Wedmore energy study

Final report

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Section 1 - introduction

Background

This report presents the findings of a study undertaken on behalf of Green Wedmore. It follows a proposal first presented in April 2017, and subsequently revised in March 2019 following a successful application for grant funding.

This study develops work and initiatives previously undertaken by Green Wedmore and other local community groups including a community woodland, community-scale renewable energy projects, provision of electric vehicle charging points, and a variety of engagement activities including an 'energy day' and pop-up advice shop.

Study objectives

On the basis of the available funding, the following objectives were agreed for this project:

- To establish a baseline for energy consumption and carbon emissions in the study area.
- To estimate how much energy is generated renewably in the study area.
- To examine the options for meeting the annual demand for energy for power, heat and transport without adding to carbon emissions.
- To produce an interim report (draft and final version) summarizing the findings and conclusions.

This is the final report for this phase of the study.

Structure and scope of the report

For ease of reading the main body of the report is divided into sections with additional information in the Appendices. The study itself has entailed desktop rather than empirical research, drawing where-possible on local data and extrapolating from national data and statistics as required. Figures for energy consumption and energy generation are presented for the study area as a whole. With the intention of making these more meaningful and a comparison between different energy uses and sources more straightforward, they are also expressed as daily averages per household and per person.

Because much of the data in the report is based on information derived from regional or national statistics, barring the odd exception actual figures for households and individuals in the study area will be somewhere either side of the figures presented here. The only way of providing numbers which reflect actual consumption patterns more closely would be to collate data for ***actual*** consumption and generation in residential and non-residential buildings over a year or more; something which is beyond the scope of this study. Nonetheless, it is hoped that the information provided here will be a good starting point for anyone wishing to review their own energy consumption and generation and for Green Wedmore to consider the scale of intervention required to meet the energy needs of the area without using fossil fuels.

Section 2 - methodology

This section explains how estimates of energy demand, CO_2 emissions and renewable energy generation have been obtained. Supporting information is provided in Appendix 1.

Study area

The study area was defined as including the following villages and hamlets:

Wedmore	Blackford	There
Sand	Westham	Heath House
Little Ireland	Panborough	Mudgley
Clewer	Cocklake	Crickham
Bagley	Chapel Allerton	Stone Allerton

The postcodes for each of these settlements were obtained using an on-line postcode finder and are listed in Appendix 1.

Estimating number of households and population in the study area

The number of households and population in Wedmore parish has been taken from the Wedmore Housing Need - Approved Final Report November 2018, which lists 1,398 households and a population of 3,318 with the latter taken from the 2011 Census. Energy demand per household has been scaled according to the population figures for Wedmore.

Energy consumption data

The Department for Business Energy and Industrial Strategy (BEIS) provides two data sets which can be used to estimate domestic energy demand in a given locality; consumption by postcode area, and consumption by Lower Super Output Area (LSOA). Lower Super Output Area is a statistical area of about 1,500 people with the boundaries defined such that the population in each is approximately the same. The most recent complete data sets BEIS provides, are for 2017.

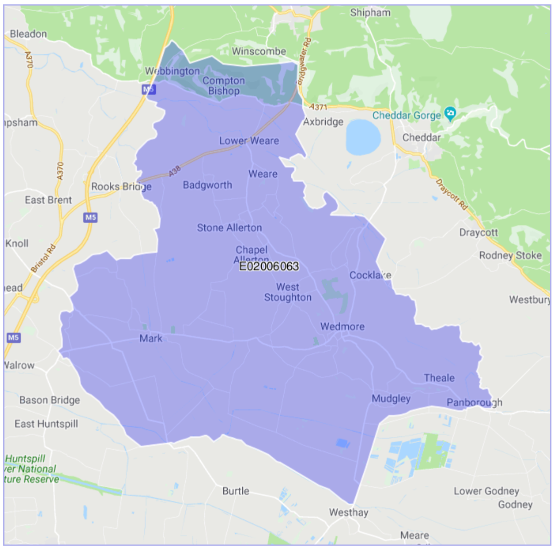
BEIS describe the postcode data as 'experimental' and state that this excludes some meter points with very low or very high consumption - in other words it may not provide a complete picture of consumption in a given postcode area, though it does include a breakdown of electricity usage by Economy 7 meter.

