Table 4.2, along with the electric bus and HGVs, domestic and total electricity demand [14] [15].

Scenarios A and B have been derived from data supplied by the two network distributors, Northern PowerGrid who distribute electricity through the Hope substation and Western Power through the Eyam substation. The non-domestic electricity demand was seen to drop in both the networks' predictions to between 71% and 90% of the current non-domestic use, depending upon the scenario, although no reasons for these decreases were provided. However, under both these scenarios, there would still be a heavy industrial reliance on gas which could be provided from a combination of both biogas and hydrogen. However, as some business processes require carbon capture and storage, within their predicted pathway to meet net zero, a doubling or more of their electricity needs could be likely as the carbon capture methods rely heavily on electricity.

Table 4.3 Electricity demand predictions from the 33/11 kV supply network in MWh

	Scenario	Industrial demand	Electric Bus and HGVs	Domestic demand	Total local demand (exc bulk supply)
2020		47528	9	22833	70371
2030	**A**	**42212**	**1176**	**32819**	**76207**
	B	**63864**	**1176**	**30680**	**95720**
	C	**45060**	**159**	**26931**	**72150**
2040	**A**	**38311**	**8631**	**49551**	**96493**
	B	**91308**	**8631**	**43865**	**143804**
	C	**40887**	**1974**	**40977**	**83839**
2050	**A**	**35679**	**14466**	**60084**	**110229**
	B	**109176**	**14466**	**52449**	**176091**
	C	**38001**	**4602**	**51500**	**94103**

Scenario B therefore recognises that for non-domestic electricity demand our electricity needs would still be likely to rise by at least double and has therefore applied the same increase to non-domestic demand, as was predicted for domestic electricity demand. This applied increase is an educated estimated but may be either too low or too high, but it is felt by the author that it is likely to be more accurate that the decreases in electricity predicted by the DNOs, if non-domestic energy use is also to move towards more electrification and carbon capture is utilized, as is specified in the future energy scenarios used nationally to predict how Net Zero will be achieved. Under scenario B, we therefore predict an increase in the annual electricity demand for non-domestic use from nearly 48,000 MWh currently [14] [15], rising to 110,000 MWh by 2050. This would mean that two thirds of our total electricity demand would be for non-domestic use, excluding the high voltage bulk supply providing electricity to Hope Cement. The electric bus and HGV data and projected changes up to 2050 has been provided by the two relevant DNOs for our area, Western Power and Northern Powergrid.

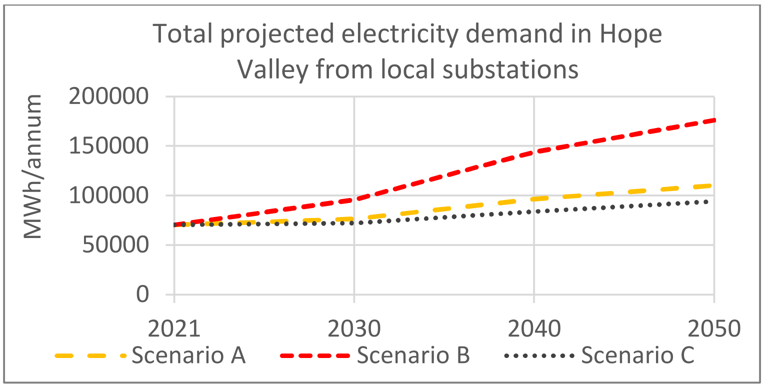


Figure 4.14 Annual industrial and total electricity demand from local substations

As anyone familiar with the Hope Valley will be aware, there is also a large cement works within the study area, that supplies cement throughout the UK. The electricity demand of the site is supplied by the bulk network at 66 kV and is just a portion of the total energy demand of the site. If this electricity, at current levels of demand, were also accounted for, we would need double the total electricity predicted by the HV scenario, hence over 350 GWh, by 2050. With carbon capture and storage also accounted for at the plant, this could exceed 500 GWh each year.

5. Main findings from energy demand predictions

Our main finding is that the domestic electricity requirements within Hope Valley will rise and are likely to at least double by 2050.

Under all future energy scenarios, we will see an increase in the electricity requirements within the Hope Valley as both vehicles and heating sources move towards electricity as their energy source. However, this switch towards more electrification reduces CO_2 emissions by around 55% based on the current fuel mix. Emissions will also reduce much further as the electricity network incorporates more renewable energy and low carbon sources of generation, allowing the decommissioning of power plants using fossil fuels.

By moving towards electric cars, a drop in the 'total domestic energy' required for vehicles of over 70% is predicted under the scenarios A and B.

Scenario A predicts that the proportion of homes heated by gas will reduce from 85% in 2021 to 1.5% by 2050. Homes will need to have been insulated to a high level for a heat pump to operate with the higher CoP of 4 seen in both scenarios A and B. The current lack of current government support for widespread programmes of home insulation, in both rural and urban settings, has led us to be more conservative in the scenario B predictions in terms of the anticipated take up of electric heating and the rate of gas boiler replacements. Hence 30% of homes are predicted to still be heated by gas in 2050, under scenario B.

Consumers will play a large part in moving towards a net-zero carbon emission future as reducing emissions requires behavioural change, including putting in the measures to increase home energy efficiency and therefore reduce their energy demands. This is highly dependent on financial incentives, advice, availability of materials and a trained workforce [26]. A push towards air source heat pumps for domestic heating, without the financial help to ensure homes are insulated to a high standard, could lead to increased fuel poverty.

It is also imperative that non-domestic energy users address the efficiency of their industrial processes and hence their increased electricity demand as they move towards more electrification for their heating, vehicle and process uses, otherwise our total base electricity demand could exceed 350 GWh annually, by 2050, nearly 6 times higher than our predicted domestic demand by 2050. Carbon capture and storage will also have a high demand on electricity consumption. Within the National Grid's future energy scenarios, Net Zero of the electricity network cannot be achieved without carbon capture and storage. This is also the case for large industrial practises, such as cement and steel manufacturers.

The electricity generation capacity needed is higher than the average base electricity demand, as we need to have the capacity to meet times of peak demand. In the future times of increased demand could be met from a combination of renewable energy installations, stored energy such as large or domestic scale battery banks and electric cars and flexible generation such as biogas. This would require smart technological advances to control it.

Currently, nearly all the electrical energy consumed in the study area is generated outside of the valley and supplied by the high voltage infrastructure. Parts of this infrastructure will need to be increased and strengthened to cope with the elevated electricity demands expected in the near future.

6. Community energy

Community energy usually refers to local collective action that can be directly involved in delivering renewable energy generation locally or sharing information or assistance on energy related matters such as efficiency through local engagement. Community energy has a strong part to play, both at a local and national level, in the push towards a net zero carbon emission future, by reducing emissions utilising local low carbon, grid connected, electricity generation. However, as well as the direct environmental benefits from carbon reduction gained from the collective action of identifying, purchasing, and generating electricity locally, there are also many other advantages that can be obtained, depending upon the project, such as:

- Building strong resilient communities and support networks
- Increasing awareness of relevant issues such as efficiency
- Encouraging necessary behaviour changes
- Producing income that can help to fund local projects
- Reducing energy bills for low-income families
- Helping to mitigate Fuel Poverty locally
- Creating local jobs
- Improving wildlife and natural habitat within and around sites
- Reducing transmission losses
- Providing energy for peak demand utilising energy storage
- Engaging local investors
- Increasing opportunities for education and tourism
- Increasing transmission network flexibility and stability
- Decreasing risks of blackouts as more energy is decentralised

In 2021 the UK Government published its ‘Net Zero Strategy', which recognised many of the additional benefits Community Energy can bring. It also highlighted its support for more onshore wind and utility scale solar power plants to be added onto the transmission network (at local level, close to demand). However, for this to be possible, barriers such as lack of financial support at Government level and local planning constraints, including those engineered by government policy, may need re-examining in the light of climate breakdown and the Net Zero goal.

Hope Valley and the Peak District National Park are classed as sensitive landscapes, but it may be time for larger scale local renewable generation proposals to be assessed on an individual basis so that some sustainable energy sources could be seen as appropriate in certain areas, rather than a blanket planning policy of no larger scale renewables within the Peak Park, as is the current policy.

Figure 6.1. Community energy in the landscape [27]

6.1 Current state of community energy in the UK

Within the UK there are many local groups looking into various aspects of Community Energy and in 2021, 319 MW of community-led renewable energy generation was identified as being connected to the transmission network. As well as generation connections, many community groups have also worked to raise awareness of climate issues, offer advice and support on making homes more energy efficient and warmer, whilst also reducing energy bills and mitigating fuel poverty. Figure 6.2 identifies other benefits also achieved by local rural community energy groups, “these groups have shown that they can increase community wealth and create thriving places while addressing the climate crisis” [28].

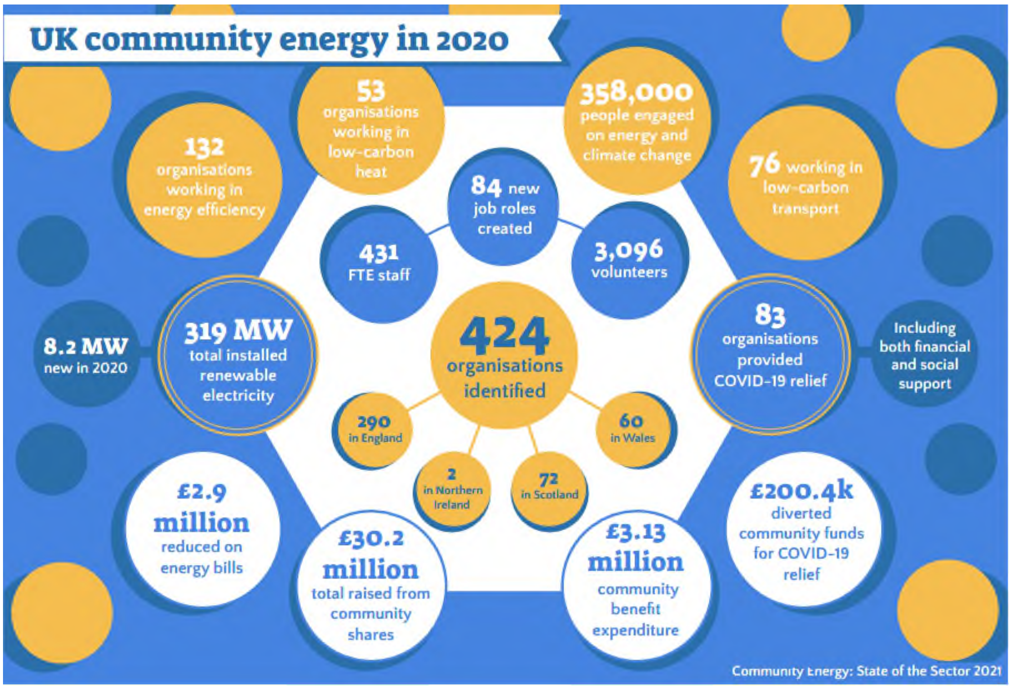


Figure 6.2 Community Energy: State of the sector 202 [28]

7. Grid connections

For community energy generation projects, the connection of any proposed renewable generation technology onto the grid will usually be a major factor influencing their technical and financial viability. As the grid constraints for each site, capacity and generation technology are specific, it is usually necessary to initially identify and define a site's potential generation before the viability of the grid connection can be assessed. However, grid connection should always be at the forefront of any research into local generation, to prevent time and effort being directed toward sites that are not feasible.

7.1 Electricity Networks

Within the UK, electricity is delivered to our homes and businesses via a grid network of cables from points of generation to points of demand. This is further broken down into two distinct networks, the transmission network, and the distribution network.

Transmission Network

This network is used to transport electricity at high voltages, 275 kV and 400 kV, and for long distances, out from the points of large generation plants. The high voltage transmission keeps grid electricity losses to a minimum. Within England and Wales, the transmission network is owned and operated by the National Grid.

Distribution Network

The distribution networks take electricity off the transmission network and distribute it to consumers. They operate at much lower voltages of 132 kV and below. These lower voltage lines will incur increased losses as the voltage decreases. These are owned and operated by several different DNOs, each covering a specific geographical area. Within the study area around Hope Valley, the more westerly and northerly area is covered by Northern Powergrid and the more easterly and southerly area by Western Power.

Community energy generation schemes are generally connected to the distribution network. Generation connected at this level of the grid is often classified as 'Embedded Generation'. Embedded generation can alter the flow of electricity and make it more unpredictable as it no longer only travels in one direction (from generation to demand) but also flows to and from customers with embedded generation such as solar PV on the roofs of buildings. Being at the end of a distribution network often means that the grid will be less reinforced leaving less flexibility and more issues for connecting local generation.