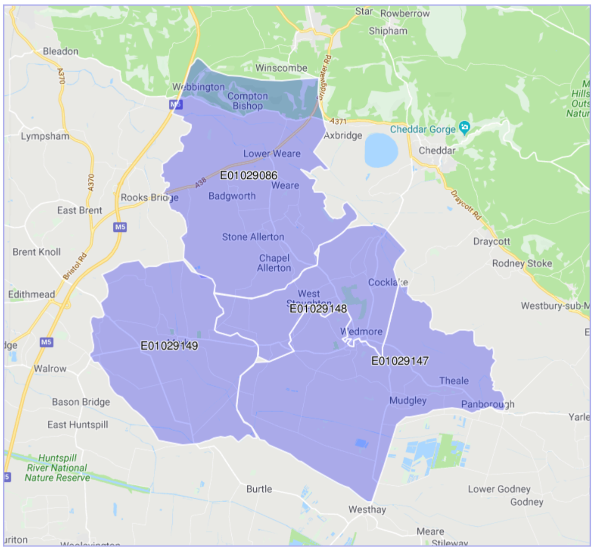
Whilst electricity and gas consumption by LSOA is more established than data by postcode, the LSOA boundaries do not match the study boundary exactly - so as with postcode areas, LSOAs do not provide a complete picture of the study area.

Given that neither of the BEIS data sets provide exactly what is needed to estimate annual energy demand for this study, both these methods were used to estimate energy consumption ***per household;*** which allowed a comparison and 'sense-check' of the outputs.

The Housing Need Assessment (2018) was used to obtain the number of households and population in the study area, which was then combined with the per household data to obtain the energy consumption in the study area as a whole.

The LSOA codes were identified using Energy Map[1] - a free, on-line tool for access energy related data. The maps below (from Energy Map) show the Middle Super Output Area (left) and Lower Super Output Areas (right) covering the geographical region of this study.





Graphics showing Middle Super Output Area (left) and Lower Super Output Areas courtesy Energy Map.

The LSOA codes are:

i. E01029086 - Stone Allerton

ii. E01029149 - Mark

iii. E01029148 West Stoughton and Wedmore

iv. E01029147 - Latcham

The second of these, E01029149, was excluded from the summary as the boundary is largely outside the study area.

[1] http://energymap.theconvergingworld.org/energymap/main

Estimating fuels used for heating and hot water by household

Just over half the households in the study area are on mains gas (see Findings below). For households ***not*** on mains gas, or using Economy 7 it has been assumed that oil, or solid fuel will be the primary means of providing space heating and domestic hot water.

It has also been assumed that the vast majority of households will have a single standard electricity meter for their domestic consumption meaning that the number of standard electricity meters is equivalent to the number of households in a given locality.

The number of homes using oil, or solid fuel for heating has been estimated by taking the total number of households with a standard electricity meter then deducting those on gas and Economy 7.

In the remainder of households the number using oil and solid fuel for heating has been estimated from national statistics as has the split between those using wood and coal (which is taken to include smokeless coal).

Estimating energy demand for transport

A practical difficulty in approximating energy usage and CO_2 emissions from private vehicles is that petrol and diesel consumption is not metered or recorded per car or driver. Estimates of demand are reliant on local surveys or projections from national data.

Whilst there have been local transport surveys these are relatively old[2] and do not provide a useful breakdown of energy demand or emissions.

For this reason, domestic transport energy consumption and emissions have been estimated from national data as follows:

- Car ownership and annual average mileage in the study area has been estimated from car ownership per capita using national statistics. Similarly, the percentage of electric vehicles has been estimated from national statistics as have annual average mileages.
- For domestic petrol and diesel cars the split between fuel type has been based on national statistics.
- Average fuel consumption for the fleet of domestic vehicles - that is both newer and older vehicles are not published annually so have been estimated from figures given in Sustainable Energy Without the Hot Air[3] with a 5% allowance for efficiency improvements since publication.
- The fuel efficiency of diesel, and petrol vehicles has been used to estimate the total annual fuel consumption based on average mileages.

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[2] For example https://www.sedgemoor.gov.uk/media/1408/Somerset-Road-Safety-Partnership-Casualty-Review-2007-2009/pdf/Casualty_Review_2014.pdf?m=636350358874200000

[3] Source: Sustainable Energy Without The Hot Air, David J.C. MacKay Chap 3, page 31, note 29, https://www.withouthotair.com This figure was for UK cars in 2005. The mpg figure has been increased by 5% to allow for improvements since 2005.

- Gross calorific values for petrol and diesel have been used to convert fuel consumption into annual energy consumption for internal combustion engine (ICE) vehicles.
- Average efficiencies of electric vehicles have been used to estimate the annual electricity consumption per kilometre.

Converting energy demand into CO_2 emissions

Estimates of domestic household and transport energy demand have been converted into CO_2 emissions using the following carbon factors:

Energy source/fuel	Carbon factor	Information source
Grid electricity	0.28307 kg CO_2e per kWh	Carbon conversion factors condensed set 2018 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018
Mains gas	0.18396 kg CO_2e per kWh (gross CV)	As above
Domestic heating oil	0.24665 kg CO_2e per kWh (gross CV)	As above
Domestic coal	0.34473 kg CO_2e per kWh (gross CV)	As above
Wood (logs)	0.01506 kg CO_2e per kWh	As above
Petrol	2.392 kgCO_2/litre	http://ecoscore.be/en/info/ecoscore/co2
Diesel	2.640 kgCO_2/litre	As above

Section 3 - baseline demand & CO_2 emissions

The following section provides estimates of current energy demand and CO_2 emissions. This excludes renewable energy generation except heat generated by burning wood and using heat pumps which is covered in the following section.

Heat and power

Estimated annual energy consumption per household

Estimates of annual energy consumption by household by fuel type were made by combining data from the two sources above. These are summarised below with a further breakdown provided in Appendix 1.

- Average annual electricity consumption per household[4] (standard tariff) (kWh/yr): 4,736
- Average annual E7 electricity consumption per household[5] Economy 7 heating (kWh/yr): 7,485
- Average annual gas consumption per household on mains gas (kWh/yr): 18,131

Comparing the two methods figures for estimated annual gas consumption are within 2% and those for electricity consumption within 10% of each other.

Break-down of heating fuel by household

Based on the number of households in Wedmore parish (in the Housing Need Assessment) the breakdown of (primary) fuel used by household is as follows:

<table>
<tr><th>Heating fuel type</th><th>Number of households based on BEIS postcode data</th><th>Number of households scaled based on Wedmore Housing Need Assessment</th><th>Notes</th></tr>
<tr><td>Mains gas</td><td>575</td><td>744</td><td rowspan="6">Scaling assumes that the ratio of different fuel types estimated from the BEIS postcode data remains unchanged for the whole study area.</td></tr>
<tr><td>Economy 7</td><td>29</td><td>38</td></tr>
<tr><td>Heating oil</td><td>389</td><td>503</td></tr>
<tr><td>Wood</td><td>7</td><td>9</td></tr>
<tr><td>Coal (including smokeless)</td><td>80</td><td>104</td></tr>
<tr><td>Total</td><td>1080</td><td>1398</td></tr>
</table>

[4] Single figure rather than average from the two approaches.

[5] Single figure rather than an average from the two approaches.

It is assumed that annual consumption of energy for heat and hot water in homes with oil or solid fuel will on-average, be similar to homes with gas heating[6].