7.2 Losses on the grid - between generation and demand

Conventional power plants are commonly large and at some distance from many of the consumers, as are offshore wind farms, hence the grid transmission losses will be greater than for more local sources of electricity generation, such as community renewable technology initiatives. Hence, when we look at the network losses in electricity from the point of generation to the point of demand, we need to look at the network in the two parts defined as the high voltage 'transmission network', and the low voltage 'distribution network'. This is because losses become higher as the voltage reduces. The average transmission network losses in England and Wales are 1.7% and the distribution network losses are 8% on average [29]. The combined network losses range from 3.1% to 10% and vary by region, dependent upon the distance between a specific power plant and the point of demand, with more rural locations, without nearby generation and with more distant substations, hence longer 'distribution' networks, being towards the higher end [29]. However, for embedded generation losses will only occur on the distribution network and will be lower for a specific demand location, than losses from electricity provided from generation connected to the transmission network.

Table 7.1 has used the current average losses in our transmission and generation network, to show the annual electricity required from a natural gas fossil fuel power plant to provide our local annual base demand in the Hope Valley area at distribution levels below 33 kV, both for domestic and for the total demands up to 2050. Natural gas has been used as it produces nearly half of the electricity in the UK. The total annual demand does not include the annual electricity demand on the higher 66 kV bulk supply network, which provides the electricity demand for Hope Cement.

Table 7.1 Energy required to provide the study areas base electricity demands from 2020 to 2050

		Annual demand (MWh)	Average distribution losses (%)	Electricity at start of distribution network (MWh)	Average transmission losses (%)	Electricity from the power plant (MWh)	Thermal energy from a gas-powered plant (MWh)
2020	Domestic	22833	8	24818	1.7	25248	56106
	Total[1]	70371		76490		77813	172918
2030	Domestic	30680	8	33348	1.7	33925	75388
	Total[1]	92720		100783		102526	227835
2040	Domestic	43865	8	47679	1.7	48504	107787
	Total[1]	143804		156309		159012	353360
2050	Domestic	52449	8	57010	1.7	57995	128879
	Total[1]	176091		191403		194713	432696

[1] Refers to the low voltage demand under the HV scenario and does not include the high voltage bulk supply

This estimates that over 180,000 MWh of thermal energy from a gas-powered plant would be needed to provide our predicted domestic electricity demand of nearly 53,000 MWh in 2050 and over 608,000 MWh of thermal energy from gas would be required to meet our predicted annual total distribution (low voltage) level demand of 176,000 MWh.

Losses for embedded generation connected to the distribution network will be lower than the larger generation plants connected to the transmission network, as the source of electricity is much closer to demand. This will still vary depending upon the distance from generation, hence sites should be chosen as close to demand as possible.

7.3 Connecting embedded generation

Many sites that may seem ideal for a given renewable technology will either not be viable due to high grid connection costs or because the local grid network does not have the capacity to accommodate the new generation power plant. Generally, a 11 kV network, cannot accommodate a generation connection of more than 3 MWs, a 33 kV network no more than 20 MW, a 66 kV network no more than 50 MW and a 132 kV network no more than 100 MW.

Most electricity distribution network operators have open access maps that can give an indication of capacity at substation level, but a more in-depth conversation will need to be had with the local DNO that covers a proposed generation site, to allow an initial assessment of suitability for grid connection to be made as early on in the project as possible, before it can progress further [14] [15].

For community energy projects, the initial conversation with the relevant DNO will usually not incur a charge. To increase the value of these initial conversations, it is important for local groups to have an idea of how flexible their proposed generation site could be to still be viable. This is especially important in areas where the grid is weaker, or in areas that may already be at the reverse power flow limit. In such situations, a non-firm connection agreement may be proposed by the DNO, which can have serious impacts on the expected revenue from the proposed generation plant. This style of agreement allows the DNO to restrict generation, during times of high output. Thus, if the wider area has a lot of solar power plants, the new proposed site may be required to dump, or otherwise store, energy during the summer, at an additional cost. These requirements are controlled by the DNO setting up an active transmission network, and currently operate on a last in, first out, basis, regardless of an individual generation technology's climate impact. Constraints such as this highlight the need for a variety of renewable generation technologies within an area, as they would likely then be providing their maximum generation capacities at different times of the day, season, and year, although this can be a requirement on any congested network.

Western Power, who are the DNO for the southerly part of our study area and operate the local substation at Eyam, have identified that any generation in that area is likely to only be possible with a non-firm connection agreement that allows them to constrain generation. This is because any generation (reverse power) that would directly go onto the Eyam substation, ultimately goes to Chesterfield which currently has local generation exceeding 700 MW connected and is already at the reverse power flow limit. Thus, Western Power are in the process of introducing an active transmission network in the area.

These constraints also highlight how necessary it is for our grid networks to assess these issues as soon as possible, although for DNOs it is the rules set by Ofgem that they follow. Electricity is predicted to become increasingly flexible in the future, with controls such as demand side smart responses, that control demand, in our homes, directly. Thus, a DNOs energy management system may choose when our electric vehicle can charge or if refrigeration can be switched off during a period of peak demand. This flexibility will run alongside energy storage from both large battery facilities and micro storage within homes and businesses, as well as in-vehicle batteries. These flexible systems are seen as cheaper alternatives to increased capacity and grid reinforcements and are being actively encouraged as a potentially cheaper alternative to reinforcement by the energy regulator Ofgem [30].

However, National Grid's latest Future Energy Scenario still estimates a doubling in the peak demand by 2050 and more than a doubling in annual demand under their Consumer Transformation scenario, the scenario predicted to move forward the most with different forms of the smart energy controls needed for flexible energy management [31].

Therefore, it is clear that network reinforcement will be necessary. It would be prudent for DNOs and the National Grid to undertake this work as soon as possible, rather than waiting until it is absolutely necessary, to ensure that we can meet the future increased base and peak electricity demands as we move further towards electrification in the push towards energy with Net Zero carbon emissions. An independent working group set up by Ofgem to analysis their own 5-year plan from 2023 to 2028 estimated that Northern Powergrid, our DNO for supply from the Hope substation, needs to spend £13 million in primary network reinforcement, the part of their network that transmits electricity at higher voltages to the substations from grid supply points, and £51 million in secondary network reinforcement, the network from the substations to customers. For Western Power, our DNO for the supply from the Eyam substation, estimates are £52 million for the primary network and £75 million for the secondary, again for the reinforcement costs that are required by 2028 [32]. To enable the required increases in local renewable energy generation that will be necessary to help achieve Net Zero to be incorporated into the distribution networks, Ofgem needs to recognise that reinforcement needs to take place as soon as possible and start to set out the requirements within the rules that they set for DNOs. It is also vital that these reinforcement costs do not all fall on the shoulders of smaller, local renewable generators, such as community energy initiatives, or all onto the consumers, creating fuel poverty.

It is also worth highlighting that these problems are not just constrained to larger local embedded generation such as MW sized wind or solar power plants, but also are just as relevant for battery storage, which would be required if storage was to be utilized as a part of the local solution to meet peak demand. When stored energy is fed back onto the grid, at the same time as electricity from the generation source, the grid connection would need to have enough capacity for the combined use of both the renewable generation and the maximum stored energy.

Where grid constraints might prevent the source of generation and the stored energy providing electricity to the grid simultaneously, storage could play a vital part by storing energy when the DNO would not accept the generation onto the grid, and then feeding it back as electricity during times when there is shortage of electricity available or during periods of peak demand where the generation source does not have the required renewable energy to operate. As the number of buildings incorporating solar panels in a local area increases, these constraints will also start to affect new solar roof connections.

One solution to such constraints that could be applicable within the Hope Valley is a private network as shown in Figure 7.1. This system is particularly attractive when the demand is constant and consistently higher than the local generation as would be the case with a private community owned network that supplied electricity to Hope Cement. Profits might be fed back into the local community to subsidise home energy efficiency measures that would reduce overall electricity demand. Such a scheme would have no grid associated costs.

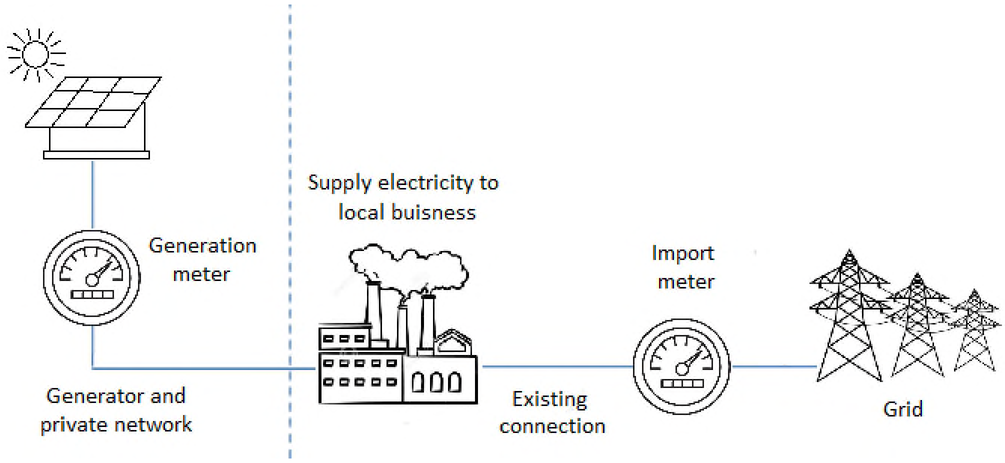


Figure 7.1. Local generation on a private network.

7.4 Grid connection costs

Once a site has been identified as having a viable grid location connection, with estimated acceptable connection costs, a detailed design study would then need to be conducted. The subsequent grid connection costs will depend upon factors such as:

- Design and connection costs
- Distance
- Land access costs
- Network reinforcements
    - Low voltage extension
    - 3-phase connection requirement
    - New substation requirement
    - Transformer requirement

The difference in costs for the grid connection of renewable generation power sources around the 2 to 5 MW size may make it more viable to connect two separate smaller generation sites on the 11 kV network rather than one on a higher voltage line. This is because for any generation over 3 MW and for some between 2–3 MW, the connection will have to be made back at the relevant primary substation. As well as the costs associated with the distance from a proposed renewable generation grid connection point, there will also need to be a new substation at the generation site with costs from £60,000 and other non-contestable connection costs that can run from the tens of thousands to the millions. Estimated grid connection costs discussed with DNOs at the feasibility stage of a project can also change significantly when compared to the final cost of the connection. This puts a premium on candid, informed, early discussions with DNOs. It is also important for community groups to act quickly as connection offers are only upheld for short periods of time, typical 30 to 90 days.

8. Renewable generation options

There are several types of renewable generation, which use some form of natural resource such as water flow, sunlight or wind and the efficiencies and costs of these systems are improving every day as they become more established technologies. Not all types are, however, equally applicable to this study area.

Figure 8.1 Main natural resource for renewable energy generation [33]

This section mainly considers the technical constraints, as those centred around planning related matters, including public voice, are subject to change over time. However, some of the non-technical considerations that will need to be addressed for any renewable energy technology planning application are:

- Scheduled Monuments
- Listed Buildings
- Sites and Monuments Record
- Sites of Special Scientific Interest
- Derbyshire Red Data Book of plants

- Natural England: rare/protected species
- Landscape sensitivity
- Ground water protection zone
- Key ecological areas
- Flood zones

8.1 Renewable technologies

Finding the right technology for a given site and set of circumstances is a complex task. Within Table 8.1, certain technologies have been deemed inapplicable in the Hope Valley area. For some the constraints are obvious, we can't produce tidal or wave energy with no available coastline.

Although for small scale home and community building installations ground source heat pumps may be applicable, the underground heat available within the UK does not make them viable as a large-scale electricity generating source. For biomass, land availability for producing organic material would be the largest constraint.

Three main families have been chosen for further investigation - solar, wind and hydro - as these are deemed to be the most appropriate renewable generation options within the study area, when the main consideration is technical. Ground source and air source heat pumps have not been considered, as although they are useful applicable renewable sources, they only supply the homes they are attached to. This differs somewhat from roof solar, where excess electricity can be fed back onto the National Grid and thus has an overall benefit at a local and national level and has therefore been included in some detail within Section 10.