Annual energy use for power and heating in the study area

Excluding energy use for personal transport (which is covered below) the break-down of energy use for power and heating is as follows:

Type of energy use	Number of households	Annual average energy use per household (kWh/annum)	Estimated annual energy usage in the study area (kWh/annum)
Standard electricity	1398	4,736	6,620,928
Mains gas	744	18,131	13,489,464
Economy 7	38	7,485	284,430
Heating oil	503	18,131	9,119,893
Wood (logs)	9	18,131	163,179
Coal (including smokeless)	104	18,131	1,885,624

Notes

- 'Wood' refers to logs, and their use as the primary source of heat and hot water rather than for secondary heating.
- Coal includes smokeless fuels such as anthracite.
- The annual energy requirement for homes ***not*** on mains gas and ***not*** using Economy 7 heating has been assumed to be the same as the average home with gas heating.
- Based on BEIS data there is a significant difference between the annual heating and hot water requirements in households on Economy 7 and those using other fuels. In homes with Economy 7 the demand is less than half the average demand in homes with gas. This implies that homes with Economy 7 are smaller (i.e. more likely to be flats) and possibly newer than the average property in the study area. It is also possible that in dwellings with Economy 7 additional top-up heating is being provided using standard electricity.

[6] Assuming that heating appliances range in age and efficiency.

- Standard electricity consumption at 4,736kWh is higher than the national average of 3100[7]kWh per annum. There are a number of possible reasons for this difference:
    - Dwellings in Wedmore parish may be larger than the national average.
    - There are slightly more people per household on average in the study area (2.37 persons per household) than nationally (2.30 per h.h).
    - In homes without gas, electricity may be used to provide additional top-up heating increasing annual demand.
    - In homes with Economy 7 heating, standard rate electricity may be being used to provide top-up heating.

Average daily energy usage

Calculating average daily usage per household and per person may help to make the numbers more meaningful as well as allowing a comparison with other energy demands such as transport and energy generation from renewables.

The figures are as follows:

Type of energy use	Annual average energy use per household (kWh/annum)	Average daily use per household (kWh/household.day)	Average annual energy usage per head (kWh/head.annum)	Average energy usage per head per day (kWh/head.day)
Standard electricity	4,736	13	1,995	5
Mains gas	18,131	50	7,639	21
Economy 7	4,937	21	3,154	9
Heating oil	18,131	50	7,639	21
Wood (logs)	18,131	50	7,639	21
Coal (including smokeless)	18,131	50	7,639	21

Notes

- Figures are rounded to the nearest whole number.

[7] https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values Typical Domestic Consumption Value - medium figure based on average consumption in 2017 (Electricity Profile Class 1). Ofgem

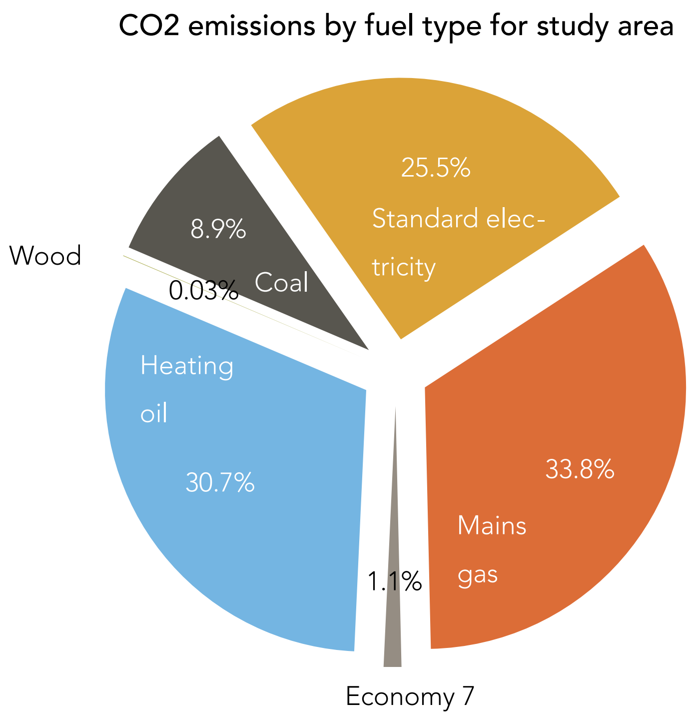
- Figures for ***Annual average energy usage per head*** (kWh/head.annum) are calculated by taking ***Estimated annual total usage*** (kWh/annum) for households using that fuel type in the study area divided by ***Number of individuals living in households using that fuel type***.
- For comparison purposes daily averages assume that energy demand is evenly distributed throughout the year.

CO_2 emissions from heat and power

Based on the carbon factors in the previous section estimated CO_2 emissions are as follows:

Type of energy use	Estimated annual average CO_2 emissions per household (kg/annum)	Estimated average annual CO_2 emissions for the study area (kg CO_2 annum)
Standard electricity	1,341	1,874,186
Mains gas	3335	2,481,522
Economy 7	2,119	80,514
Heating oil	4472	2,249,422
Wood (logs)	273	2,457
Coal (including smokeless)	6250	650,031
Sub-total (kg)		**7,338,132**
Sub-total (tonnes)		**7,338**

The breakdown of CO_2 emissions by fuel type for the study area is shown in the pie chart below:



Transport

Energy usage for transport

Based on national statistics the estimated energy demand for personal (rather than commercial) transport is as follows:

Category	Value	Notes/Source
Average car ownership per person in the UK (cars per person)	0.47	Calculated from population and statistics on car ownership Source: Vehicle licensing statistics (Quarter 2) April to June 2016 for related statistics https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551499/vehicle-licensing-april-to-june-2016.pdf See also https://www.racfoundation.org/motoring-faqs/mobility#a24
Estimated car ownership in the study area (number of cars)	1,552	Calculated figure
Estimated number of battery electric vehicles in the study area	8	Based on 0.5% of vehicles in the 'fleet' being battery electric. Excludes PHEV - plug-in hybrid electric vehicles - see commentary below for explanation.
Percentage of diesel cars in the fleet (%)	39	Source: Vehicle Licensing Statistics: Annual figure for 2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/608374/vehicle-licensing-statistics-2016.pdf
Annual average mileage per car in UK (miles per annum)	7,800	Source: https://www.racfoundation.org/motoring-faqs/mobility#a24
Annual average distance travelled per car in UK (km per annum)	12,553	Calculated figure
Estimated total annual distance travelled by all petrol and diesel cars in the study area (km)	19,380,241	Calculated figure
Estimated total annual distance travelled by battery electric vehicles in the study area (km)	97,388	Calculated figure
Average fuel efficiency of all petrol cars (mpg)	33	Figure for the fleet as a whole, across all types of driving - see commentary below.
Average fuel consumption of all diesel cars (mpg)	41	See above

Category	Value	Notes/Source
Energy required per 100 passenger km for average petrol car (kWh)	86	Calculated figure based on calorific value
Energy required per 100 passenger km for average diesel car (kWh)	76	As above
Energy require per 100 passenger km for average electric car (kWh)	19	Estimated figure. Sustainable Energy Without the Hot Air estimates consumption to be 15kWh. Information provided on-line suggests EV drivers require 19kWh per 100 p km under real-world driving conditions.
Estimated energy content of fuel used annually by petrol cars in the area (kWh)	10,121,596	Calculated figure based on gross calorific value
Estimated energy content of fuel used annually by diesel cars in the area (kWh)	5,727,345	Calculated figure based on gross calorific value
Estimated energy content of fuel used annually by electric cars in the area (kWh)	18,504	Calculated figure based on average energy requirement per 100 passenger km