Table 8.1 Renewable technologies

Main resource	Family Name	Overview	Types	Generation method	Suitable in Hope Valley
Daylight	Solar	Abundant but the amount of solar energy available from any system will vary throughout the day and the seasons and by geographical location and orientation.	Photovoltaic	Uses semi-conductive material to convert sunlight into electricity.	Yes
			Parabolic	Uses mirrors to heat a fluid to turn turbines.	No (very large scale)
			Thermal	Heats a fluid to heat water in a tank.	Minimal
Water	Hydro	Uses the energy in the motion of water to turn turbine generators that produce electricity.	Storage	Uses predictable gravitational energy (water stored at height).	Yes (high density low head sites)
			Run of the river	Uses flow rate and head to drive a turbine.	Yes
			Tidal	Uses predictable twice-daily tidal currents.	No
			Wave	Predictable energy in waves drives a turbine (pressure difference).	No
Wind	Wind	Uses the energy in the flow of wind to turn a generator that produces electricity	Turbines	Rotational energy from aerodynamic blades	Yes
Under-ground heat	Geo-thermal energy	Harness the natural heat below the surface of the earth.	Underfloor heating	Heat is used directly to heat homes.	Minimal
			Electricity	Heat is used to drive a turbine and generate electricity	No
Air heat	Air source heat pumps	Takes heat from the air and compresses it to increase temp		Heated fluid, heats radiators and water tank	Yes
Organic material	Biomass	Converts waste or plants into liquid and gas fuel or electricity	Anaerobic	Produces a gas through an oxygen free chemical reaction.	Minimal
			Aerobic	Produces a gas through chemical reactions where oxygen is present.	Minimal
			Burning	Uses specifically grown plants or waste to produce electricity.	Minimal

9. Large scale solar photovoltaics

Solar panels generate electricity as the materials they are made from are semi-conducting. A flow of electricity is generated when light is on the panels, and this is called the photovoltaic (PV) effect. Energy from daylight can be transformed to electricity even on cloudy days, however they will be more efficient during periods of bright sunshine with generation falling to around 10-25% in heavy cloud conditions. Conversely, the net efficiency of solar PV panels is reduced at high temperatures. The performance due to the irradiance (light energy per square meter) and temperature will vary between solar PV types and manufactures.

9.1 Solar PV panel angle and orientation

To achieve maximum efficiency from a specific solar array, the orientation and angle of the solar panels would also need to be adjusted throughout the day and seasons to match the sun's movement and relative height in the sky. This can be beneficial within large solar farms where the increased generation (in the order of 25-32% more than their stationary equivalents), and hence profit, outweighs the additional infrastructure and operating costs of the tracking system [34].

Figure 9.1 (LHS) Double axis solar tracker [35] (RHS) Single axis solar tracker [36]

Figure 9.2 highlights the difference in generation each month that can occur at a specific location, solely due to the different panel tracking methods or fixed settings at that site. The turquoise line is for a permanently fixed set at the best summer angle. The red line is for a system adjusted four times a year.

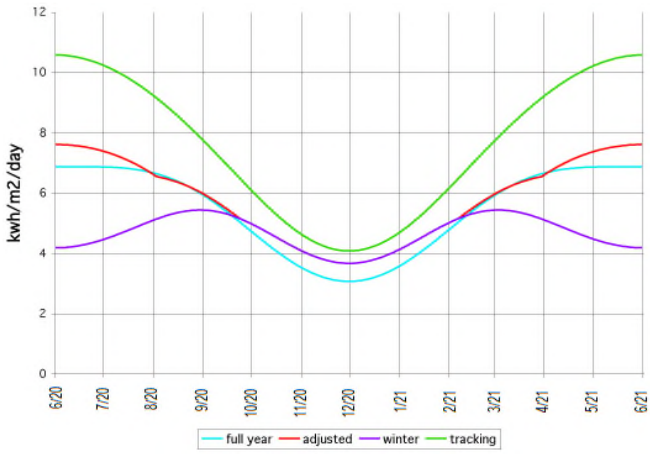


Figure 9.2 The effect of adjusting the tilt of solar panels through the seasons *[37]*

A two-axis tracking system, which changes the vertical angle throughout the day as well as the horizontal angle through the seasons, is represented by the green line and violet line is for a permanently fixed panel at the winter angle.

Annual electricity production

Table 9.1 shows the expected variation in annual generation dependent upon the axis system chosen for a specific solar array sited in the UK. Currently, the most popular configuration is a single axis tracking system. When an array is installed at a fixed orientation, this is generally set at the predicted point of maximum power generation for that specific site.

Table 9.1 Annual production per tracking system in the UK

Annual UK generation	Fixed Axis	Vertical axis	Horizontal Axis	Two Axis
per MW (MWh)	1000	1279	1274	1311
Capacity factor	11.42	14.60	14.54	14.97
3 MW farm (MWh)	3000	3837	3822	3933
5 MW farm (MWh)	5000	6395	6370	6555
10 MW farm (MWh)	10000	12790	12740	13110

Installation and operation and maintenance costs

The costs of any solar farm vary greatly dependent upon factors such as land costs, system and module type, grid upgrading requirements and distance to the grid connection point. Average costs in the UK are presented in Table 9.2, to be taken as a guide between system types rather than a definitive cost [34] [38]. The cost of large-scale solar PV tends to decrease with increased size and is falling year on year.

Table 9.2 Comparison of possible costs for each system in the UK

PV Technology	Investment Costs per MW (£)	Operation & Maintenance Costs per MW (£/yr)
Fixed Axis	£763,500	£7,635
Single axis (V & H)	£884,055	£11,316
Two Axis	£1,105,067	£16,576

Large scale solar PV land requirements

The land for a solar array is ideally either flat or a gentle south facing slope, although it is possible to utilize variable more undulating ground as highlighted in Figure 9.3, although the more complex structural requirements and hence increased costs, may make such a site unviable.

The area required per MW falls as the size of a system increases as the area for the additional infrastructure, the inverters, and transformers, do not proportionately grow with capacity increase. The inverters are required to convert the direct current (DC) into alternating current

(AC) and then the transformer increases the voltage, to align with the voltage of the grid, so that the generated electricity can be fed on to the utility scale grid network.

Figure 9.3 Installed panels on hilly uneven terrain [39]

The area for a specific capacity is also dependent upon the style of the solar panels. A 1 MW fixed panel system in the UK would need approximately 5 acres and a 5 MW fixed array wound require around 20 acres. A single axis tracking system will increase the area by approximately 10% and for a 2-axis tracking system the area required would increase by 20%, due to the longer shadows cast and hence increased spacing requirements of tracked panels.

9.2 Floating solar

Floating solar farms are installed on the surface of large lakes and reservoirs or flooded mines and quarries. The additional infrastructure for inverter and transformer stations can be sited on the ground close to solar generating panel installations or on floating platoons on the water. There will be less groundwork requirements for a floating solar farm as the panel frames are not driven into the ground, but instead are fixed to floating platforms, anchored to the bed of the water body, and are usually fixed systems, set at the required angle and orientation for maximum summer generation at the site.

Figure 9.4 A floating solar farm with orientated panels for maximum generation [40]

For the UK this would be facing due south at an angle between 35 to 40 degrees.

Figure 9.5 shows the largest floating solar farm within the UK currently (and the largest in the world at the time of its construction), a 6.3 MW installation commissioned by Thames Water and situated on the Queen Elizabeth II reservoir in Walton on Thames. This provides 20% of Thames Water's electricity needs [41]. Water processing and supply accounts for approximately 2% of the total electricity usage in the UK.

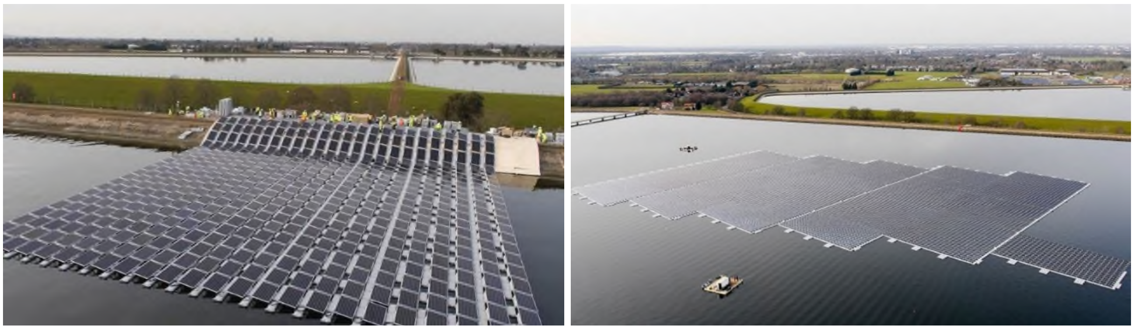


Figure 9.5 UK floating solar PV farm under construction (LHS) [42] and in operation (RHS) at Queen Elizabeth II reservoir in Walton on Thames [43]

Benefits of floating systems

Floating solar PV arrays can provide up to a 10% increase in yield, when compared to a similar land-based system, as the electricity generation is increased mainly by the cooling effects, but also marginally by light reflecting off the water and the reduced presence of dust on the panel surfaces [44]. When sited on water reservoirs, the presence of floating solar panels at the surface can have additional benefits as they reduce evaporation from winds and can improves the quality of the water by decreased algae growth, thus, when carefully managed, these factors can increase the ecological, environmental, and economic value of the site [45].

The reduced site preparation and the high degree of modularity compared to land-based installations, can also lead to faster installations and hence earlier electricity and income generation.

Due to much of the ground topography within the Hope Valley area being sloped, floating solar installations could provide additional opportunities for renewable energy generation.

Possible water saved through decreased evaporation

A 4 MW floating solar PV farm would cover around 15 acres of water, with some of the required infrastructure based on land. The average annual evaporation rate has been estimated to be 37 mm in Central England, although this varies greatly between sites due to factors such as water depth, wind exposure and elevation and is likely to be higher due to increased temperatures and winds created from climate change [46][47]. However, using this average around 2250 m^3 of water could be saved, equivalent to the average annual usage of around 45 people [48].

Floating solar costs

The capital costs of floating solar systems are around 10 to 25% more expensive than those installed on the ground, partially due to being a newer system and to site-specific environmental factors. However, the operation and maintenance costs are lower, making some floating farms as cost effective as land-based systems, over respective lifetimes [49].

9.3 Possible large-scale floating solar site in Hope Valley

There are two potential sites suitable for floating solar in the Hope Valley area: Ladybower Reservoir with a surface area of 520 acres and Redmires Reservoirs consisting of three reservoirs, the upper, middle, and lower sites at 57, 47 and 30 acres respectively. Although the Redmires Reservoirs are smaller, their location could be seen as more appropriate in terms of landscape sensitivity. The area to the south is however a Site of Special Scientific Interest and supports a variety of mammals, reptiles, and birds. Figure 9.6 shows the site map of the three Redmires Reservoirs with the smaller lower 30-acre site to the right, which is within a few meters of an electricity power supply situated to the north side of the reservoir.

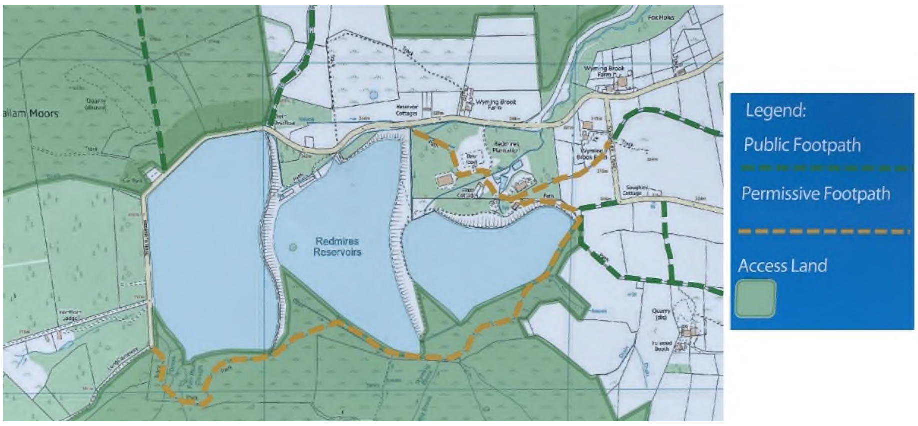


Figure 9.6 Site map of the 3 Redmires Reservoirs

Figure 9.7 The lower of the three Redmires Reservoirs, viewed from the north

If half of the lower reservoir, 15 acres, was utilized for solar panels with the inverters and transformers sited on land as illustrated in Figure 9.8, then a 4 MW fixed solar PV array could be installed at the site. This would be expected to generate at least 4000 MWh each year This could result in a reduction in emissions of over 800 tonnes of CO_2 each year, depending upon the carbon intensity of the energy being displaced.