Notes

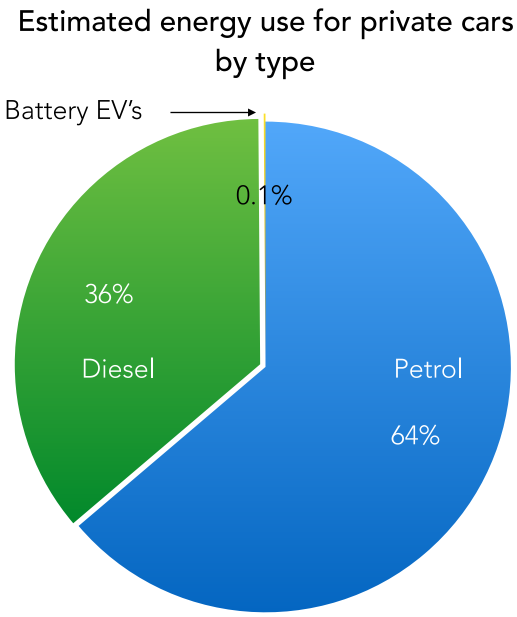
- Energy consumption figures in the table are from a calculation spreadsheet and rounded to the nearest whole number.
- The unit of '100 passenger km' is a standard way of comparing energy demand in vehicles and units of 'transportation'.
- Plug-in hybrid electric vehicles have been excluded from the total number of battery electric vehicles. Whilst the majority of plug-in vehicles sold to date in the UK have been plug-in hybrids rather than pure electric vehicles, recent reports suggest that the distance travelled in EV mode is significantly lower than had been assumed. A PHEV driven in petrol or diesel mode will have a higher energy consumption (lower mpg figure) and higher emissions than a conventional petrol or diesel car due to the additional weight of the battery. As it is difficult to estimate how PHEVs are used they have been excluded from these calculations.
- The average fuel efficiency of petrol and diesel vehicles is an estimate for the fleet as a whole i.e. it takes account of the age of the fleet and variation in efficiency across the whole fleet. Research suggests that average efficiencies under real world conditions are significantly lower than those derived under test conditions for both new and used vehicles and influenced by a range of factors including driving style and behaviour.

- The average energy consumption of electric vehicles is based on figures in Sustainable Energy Without The Hot Air[8], and slightly increased on the basis of information quoted by EV drivers on-line, for real world conditions.

Average daily energy demand for transport in the study area

The table and pie chart below show the average energy use attributed to the driver of the vehicle[9] per year and per day.

Type of vehicle	Estimated number of vehicles in the study area	Estimated annual energy consumption for all vehicles in the study area (kWh/annum)	Estimated annual energy use per driver (kWh/ person.annum)	Estimated daily energy use per driver (kWh/ person.day)	Notes
All vehicles	1,552	15,869,445	10,225	28	Figures assume 1 driver per car
Petrol cars	942	10,121,596	10,745	29	
Diesel cars	602	5,729,345	9,517	26	
Battery electric cars	8	18,504	2,313	6	



[8] Sustainable Energy Without the Hot Air suggests a figure of 15kWh per 100 passenger km, this has been adjusted to 19kWh per 100 passenger km based on experience of EV drivers. As with internal combustion engine vehicles energy usage is strongly influenced by driving style and behaviour.

[9] Calculations of this type are generally presented on the basis of one person (i.e. the driver) per vehicle. The most straight-forward means of reducing vehicle emissions per head is to increase the number of people in each vehicle for example by car-sharing.