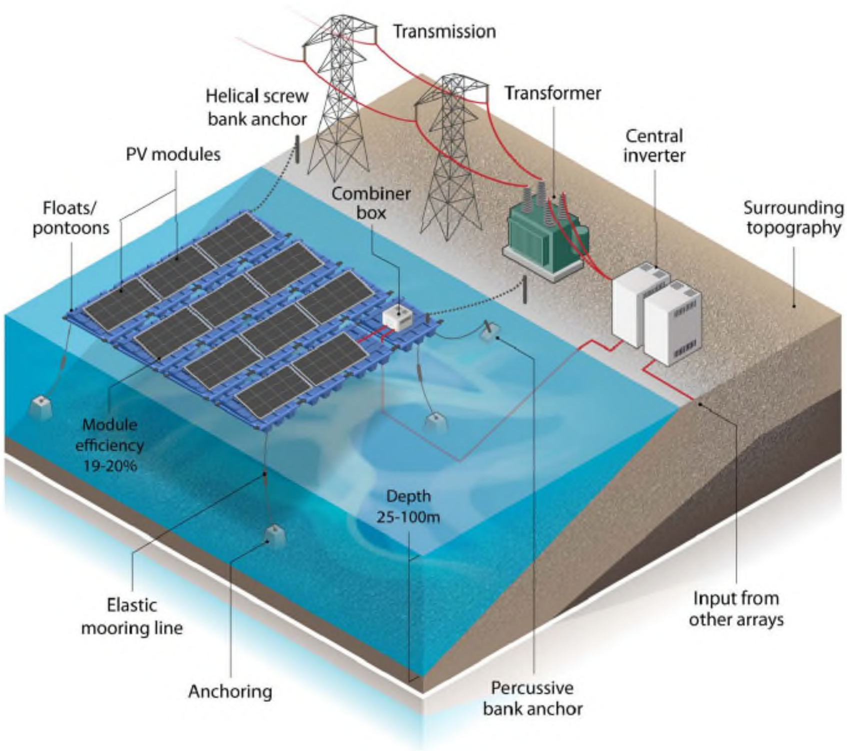


Figure 9.8 Schematic of a floating solar PV installation [50]

10. Solar PV on roofs

Solar PV on the roofs of buildings, whether domestic, public or industrial has a real benefit, as electricity can be generated without the need to convert land from other uses. However, the orientations and angles are not always ideal and hence the generation may be slightly lower for the same footprint area of insulation, compared to optimum fixed angle or tracking systems.

10.1 Domestic installations

Installing PV solar panels on the roof of homes or an outbuilding a simple way for individual householders to reduce their carbon footprint and help in the push towards a net-zero emission future. They can also reduce energy bills and protect householders from increasing energy prices.

Solar panels generate electricity as the materials they are made from are semi-conducting. Therefore, a flow of electricity is generated when light is on the panels. Energy from the sunlight can be transformed to electricity even on cloudy days, however they will be more efficient during periods of bright sunshine. The resulting electricity will first be used for any household requirement occurring at the time of generation and the excess will be exported on to the grid, for other households to use.

Solar panels can be installed on suitable roofs that are not facing due north. However, a PV array that faces due east or west will give about 20% less energy than one facing due south.

An average 4 kW system could provide around 3400 kWh annually in the UK, which is equivalent to the electricity demand of the average 3-bed domestic household. Prices are also continuing to fall with full system and insulation costs starting at around £4000 (including vat) for a 3 kW system, depending upon the panel type and installer chosen.

By 2050 an average home would be likely to need at least an 8 kW system to provide their annual electricity needs, however many homes may not have adequate suitable roof areas available for this amount of generation.

Table 10.1 Average solar panel set up for different household types [51]

	Small array	Small semi-detached	Average semi-detached/detached
Approx. roof area	8 m^2	15 m^2	21 m^2- 28 m^2
Approx. system size	1 kW	2 kW	3 kW – 4 kW
Average system cost	£2500- £3000	£3000- £4000	£4000- £8000
CO_2 saved annually (tonnes)	0.5	1	1.5 – 2
Average annual generation	900 kWh	1,800 kWh	2,700 kWh – 3,400 kWh

10.2 Solar panel types

There are three solar panel types, each with different efficiencies, costs, and aesthetics to consider. There are also several other factors that can affect the aesthetics such as frame style, colour and assembly methods, and newer designs such as solar tiles or slates and flexible solar panels, suitable for curved roofs.

Table 10.2 Panel type comparison

Monocrystalline Solar Panels	Polycrystalline Solar Panels	Thin-Film Solar Panels
Up to 20% efficiency	15 to 17% efficiency	Up to 11% efficiency
Most expensive type	Mid-range cost	Cheapest type
Appearance - black	Appearance - blue	Appearance black or blue
Made from pure silicon	Fragments of melted silicon crystals	Made from a variety of materials including silicon

Monocrystalline Solar Panels

The most developed and original type of solar panels are monocrystalline panels made from pure silicon. The monocrystalline solar cells have a black appearance due to the way sunlight interacts with pure silicon. However, although the cells are black the whole panel appearance will depend on factors such as the frame and back sheet design and colouring. These generally have the best efficiency ratings of up to 20% and are therefore the most expensive of the three types of panels.

Figure 10.1 An example of a 4 kW monocrystalline solar panel installation (with black frames) within Hope Valley

Polycrystalline Solar Panels

A newer form of solar panel also made from silicon, but from fragments melted together, are polycrystalline panels, which are blue in colour due to the way that sunlight on the crystals is reflected

The back sheet and frames of polycrystalline panels are often silver, but this can vary by manufacturer. The efficiency ratings of polycrystalline solar panels continue to increase, with current ranges of 15 to 17% likely. They are a mid-range cost option.

Figure 10.2 An example of a polycrystalline solar panel installation white frames) [52]

Thin-Film Solar Panels

The newest form of solar panel technology are thin-film panels. They are usually made using a variety of different substances, such as cadmium, silicon and copper-based materials which are assembled between thin sheets made from a conductive material and then covered by sheets of protective glass. Although the sheets themselves are much thinner than the other types, the frames of the panels themselves can be larger so that no noticeable size difference is seen between the three types. The appearance of the thin-film cells ranges between black and blue, depending on the materials used in their construction.

Figure 10.3 An example of the flexibility of thin-film panel installations [53]

Solar slates and tiles

For new roofs or when a roof is being replaced, one solar electricity generating option is to incorporate solar slates or tiles that match those assembled on non-generating portions of the roof. These systems are more expensive at around £12,000 to £16,000 per 4 kWs. However, these could be the most appropriate option for consideration for Grade II buildings or specifically sensitive areas.

Figure 10.4 Solar slates with the appearance of natural slate [54]

10.3 Non-domestic solar on current infrastructure

Mounting solar panels on public areas or buildings where it can be incorporated alongside its primary use such as carparks, village halls and schools could potentially provide a significant increase in generation in the study area. The centralised positioning of many such sites would allow the generated electricity to be on the doorstep of local electricity users and has the potential to provide many educational opportunities to school children, residents, and visitors alike.

Figure 10.5 A school incorporating panels on a flat roof (LHS) [51] and panels installed as a canopy above an existing carpark (RHS) [56]

10.4 Decentralised solar at high energy using industrial sites

Some sites suitable for roof mounted solar are close to high volume industrial electricity users, which would benefit from a direct connection to the generated electricity, thus reducing the costs and losses associated with grid connection and increasing generating revenue. Coupling this generation to an onsite energy storage facility would allow excess energy during downtime to be utilized, further reducing grid reliance and costs.

Figure 10.6 Industrial site where decentralised roof mounted solar in conjunction with battery storage would be a favourable choice [57]

10.5 Possible domestic roof-mounted solar generation

There are currently approximately 6300 domestic buildings within the study area, possibly rising to nearly 7000 by 2050. A third of UK houses (1 in 3) could be suitable for solar PV on their roofs [58], however, three possible levels of installation have been assessed to see the possible generation and the emission savings within the study area as presented in Table 10.3.

If the maximum number of suggested homes, 1 in every 3, were each installed with 4 kWs of solar panels, then collectively they would have an annually capacity of over 8 MW capable of generating over 7000 MWh each year. This could result in a saving in emissions up to 1,500 tonnes of CO_2 each year. Lesser rates of installation result in less generation and reduced emission savings.

Table 10.3 Capacity, generation, and emission saving possibilities

	1 in 9 homes	1 in 6 homes	1 in 3 homes
Number of homes with PV panels	699	1049	2098
Domestic installed solar capacity (MW)	2.8	4.2	8.4
Annual generation solar capacity (MWh)	2378	3567	7135
Annual CO_2 emission saving (tonnes)	500	750	1499

Incentives for homeowners

New installations no longer qualify for feed-in tariffs (FIT) payments which made solar panels so attractive, and enabled homeowners on low incomes to benefit from free electricity whenever the panels on their roofs were generating electricity in exchange for a lease of their roof. With such schemes, the installer received the FIT payments for any excess going back onto the grid, which was at a high enough rate to make the installations attractive.

The Smart Export Guarantee (SEG) scheme was brought in, in 2020, to replace the feed-in tariffs and provides guaranteed payment for electricity fed into the grid from renewable generation up to a 5 MW capacity. Roof mounted solar, falls into this scheme. However, the contracted payments are low, ranging from 1p/kWh to 5.5p/kWh for any electricity fed back onto the grid [59], whilst the average cost of electricity bought from the grid in the UK is 17.4 p/kWh [60]. These extremely low payback prices make solar panels with energy storage possibilities, utilizing batteries, more attractive for higher energy users, as although the cost of schemes is around £3000 higher than solar panels alone. Excess electricity generated can then be stored to be used by the household at times of low or no generation.

Although the prices of purchasing solar panel installations have dropped, homeowners still need to be financially stable enough to either pay the upfront installation costs or cover repayment costs if bought in instalments, without any reasonable additional payments received for their excess generation. Current financial arrangements, and costings, discourage low energy users from installing solar panels.

Homeowners, landlords and businesses should be being encouraged to instal solar panels, although energy efficiency measures such as insulation should be attended to first to reduce the energy needs of households and allow low carbon heating to be installed. One option would be to bring back a reasonable rate for excess energy put onto the grid. Another incentive could be to have a means-tested solar energy installation fund, run by the local authority, which could make the installation of solar generation more financially viable for individuals and which would provide benefit for the whole community by reducing the emissions for an area accordingly. Alternatively, grants could be provided by a Community Benefit Fund.

Some local community groups, such as Sustainable Hayfield, have also run schemes to attract discounts with installers by progressing proposals for several houses as an 'entity'. Through this scheme a discount was secured of around £700 per household. Predicted collective costs for the area, under such a scheme are presented in Table 10.4.

Table 10.4 Collective cost possibilities under different installation scenarios

	1 in 9 homes	1 in 6 homes	1 in 3 homes
Number of homes with PV panels	699	1049	2098
Domestic installed solar capacity (MW)	2.8	4.2	8.4
Collective installation costs [1]	£2,448,152	£3,672,228	£7,344,456

[1] Based on each home having a 4kW system without battery storage but with a collective reduced cost of 12.5%

11. Wind turbines

Wind turbines have specifically engineered blade profiles that harness the energy in wind through rotational motion, which is then converted to electrical energy utilizing a generator, which can then be fed into the National Grid network. There are several design types, but onshore models are generally horizontal axis wind turbines (HAWTs) with three blades connected to a hub and nacelle.

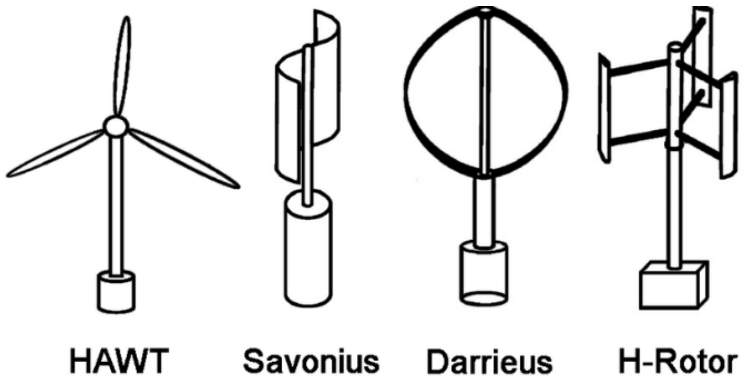


Figure 11.1 Horizontal axis wind turbine (HAWT) compared to vertical axis wind turbine (VAWT) types [61]

The three-blade design commonly seen on HAWTs are not chosen for energy conversion efficiency, but because they do not cause 'flicker', a visual disturbance experienced by some individuals from two blade wind turbine designs. Larger MW plus size wind turbines, are commonly situated in areas of regular natural high winds. This usually equates to elevated and/or exposed sites, although it is paramount that any site intended for grid connection is at a location that is cost effective and has the capacity required for the maximum additional electricity generation, in terms of infrastructure connections.

Figure 11.2 Wind turbines situated on a high exposed site [62]

This study recognises the sensitivity of the landscape of Hope Valley. Larger scale wind turbines currently conflict with National Park core strategic policies GSP1 Securing National Park Purposes (‘all development shall be consistent with the national parks legal and CC2 Low carbon and Renewable Development proposals for low carbon renewable energy development will be encouraged provided they can be accommodated without adversely affecting landscape character, cultural heritage assets, other valued characteristics or other established uses of the area purposes and duty’) [63].

Siting small scale domestic turbines close to existing buildings or trees to ensure that the skyline is not broken, is an alternative use of utilising wind power. However, it would not provide electricity on a scale that could really benefit the whole area as we electrify our homes. The Peak Park is currently reviewing its local plan, which could provide more opportunities for local renewable generation and larger scale wind turbines in the future. For its current stance and more details of what renewables are supported, the reader is directed towards their Climate Change and Sustainable Building supplementary planning document and specifically to Policy CC2 [63].

11.1 Operational constraints

There are many elements that need careful assessment during the development stages of a proposed single or multiple wind turbine site, including wind resource, site, visual and landscape amenity factors, grid connection, environmental and economical assessments. Here we provide some information on the broader aspects of site selection and the operational constraints affecting the feasibility of a proposed wind turbine/farm.

Wind speed

Wind turbines need a minimum wind speed of around 3 m/s for generation to begin and have a safety mechanism to prevent rotation and possible damage when wind speeds exceed 25 m/s for a short continuous period. They will also have a wind speed rating, the speed at which maximum generation is achieved. The topography of the area around a single or several turbine farms can adversely affect the generation possibilities. The land surface roughness decreases wind speeds, hence wind passing over short grassland will be greater that over tall crops and woodlands. Such differences can facilitate or compromise the viability of sites.

For a wind farm with more than one turbine, a turbine sited behind another will also generally convert less wind energy to electricity as the wake effect from the turbine in front, slows the wind, hence less energy is available. So, the siting of several turbines needs to take specific account of the particular characteristics of the site, including topography and predominant wind direction. When the wind is driving from a different direction the turbines will 'yaw' turning the nose of the turbine towards the wind direction to maximise energy generation. However, during these times the wake effects of other turbines in a farm will have a greater negative impact on generation.

Wind direction

For many sites within England, the wind direction comes predominantly from a south-westerly direction. Part of a wind farm's planning processor will include long-term site-specific wind data measured using anemometers at different heights. 5 years of wind speed and direction data may commonly be needed to enable 'best fit for turbine positioning, hub height, and wind turbine rating.

This data can also be used to predict the annual generation from a specific design. Although wind profiles vary each season and year, they do tend to be slightly higher during the winter months which is also when the UK's electricity needs are at their highest.

Electromagnetic interference (EMI)

It is important to assess any possible electromagnetic interference by assessing the telecom transmissions in the local area. Undesirable effects could be experienced at quite a distance from a proposed site due to the lines of sight between transmitters and receivers (Figure 11.3).

Figure 11.3 Line of sight from receiver to transmitter [64]

Figure 11.4 presents examples of the clearances that may be needed along a path between a transmitter and a receiver to prevent interference occurring due to the frequencies of the turbine/s when rotating.

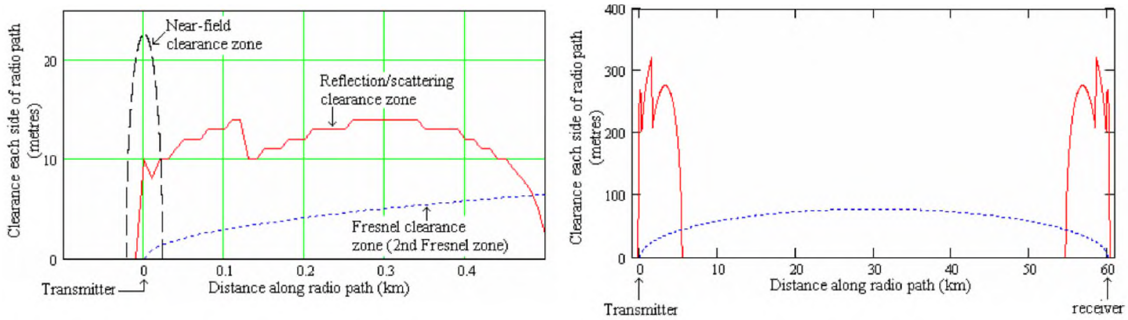


Figure 11.4 Examples of near field (LHS) and full path (RHS) clearance distances to prevent interference. [65]

11.2 Annual electricity production from wind turbines

Annual generation can change quite drastically due to weather conditions and wind speeds. This can be seen in the range of the capacity (load) factors for onshore wind in the UK from 2000 to 2020 in Figure 11.5. From this the drop in wind experienced in 2010 would have resulted in around a one third reduction in the annual electricity produced nationally.

Figure 11.5 Capacity factors for onshore wind turbines in the UK [66]

The amount of energy generated annually is therefore dependent upon the wind speed, profile, turbine, and hence farm size, layout and maintenance schedule. The current onshore average capacity factor for England is 30.5 (%) [66]. However, a higher hub hight and a larger swept area of the turbine rotor, the higher the capacity factor will be, due to the wind gradient. Generally, newer turbines also have increased capacity factors compared to older similar size machines, due to improved designs and less down time.

Table 11.1 presents the estimated generation of different size turbines or farms within England in 2020, with their corresponding sizes in Figure 11.6. Although, as an example a 4.5 MW wind power plant could have a single 4.5 MW turbine, or a group of three 1.5 MW turbines or even nine 500 kW turbines, costs and maintenance decrease and capacity factor increase as turbine sizes increase. Hence, the average capacity factor used in Table 11.1 shows an elevated generation from smaller turbines than that achievable in reality. However, one benefit of several smaller turbines is some continued generation should there be a maintenance shutdown from one turbine and they may be seen as more suitable in an area of outstanding natural beauty, such as Hope Valley.

Table 11.1 Average annual generation of onshore wind in the UK in 2020

UK land-based turbines with an average capacity factor of 30.5	Estimated annual generation (MWh)	Percentage of current domestic electricity demand (%)
0.010 MW turbine (10 kW)	27	0.12
0.1 MW turbine (100 kW)	267	1.17
0.2 MW turbine (200 kW)	534	2.34
0.5 MW turbine (500 kW)	1336	5.85
1.5 MW turbine	4008	17.55
3 MW farm	8015	35.10
4.5 MW farm	12023	52.66
6 MW farm	16031	70.21

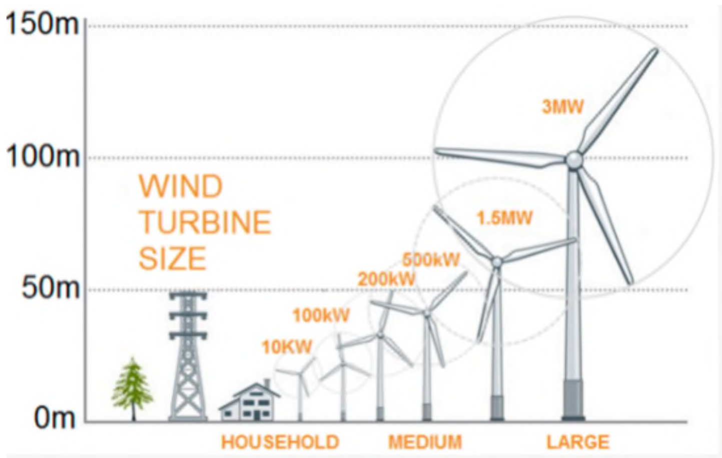


Figure 11.6 Average size of different capacity wind turbines [67]

11.3 Possible large-scale wind turbine site in Hope Valley

One future potential site suitable for a larger scale wind turbine within the area of this study is Sir Williams Hill. There is currently a radio mast situated here, used for police communications, which might be decommissioned in the next few years, as emergency service communication moves towards terrestrial trunked radio platforms that have far reaching geographical coverage.

Figure 11.7 Sir William Hill radio mast

This location could therefore be seen as particularly appropriate in terms of landscape sensitivity, as the skyline has incorporated the mast within the view for many years. A single turbine or small group with lattice towers, like that utilized for the current transmitter, could be a preferred option, as they do tend to blend into the background more easily from a distance as seen in Figure 11.8 and already have a precedent on the skyline. The current mast is also already connected to the grid, which could lower the costs associated with connection and infrastructure if sufficient grid capacity is available.

Figure 11.8 The radio tower blending into the landscape at William Hill

If a single 1.5 MW turbine, with a hub height of around 60 m, was installed on Sir William Hill, it could be expected to generate at least 3600 MWh each year; the annual electricity needs of around 1000 homes and would provide around 15% of the area's current 23,000 MWh annual base electricity demand, resulting in a reduction in emissions of over 720 tonnes of CO_2 each year.

Figure 11.9 Wind turbines with lattice style (LHS) [68] and tubular steel (RHS) [69] towers

Alternatively, if three lattice tower turbines of the same size (4.5 MW farm) were installed on Sir William Hill, they could produce over 12,000 MWh annually, enough electricity to power over 3000 homes at the current domestic average within Hope Valley, and nearly half of our domestic demand in 2021. This could result in a reduction in emissions of around 2100 tonnes of CO_2 each year.

12. Micro-hydro

Small scale hydro, often referred to as 'micro hydro' or historically 'run of the river' systems have been used around the world since the Byzantines first took advantage of the energy in the natural movement of rivers to turn a simple waterwheel that then irrigated their fields, over 2000 years ago [70]. Within the Hope Valley, a water mill utilizing that same energy source at Hope itself, was listed within the Domesday Book, written nearly a thousand years ago, and more recently water was used to power a cotton mill at Edale, and a corn and sawmill at Hope [71]. Now, within developed countries, most micro-hydro systems are used to turn turbines to generate electricity, in much the same way as a pumped storage system does from their artificial water flow and head, but on a much smaller scale, with generation generally below 100 kW [72] and head hights up to 50 m. Larger schemes from 100 kW to 1 MW are generally referred to as mini-hydro schemes, however no sites of this larger generation capacity have been identified within the study area [73]. Although the generation of an individual site may be low compared to other forms of renewable energy, they have a much higher efficiency of up to 90% and like most forms of waterpower including tidal and wave, they are predictable.

12.1 Hydro in the Peak District

In 2010 a comprehensive paper was published by Friends of the Peak District which identified and assessed the small-scale hydro potential of the Peak District National Park [73]. Rather than repeating much of their valuable research, for more details on the types of turbines, system layouts and detailed site assessments, this study would refer the reader to that report [73].

Table 12.1 presents potential sites within the Hope Valley area, which were identified within the 'Peak Power: Developing Micro Hydro Power in the Peak District' report. Two of these sites, Bamford Mill and Grinds Brook were also part of a small selection taken forward as case studies. A current installed capacity of 234 kW was also identified at Ladybower Reservoir.

Many run-of-the river hydro systems are designed to operate on the lower flowrate available during summer months and therefore have the capacity to generate electricity continuously. Thus, although the capacities can be small the annual generation can be much more favourable.

Table 12.1 Potential sites within the study area for micro hydro generation

District or Town	Mill Name	NOR	Ref No	Capacity (kW)	Tributary
Bamford	Bamford Mill	SK 205 833	M8	27	
Bradwell	Butts Mill	SK 173 812	M11		Bradwell Brook
Bradwell	Stretfield Mill	SK 178 820	M13		Bradwell Brook
Brough	Brough (Vincent Works) Mill	SK 184 825			Bradwell Brook
Brough	Brough Mill	SK 184 826	M12		Noe
Calver	Calver Corn Mill	SK245 743		4	Calver Mill Sough
Calver	Calver Mill	SK 247 745	M14	125	
Edale	Edale Mill	SK 133 853	M40		Noe
Grindleford	Padley Mill	SK 251 789	M19		Padley Brook
Hathersage	Lead Mill	SK 233 807	M21	17	
Millers Dale	Litton Mill	SK 161 729	M24		Wye
Millers Dale	Millers Dale Meal Mill	SK 142 733	M41		Wye
Stoney Middleton	Stoney Middleton Mill	SK 230 755	M29	4	Stoke Brook
Grindleford	Padley Gorge	SK 251 789	N5	120	Burbage Brook
Edale	Greenlands	SK 125 844	N10		Harden Clough
Edale	Grinds Brook	SK 121 863	N15	12.5	Grinds Brook

12.2 Possible micro-hydro generation site in Hope Valley

The Calver Mill weir on the River Derwent was original built to hold back the water to power Calver Mill to enable the cotton to be spun there and the mill has been identified as having a potential continuous capacity of 125 kW. The weir was restored through funding from local residents, businesses and Heritage Lottery, Environment Agency and English Heritage Funding at the beginning of the 21st century. Although the mill house is now apartments, the mill infrastructure is still intact and has been identified as a site worth further investigation within the Friends of the Peak District report, due to less constraints and the higher hydro generation potential [73]. The site is also close to the residential areas of Calver and Curbar and is less than a 100 m to a grid connection point.

Figure 12.1 Calver mill and weir locations [74]

If a 125 kW hydro electricity generating installation at Calver Mill was commissioned and ran with an average capacity factor of 50%, the annual electricity generated would be around 500 MWh, the same as the annual generation of a 0.5 MW solar installation with fixed axis panels. This could reduce the CO_2 emissions from electricity locally by around 100 tonnes each year.

Figure 12.2 Water entering the Mill house at Calver Mill [75]

13. Renewable technology comparisons

The requirements for renewable energy generation plants differ between not just each type but also each location but the following considerations in addition to the generation plant components should be addressed at the early stage of any project:

- Community engagement
- Land purchase or lease costs
- Capacity of the site
- Terrain and orientation suitability
- Access (particularly crucial for large wind turbine blades)
- Grid connection distance and costs
- Wildlife habitats and protected species
- Sites of Special Scientific Interest
- Archaeological and geological features
- Landscape sensitivity
- Water run-off implications and flood damage

13.1 Solar vs wind

There are also some general advantages and disadvantages of different renewable types. The pros and cons of the two main large scale renewable generation methods, solar and wind are provided in Tables 13.1 and 13.2.