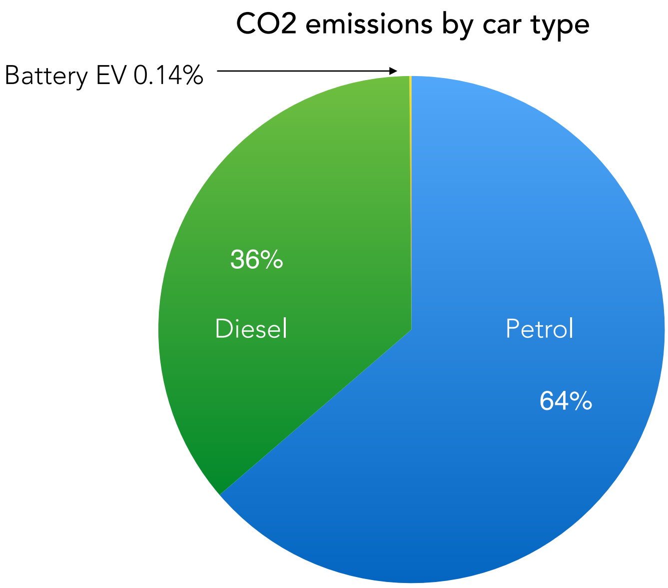
Notes

- The figures for annual and daily energy consumption for petrol, diesel and battery electric vehicles illustrate the energy efficiency benefit of EV's. Electric vehicles are nearly five times more efficient at converting chemical energy[10] into movement than petrol cars and four times as efficient as diesel cars.

Estimated CO_2 emissions from personal transport

The table and pie chart below provide an estimate of the CO_2 emissions arising from personal transport excluding public transport[11].

Type of vehicle	Estimated number of vehicles in the study area	Estimated annual CO_2 emissions for all vehicles in the study area (kWh/annum)	Estimated annual CO_2 emissions per driver (kWh/ person.annum)	Estimated daily CO_2 emissions per driver (kWh/ person.day)	Notes
All vehicles	1,552	3,801,367	2,449	7	Figures assume 1 driver per car
Petrol cars	942	2,421,086	2,570	7	
Diesel cars	602	1,375,043	2,284	6	
Battery electric cars	8	5,238	655	2	



[10] Meaning the energy stored in a battery.

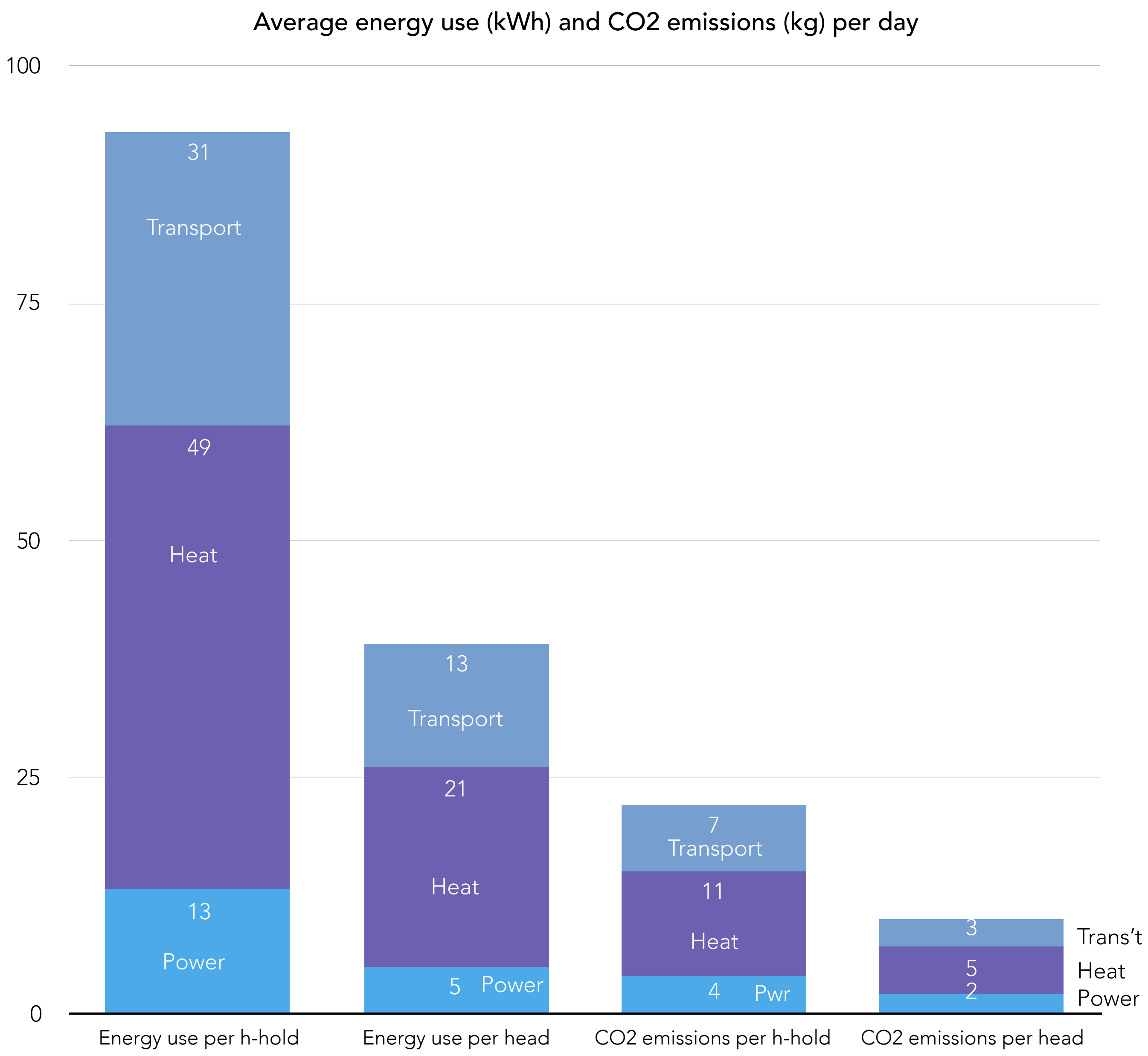
[11] The very small quantity of emissions from other forms of transport such as bicycles are also excluded from this figure.