Table 13.1 Pros and cons of wind power

Pros		Cons
Can produce energy day or night	Vs	Higher resource sites are often further from the grid
Generation higher during periods of greatest demand		Higher more skilled maintenance requirements
Much higher annual energy generation than solar		Can cause noise and visual disturbances

Table 13.2 Pros and cons of solar power

Pros		Cons
More predictable generation	Vs	Generation falls during periods of greatest demand
Less conspicuous from a distance		Manufacturing processes are more polluting
No or very low noise		Cannot produce electricity when dark

13.2 Renewable technology cost comparison

To provide an accurate cost comparison between the renewable technology most relevant to the study area we need to look at the average "levelized cost of electricity" (LCOE) for each renewable generation type. The LCOE is used as it estimates the average cost of the electricity provided, over the full lifetime of a generating system, per MWh and therefore aim to provide consistent cost comparisons between different electricity generating technologies. It takes account of the costs to build, operate and maintain a power plant, and the average electricity it will be expected to generate annually. LCOE estimates also take account of projected fossil fuels and CO_2 emissions costs throughout the power plant's lifetime.

Most of the LCOE values provided in £/MWh for the different relevant technologies have been provided for power plants that would be assumed to be operational in 2025 [76].

Unfortunately, no LCOE were provided for medium-large scale solar PV [76] the 1 to 5 MW sizes that would be more applicable in the Hope alley area. These smaller size solar array power plants could have an increased LCOE as could the smaller wind turbines that would be more suitable within an area with a sensitive landscape. The hydro LCOE provided in Table 13.3 has been derived from values given in dollars per MWh based on global average in 2010, as more recent LCOE for small run-of-the-river systems were not available [77]. The British Hydropower association estimates current installation costs of around £8,000 per kW capacity for smaller hydro power plants [78].

Table 13.3 LCOE for different renewable technologies in 2020

Type	Installation	Scale	Notes	LCOE (£/MWh)
Solar photovoltaic	Roof mounted	small	Average costs for 0 to 4 kW installations [1]	£114.00
	Roof mounted	small	Average costs for 4 to 10 kW installations [1]	£86.00
	Roof mounted	small-medium	Average costs for 10 kW to 50 KW installations [1]	£74.00
	Land array	large	Average costs for arrays of 5 MW and above [1]	£44.00
	Floating array	large	Average costs for arrays of 5 MW and above [2]	£44.00
Hydro	Mills	small - medium	Average costs for pico-hydro systems of 100 kW to 1 MW [3]	£200.00
Wind	Turbines	large	Average costs for onshore wind [1 4]	£46.00

[1] Reference [76]
[2] Similar LCOE as land-based large-scale solar assumed due to increased generation [49]
[3] Reference [77]
[4] Size range of onshore wind turbine power plants was not provided

Costs and hence the lifetime £/MWh of electricity generated are very dependent on the individual site, grid connection and scale of a specific renewable power plant and hence the average LCOE values for each technology provided in Table 13.3 should be used for guidance only. However, it is also noteworthy, that large-scale solar and onshore wind have now been identified as the cheapest forms of electricity, across both renewable and non-renewable technologies, within the UK [75].

13.3 Capacity factors of the relevant renewable technologies

The capacity (load) factor is a term commonly used in the generation of electricity from renewable sources to predict how much electricity may be generated annual from a specific renewable generation power plant.

Taking an example of a 1 MW wind turbine. If the wind blew at the optimum speed for that turbine all through the year and there were no shutdowns of the turbine for maintenance or repair, then the annual generation for this ‘perfect scenario’ would be:

1 MW x 24 hours x 365 days = 8760 MWh

However, this of course does not happen. For an onshore wind turbine in England, the average capacity factor in 2020 was 30.5% [66]. This means that the average amount of energy estimated to be generated annually is 30.5% of the ‘perfect scenario’ hence 2672 MWh. It is important to recognise that this does not mean that the 1 MW onshore wind turbine in our example is only generating electricity for 30.5% of the time each year, as there will be many periods when the wind speed is below the turbines rated speed, but it will still be high enough to be generating some electricity. As an example, a turbine may be rated at 10 m/s winds but will generate electricity when windspeeds are above 3 m/s. The average capacity factor given accounts for all sizes and locations of onshore wind turbines and newer machines can be expected to have increased generation and hence higher capacity factors.

Table 13.4 highlights how the average capacity factors for the UK, for the different renewable technologies, affect the annual generation. Out of these, hydro is generally considered the most predictable, followed by solar and with onshore wind considered to be the most unpredictable renewable energy generating technology.

Table 13.4 Annual generation predictions per MW of installed capacity for different renewable technologies

Technology	Average current capacity factor[1]	Annual Generation (MWh/MW)	Percentage of domestic electricity demand in 2020	Percentage of predicted domestic electricity demand in 2050 under the HV scenario
Solar roofs – fixed[2]	9.7	850	3.7%	1.6%
Solar land-based - vertical axis[2]	14.6	1279	5.6%	2.4%
Solar floating[2]	16.1	1407	6.2%	2.7%
Onshore wind turbine	30.5	2672	11.7%	5.1%
Hydro run-of-the-river	50	4380	19.2%	8.4%

[1] UK averages
[2] for an unshaded site

13.4 Conventional electricity generation

When assessing the generation of electricity from a renewable source it is quite commonly understood that the electricity generated will only happen when the weather and daylight conditions are favourable for a specific plant as covered in Section 13.3. As the energy used by renewable generating plants is freely available, energy losses in the conversion process from say wind speed to rotational motion and hence into electricity are not generally factored in, as the capacity factor gives us the information required and conversion losses do not have fuel costs associated with them.

In more conventional primary fuel, thermal electricity generation plants, such as coal, gas and nuclear, the losses associated with converting thermal energy (steam) into electricity, can have a significant impact on availability, costs and profits. The process of conversion from thermal energy to electricity is similar for nuclear and coal power plants, although nuclear power plants are often not associated with a primary fuel source as the amounts and costs of uranium are much lower than primary fossil fuel power plant requirements. However, the capital, operational and decommissioning costs are much higher for nuclear, making the LCOE of nuclear higher than gas [76][79]. The efficiencies provided in Table 13.4, relate to how much of the thermal power is converted into electric power and hence how much primary fuel is required to generate a MWh of electricity. The LCOE for all three conventional thermal to electric power plant types are nearly double or more the LCOE of large utility scale solar and onshore wind.

Table 13.4 Efficiency and LCOE of primary fuel source for different conventional electricity generation plants

Technology	Primary fuel	Efficiency (thermal energy to electricity) (%)	LCOE (£/MWh)
Coal	Black coal	32[1]	131[2]
Gas	Natural gas	45[1]	85[3]
Nuclear	Uranium	35[1]	95[2]

[1] [80], [2] [79], [3] [76]

14. Storage and smart control

Most more conventional power stations use stored energy in a primary fuel to create electricity, such as gas or coal. Whilst nuclear energy also uses a primary energy stored in atoms, and wind and solar energy is derived primarily from the sun, these technologies do not have the flexibility to increase their energy output and hence electricity on demand, in the same way that fossil fuels-based systems do.

The electricity requirements of consumers change by the minute and meeting this variable demand requires fast response methods of storage. This has mainly been provided by large scale hydro storage facilities for immediate demand increases, closely followed by gas, coal and other fossil fuels. There are also times when the energy requirements are much higher, usually referred to as 'Peak Demand', which are quite predictable but require extra generation capacity to be available to both meet the increased demand and to provide backup for routine maintenance and power outages.

Hence more storage will be needed in the future to enable a transition towards solely utilising energy from intermittent renewable forms of generation, to enable us to meet consumers electricity requirements during times when generation is reduced due to the environmental conditions such as low winds or hours of darkness, and to meet burgeoning electricity demand. For this to be achievable there will also need to be smart ways of controlling demand to reduce the peak requirements.

Currently, storage such as large-scale hydro is provided by utilising energy generated during periods of low demand. With smart technologies, some storage at household level, in the form of batteries incorporated into solar installations or electric vehicles, could be either switched off from charging when demand is high, or the flow could be reversed so that they are putting electricity back onto the grid to help DNOs balance the fluctuating demand. Such control methods should enable overall peaks in demand to be lowered, reducing the need for some of the extra generation capacity.

Incorporating larger methods of storage alongside renewable generation helps to smooth out this inherent unpredictability. It has particular value during times of low demand or when generation is being curtailed by the DNO. Such systems could also be charged directly from the grid, as necessary.

Some future energy scenarios that aim to achieve Net Zero emissions rely upon green hydrogen, which is produced via the electrolysis of water using renewable energy to form a gas or charge fuel cells. However, currently the high costs of hydrogen production limits its present use for electricity production. Other forms of energy such as flywheels, compressed air energy storage and thermal energy storage are also in use and are being explored further in the push towards Net Zero. However, most energy storage at the distribution level is likely to come from batteries, both from the homes and vehicles of individual consumers, domestic and business, and as larger installations, either as an accompaniment to local renewable generation or as separate systems. There is also a form of high-density fluid storage that could allow systems that are similar in their operation to large-scale pumped hydro to be installed in areas that have the required topography, such as the old disused quarries that are in abundance within Hope Valley and the surrounding area.

15. Battery storage

There are many different battery storage technologies available such as lithium-ion, salt-water, flow or lead acid. For battery storage that can be coupled to the grid to be effective, systems will need to be able to have a rapid response time and a long-life expectancy to allow both absorption of energy when the demand is low and supply back to the grid for load levelling as well as peak demand and emergency backup.

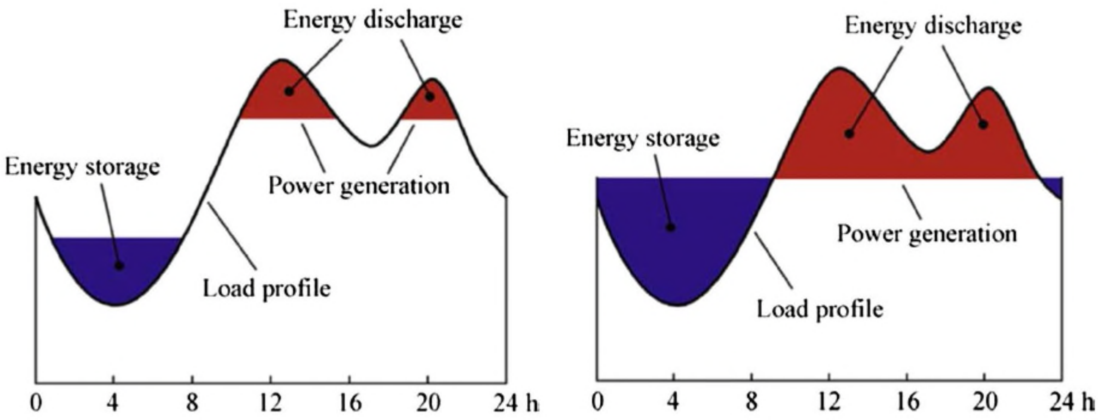


Figure 15.1 Peak shaving (LHS) and Load levelling (RHS) [81]

15.1 Consumer level battery storage

In recent years, the option of incorporating battery storage into a home alongside solar PV roof panel generation has become widely available with additional costs starting at around 40% extra when compared to a PV only system. The connection type dictates what the energy storage will provide to the consumer.

A DC system is installed on the PV panel side of the solar inverter and hence the battery will only charge from the panels and cannot utilise cheaper electricity from the grid during the earlier hours of the morning when demand is low and generally will not operate if there is a power cut on the grid [82].

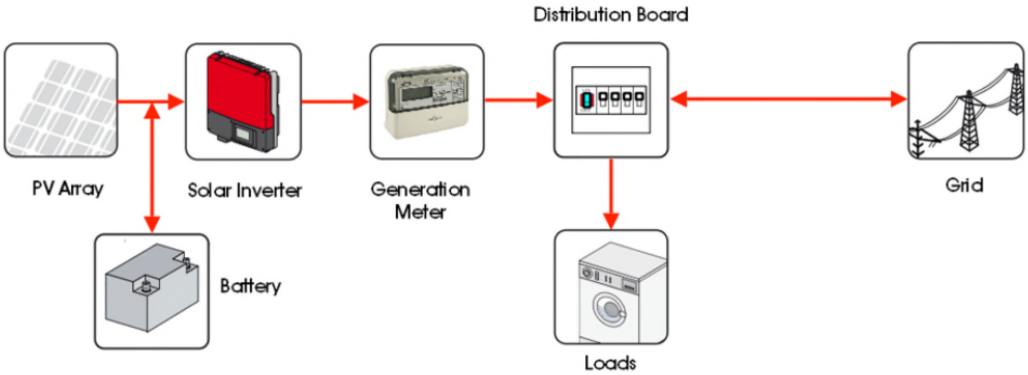


Figure 15.2 PV array with DC battery storage system [82]

An AC system utilises an additional battery charger to connect to the AC side of the solar inverter, makes it possible to also charge the battery from the grid as well as from the solar PV system and can, with additional equipment, be designed to operate when the grid is not operating during a power cut [82]. Regardless of whether a system is DC or AC, the solar inverter will be sized to the solar array.

For battery back-up systems, the size dictates the discharge rate of the battery and smaller systems at around 2 kW will not be sufficient to start and run large, energy dense appliances but would provide for critical electricity needs such as lighting, home entertainment and refrigeration [83]. Larger 5 kW systems, should be sufficient for most home appliances excluding an electric shower. The size of the storage also dictates the speed at which the unit will charge, hence a 5 kW unit will have a faster charging rate than a 2 kW unit. For larger units, the DNO may require the household to have a 3-phase electricity supply which can be expensive but will allow a faster exchange of energy.

The storage capacity of home systems generally ranges from around 3 kWh to 13 kWh and will last from 3 to 12 years depending upon type and the number of cycles endured, hence the energy habits of the household. One cycle is defined as from the point when a battery is fully charged then discharged down to its Depth of Discharge (DoD), then fully charged again. A lead acid battery has a DoD of 50% of the full capacity, for a lithium-ion battery the DoD is 80%. Flow batteries, still in their development stages, are expected to have an increased lifespan, compared to the current options available. Exceeding the DoD of a battery system will reduce its life span and should be prevented by the charge controller.

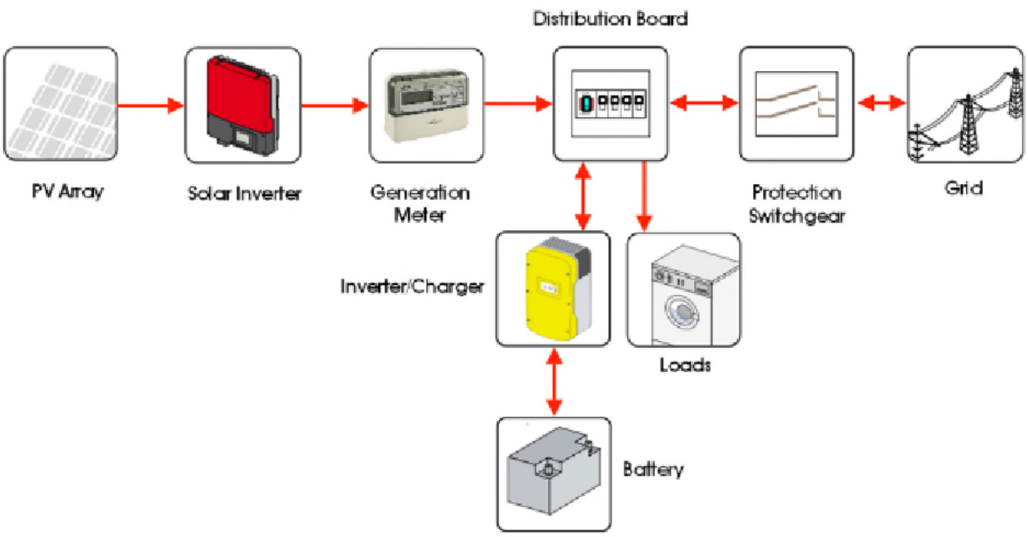


Figure 15.3 PV array with AC battery storage system and additional back-up [82]

Incorporating smart energy management systems into the home, such as that shown in Figure 15.4 [84], allows consumers to maximize the efficiencies of their generation and storage systems to reduce their reliance on electricity from the grid, save money, but also helps reduce overall network demand especially during the peaks when energy supply is at its highest carbon intensity.

In the future, it is envisaged that bi-directional home systems, a combination of stationary storage and in-vehicle storage, will be fully automatic and will also 'talk' to the energy management systems of DNOs. This would then allow certain non-essential loads to be switched off during periods of high demand. It could also allow the systems to harvest stored energy from consumer installations and plugged-in electric vehicles, to enable peak shaving. They will also predict the solar generation for the coming day, and then charge the stationary storage units to the appropriate amount.

It is also envisioned that households will be able to utilize storage without solar if their home is not suitable for an array due to orientation or type such as flats and apartments. Thus, they will be able to charge their storage units at night when electricity is in low demand and is cheaper, and then use it during the day. However, since the 2022 spring budget, solar systems will now benefit from no vat for at least the next 5 years, although it is unsure if battery storage systems bought alongside solar PV will also benefit. VAT at 20% still applies for stand-alone or retrofitting of battery storage.

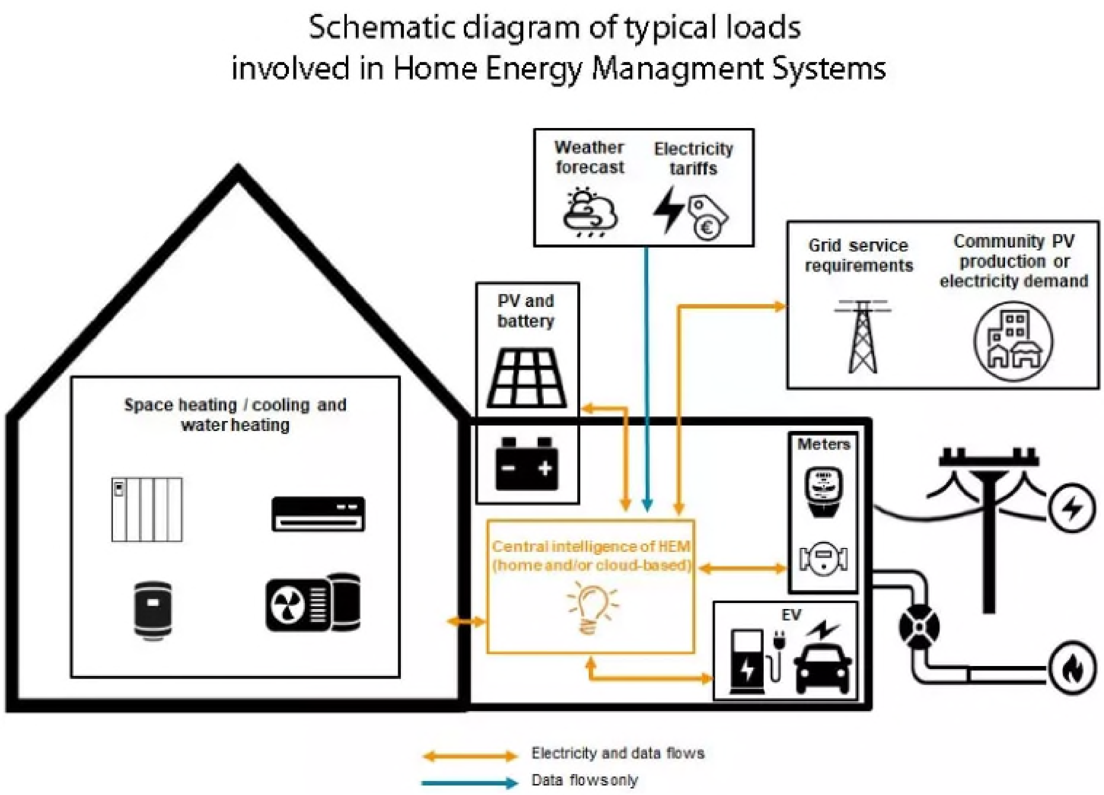


Figure 15.4 Home energy management system [84]

15.2 Community level battery storage

Community level storage would operate in the same way as a home system, with an automatic energy management system that can be controlled by the relevant DNO. These storage systems will also be able to either be connected to a renewable generation power plant or be stand-alone systems housed close to consumers. Both types could provide peak shaving and energy levelling with additional benefits for systems connected to renewable generation due to their ability to capture otherwise wasted energy during times of high energy generation.

Figure 15.5 Large scale battery storage [85]

16. Pumped storage hydro systems

One of the oldest forms of energy generation is harvesting the kinetic energy in the motion of water to turn a turbine. For large, pumped storage hydro systems, this motion is usually used to spin turbines to generate electricity that is fed onto the National Grid (in the UK) network.

Within the UK, 7.77 TWh of electricity was provided from pumped storage hydro facilities in 2019, providing 2.2% of the annual demand, as high value peak electricity [86] [87].

Pumped storage hydro produces electricity by utilising two reservoirs with a significant height difference between them. The upper reservoir stores energy in the form of gravitational potential energy of the elevated water. Close to the entrance into the lower reservoir, turbines are utilised to generate electricity from the fast-flowing water, as it is released from the upper reservoir, and this electricity is then fed onto the grid. The water is then discharged into the lower reservoir, where it is stored until it is pumped back up to the upper reservoir. The reservoirs can be some considerable distance apart and must have an adequate difference in elevation, often of over a hundred meters.

Traditionally the upper reservoirs were refilled during the early hours of each day when there is a much lower electric energy demand, but some forms of generation such as nuclear continue to generate during these periods regardless. However, with the recent increase in generation from wind and gas, many pumped storage hydro facilities no longer operate on a daily cycle and can cycle up to 60 times in a 24-hour period [86].

Pumped storage hydro can provide large amounts of electric energy at very short notice and can therefore be used for high value peak demands. It can also be used during periods of unexpected power station failure, occurring at other generation plants in the grid network [88].

However, the main site requirements; elevation, topography, and an adequate water source, inhibit increases in the number of and hence generation possibilities, from large scale pumped storage hydro systems. There are also many social, economic and environmental constraints preventing the development of further large scale pumped storage hydro plants.

Figure 16.1 The Cortes-La Muela hydroelectric power station in Spain [89]

16.1 High density hydro

A new form of underground pumped storage hydro is in development, the High Density (HD) Hydro system designed by RheEnergise, that could be situated in hilly areas without the same large elevation differences between the reservoirs being a requirement. The reduced height requirement between the upper and lower reservoirs is possible as the hydro plants use a non-toxic, mineral-rich, 'high-density' hydro fluid. This fluid has an increased density, two and a half times higher than water, so for the same generation as a specific standard pumped storage hydro, the 'high density' plant could be 60% smaller. The relative elevation (head), between the lower and upper reservoir would also reduce by 60% [90]. Hence a 'high density' system with an upper reservoir with a volume of 3000 m^3 at 200 m elevation from the lower reservoir, would have the same electricity generating capacity as a pumped storage water hydro plant with a volume of 7500 m^3 and an elevation difference of 500 m.

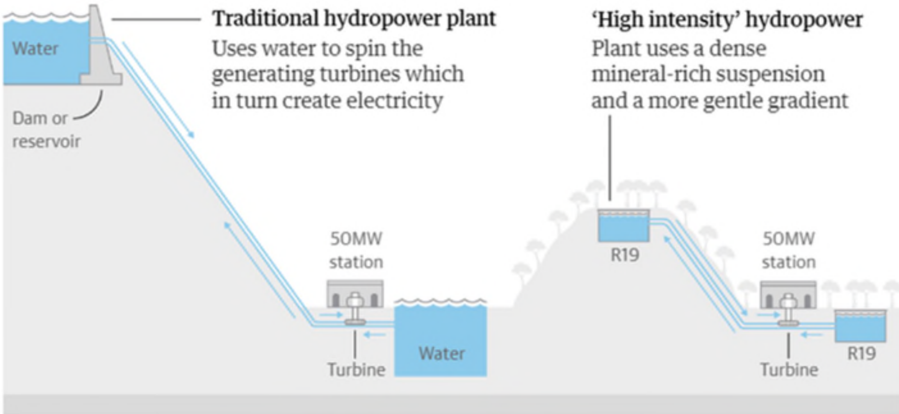


Figure 16.2 Schematic of a traditional and a high intensity pumped storage hydro plants of the same generation capacity [90]

The reservoirs for a 'high density' pumped storage hydro plant would both be in enclosed tanks, buried underground, and therefore would have a lower environmental and aesthetic impact on an area as the ground can be rewilded, to restore natural grassland and tree cover whilst the plant is still operating below. It is estimated that 'high density' hydro system could provide an additional 7 GW of energy storage within the UK and would be suitable for sites with an elevation difference of 75 to 300 m.

Hope Valley and the surrounding area has a high concentration of mineral quarries, most now inactive [91], which could potentially be appropriate for a high density pumped storage hydro facility.

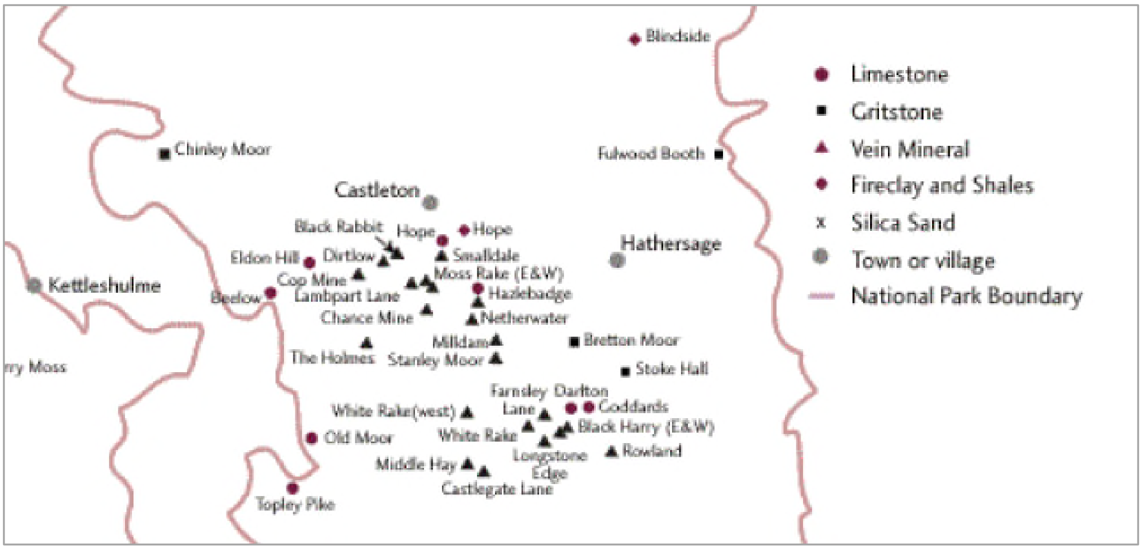


Figure 16.3 Disused and active mineral sites within the study area [91]

17. Discussion

Under all future energy scenarios presented, we see an increase in the predicted domestic electricity requirements within the Hope Valley, at least double the current demand. For industrial electricity scenarios A and C, provided by the local DNOs, predict a reduction in the electricity businesses will require by 2050, compared to their current electricity demand. However, even with a large increase in the efficiency of industrial processes and office heating it is highly unlikely that these predictions are achievable without a continued, or even increased, reliance on other forms of dirty energy. Therefore, under scenario B, the industrial annual electricity demand predicts an increase in annual electricity to 110 GWh by 2050, excluding the industrial bulk supply

Hope Valley's total domestic, industrial and non-domestic vehicle demand could therefore be as high as 350 GWh annually, by 2050.

Although Ofgem are not currently stipulating that DNOs should be reinforcing their distribution networks now, the predicted extra electricity demand both nationally and locally will require that they carry out grid infrastructure reinforcing, as well as implementing more sophisticated flexible smart energy management systems along with mass battery storage plants, if we are to achieve the targets set out in the Government paper 'Net Zero Strategy: Build Back Greener'.

For Hope Valley, the grid capacity is also further reduced by the nature of the networks, as it is on the periphery of both Northern Powergrid's and Western Power's distribution networks. This makes reinforcements here even more imperative, if local energy generation, even mass roof solar PV generation, is to be achievable.

Increases in energy prices are already having a negative impact on many households, with lower income and vulnerable users being disproportionately affected. The system and infrastructure upgrading, that the increased electricity demand will require, will inevitably come at a high financial cost. It is imperative that we also consider how we can mitigate the financial implications of this on individuals. This will be a hard task to achieve whilst our DNOs are private, profit driven, companies.

As home heating moves towards electricity as the main energy source, the thermal properties of homes will need to significantly improve, both to provide sufficient warmth and to prevent further fuel poverty and the knock-on effects that this has on people's quality of life and wellbeing.

Consumer behaviour is often cited as a key factor to achieve the measures necessary to reach net-zero carbon emissions by 2050, however there will be a requirement for far reaching extensive financial support from the Government to enable the required home improvement updates to be made to all of the current UK housing stock. Support for energy storage solutions is also essential as it is a vital step towards flexible energy systems and reducing peak demands. This gives storage additional benefits, when it comes to reducing emissions, as our peak demand often comes from the dirtiest forms of electricity generation.

Generating double or more of our current electricity requirements outside of the valley, will impact on other places and communities in Britain and this therefore brings up the question of whether we should be taking responsibility for providing some of our own energy and storage within Hope Valley? If so, we need to assess what the best local energy generation and storage solutions would be within Hope Valley.

> *"The climate emergency is the biggest threat facing our countryside and planet… there's good news: the countryside can provide many of the solutions."*

CPRE The Countryside Charity

Table 7.1 suggests a mix of generation that could provide nearly all of the domestic electricity needs of Hope Valley by 2050. This has assumed that each home would require an average annual electricity demand exceeding 8000 kWh under the highest prediction of 60,000 MWh in 2050.

Table 17.1 Embedded generation within the Hope Valley that could provide our domestic electricity demand in 2050

Technology	Size	Quantity	Average annual generation (MWh)	Homes powered in 2050
Solar roofs - 1 in 3 by 2050	4 kW	2300 homes	7,900	1000
Solar array	5 MW	2	12,600	1500
Wind turbine	4.5 MW	3	36,000	4500

The information provided within this report on different renewable technologies and possible sites, does not exclude consideration of other types, capacities or locations within our valley, but seeks to provide the reader and stakeholders with some relative information in order for us to make the necessary decisions that we and all communities will need to take in the coming years.

Some homes within the Hope Valley already provide some of their electricity requirement from solar panels on their roofs. There are also a few examples of small-scale wind turbines, supplying individual homes and businesses, as well as ground source and air source heat pumps.

As a community should we increase the take up of these small-scale renewable generating sources and is there also a place for larger scale renewable local generation? If so, what type of renewable installations are most appropriate and where should they be sited, recognising the importance of landscape sensitivity in the national park?

18. Conclusion

There is strong evidence that we are experiencing a climate emergency and the UK Government has pledged to halve our carbon emissions by 2030 and to reach net zero by 2050. Part of the strategy of achieving this reduction is to electrify our homes and vehicles and provide that additional demand from renewable sources. This means that the annual domestic demand for electricity is likely to at least double, as seen in Table 18.1. If industrial practices also move towards more electrification in a similar manner as our domestic demand, the total electricity requirement within Hope Valley could exceed 350 GWh by 2050, nearly seven times higher than our predicted domestic requirement by 2050 and 15 times higher than our current domestic demand. It is difficult to analyse other forms of energy use and hence achievable overall emission reductions achievable at industrial level, as details of current and predicted total energy use are not publicly available.

Table 18.1. Projected annual domestic electricity demand in Hope Valley in MWh

Year	2021	2030	2040	2050
Scenario A	22834	32819	49551	60084
Scenario B	22834	30680	43865	52449
Scenario C	22847	26931	40977	51500

If we continue, as we currently are, with small steps as outlined within scenario C, then the emissions from our domestic energy requirements can be expected to be the same by 2050 as they are today.

However, under scenario B, a reduction of 40% of domestic energy emissions could be achieved by 2050 and reduction of up to 55% under scenario A. These predicted emissions would, in reality, reduce by considerably more as the amount of electricity from renewable energy increases and fossil fuel and gas power stations close.

This will require a push towards electric vehicles, highly energy efficient, well insulated homes and electricity-based heating sources, all provided for by electricity generated from renewable energy. Although many of these measures require individual homeowner behavioural changes, there is also an imperative requirement for adequate and easily accessible financial assistance, for the necessary home improvements, at governmental level.

To ensure that the increased electrification does all come from renewable sources, DNOs, local authorities and stakeholders need to work with communities, and local climate groups, to explore how they can support renewable generation in their areas as outlined within the Government's recent paper 'Net Zero Strategy: Building Back Greener.

To allow any form of larger scale generation, including a lot of roof solar installations and battery storage solutions, the capacity of the grid network would need improving and the connection costs to local communities would need to be spread amongst generators.

Given the predicted increase in energy demand we need to explore the feasibility of producing some of the increased demand within the Hope Valley. One part of the solution would be to increase the uptake of solar PV on the roofs of homes in the Hope Valley. If one out of every six houses were to incorporate a 4 kW system, 750 tonnes of CO_2 could be saved annually. Incorporating batteries alongside each insulation, would give more value to householders and would allow peak shaving and load leveling through future flexible DNO energy management systems. Country wide uptake of home battery storage systems could allow the decommissioning of some of the dirtiest forms of energy generation.

Table 18.2 Electricity generation and emission reduction in the Hope Valley

	1 in 6 homes
Number of homes with PV panels	1049
Domestic installed solar capacity (MW)	4.2
Annual generation solar capacity (MWh)	3567
Annual CO_2 emission saving (tonnes)	750

We also need to investigate if there is a place for larger scale renewables, and if so, what sources would be the most beneficial and acceptable to the whole community, recognising the importance of landscape sensitivity in the Peak Park.

We need to work together to explore the feasibility of producing some of the increased base electricity demand whilst striving to be innovative and adaptive to establish what works in the context of this local, national and global challenge.

Appendix A Glossary

AC	Alternating current
ASHP	Air source heat pump
CCAS	Carbon capture and storage
CCC	Climate Change Committee
CoP	Coefficient of performance
DC	Direct current
DNO	Distribution network operator
DoD	Depth of discharge
EMI	Electromagnetic interference
FES	Future energy scenario(s)
FIT	Feed-in-tariffs
GWh	Gigawatt hour
HAWT	Horizontal axis wind turbine
HD	High density
HVCA	Hope Valley Climate Action
IPCC	Intergovernmental Panel on Climate Change
kW	kilowatts
LCOE	Levalized cost of electricity
MWh	Megawatt hour
NG	National Grid
PV	Photovoltaic
SEG	Smart Export Guarantee
VAWT	Vertical axis wind turbine
CO_2	Carbon dioxide
V2G	Vehicle to grid

Appendix B Future energy scenarios

The main assumptions for each scenario are based around two of the scenarios within the National Grids ‘FES 2020 Scenario Framework’. Scenario A and B are based on their ‘Consumer Transformation’ however, scenario B has several adjustments as outlined in B2 below.

Scenario C is based upon the National Grid’s ‘Steady Progress’ scenario, although it may have been more appropriately named as ‘Business as Usual’, as the measures within this scenario will not achieve Net Zero in 2050. An adjustment was also made to scenario C as outlined in B3.

B1. Assumptions under scenario A

- Decarbonisation becomes the top policy goal, supported, and sustained by a concerned and engaged public
- High development of renewable and low carbon (or negative carbon) technologies but geared slightly towards smaller, more decentralised projects.
- Home heating and domestic vehicles largely electrified
- High consumer engagement in smart systems, tariffs, and energy storage
- Vehicle to Grid adoption levels high
- Consumers are highly engaged in smart charging and vehicle-
- to-grid (V2G).
- Charging predominately happens at home.
- There is more consumer demand for both autonomous vehicles and public transport.
- Substantial increase in energy efficiency measures within every home
- Lower end-user energy demand
- Increased renewable energy generation required
- 40% of homes with heat pumps will have thermal storage
- Good progress in electrical efficiency of appliances which meet the EU 30% target.
- Consumers rapidly move towards smaller or more portable appliances.
- A GB-wide insulation programme implemented that requires minimum efficiency standards which regions are incentivised to exceed.

B2. Assumptions under scenario B

- Domestic vehicles largely electrified, however 30% of homes are still heated by gas in 2050 due to more complexity making old rural detached properties energy efficient (external insulation on top of the stone face of many older traditional buildings is not desired by homeowners)
- Decarbonisation becomes the top policy goal, supported, and sustained by a concerned and engaged public
- High development of renewable and low carbon (or negative carbon) technologies but geared slightly towards smaller, more decentralised projects.
- High consumer engagement in smart systems, tariffs, and energy storage
- Vehicle to Grid adoption levels high
- Consumers are highly engaged in smart charging and vehicle-
- to-grid (V2G).
- Charging predominately happens at home.
- There is more consumer demand for both autonomous vehicles and public transport.
- Substantial increase in energy efficiency measures within most homes
- Lower end-user energy demand
- Increased renewable energy generation required
- 40% of homes with heat pumps will have thermal storage
- Good progress in electrical efficiency of appliances which meet the EU 30% target.
- Consumers rapidly move towards smaller or more portable appliances.
- A GB-wide insulation programme implemented that requires minimum efficiency standards which regions are incentivised to exceed.

B3 Assumptions under scenario C

- 25% of cars are still run-on fossil fuel by 2050 as the costs of electric cars makes those on lower incomes are more likely to keep older cars on the road
- Slower transition towards decarbonisation means traditional sources of supply continue to be used for a longer period.
- No strong mandate from public for strong decarbonisation drive and thus no step change in policy
- Historic progress in residential electrical efficiency - EU targets missed.
- Low consumer engagement in smart systems, tariffs, and energy storage
- Consumer resistance and other barriers means the uptake of electric cars is slower.
- There is low growth in public transport due to a lack of consumer willingness to mode shift.
- Vehicle-to-Grid adoption levels are low
- Consumers buy similar appliances to today.
- Incentive schemes are not extended, and supply chain doesn't get the chance to mature and develop
- Strong bias towards status quo technologies not overcome and gas boilers remain dominant
- Heat networks not decarbonised and remain largely unregulated.
- Gas remains very cheap at the point of use
- Energy efficiency programmes remain focused on addressing fuel poverty

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