Summarizing energy demand and CO_2 emissions by household and per person

The tables above estimate energy use for heat, power and transport by fuel type, and by household and per head on an annual and daily basis.

Taking the figures for ***total*** energy use for heat, power and transport in the study area and dividing this by the total number of households and total population of the study area gives an average daily consumption per household and per head. These figures are presented before the application of any energy efficiency measures. Energy consumption from Economy 7 heating is included under 'heat'.

The graph below shows the baseline of estimated daily (total) energy use for power, heat and transport and related CO_2 emissions.



Note

- Average per heat energy use and emissions for transport are calculated for the whole population in the study area i.e. not only drivers

Section 4 - existing renewable energy capacity

Renewable power

Domestic scale PV

Initially the number of roof-mounted PV systems in the study area was estimated from Micro-generation Certification Scheme data[12]. Though this does not record installations at postcode or LSOA level, cumulative installations are recorded by local authority area and were used to estimate installed capacity.

The amount of electricity generated annually per kilowatt peak (kWp) of installed capacity was also derived from the MCS[13], assuming that panels are south facing with a tilt of 33 degrees from horizontal.

The estimate based on the Sedgemoor data is as follows:

Local authority area	Estimated number of households	Installed capacity (kWp)	Installed capacity per household (kWp/ household)	Number of households in study area	Projected installed capacity in study area (kWp)	Assumed annual yield per kWp of installed capacity (kWh)	Projected annual yield for projected installed capacity (kWh)
Sedgemoor	53,318	10,122	0.1896	1,398	265	947	251,036

Green Wedmore have since provided their own estimate of domestic scale installations, which is shown in the table below:

[12]Sub-national Feed-in Tariff Statistics - December 2018. Department for Business, Energy and Industrial Strategy

[13]Guide to the Installation of Photovoltaic Systems www.microgenerationcertification.org

Settlement	No of houses	No of 4kWp domestic PV installations	Estimated peak capacity (kWp)	%age of houses with PV
Bagley	53	2	8	4%
Blackford	181	17	68	9%
Chapel Allerton	64	11	44	17%
Clewer	31	5	20	16%
Cocklake	76	10	40	13%
Crickham	35	5	20	14%
Heath House	51	10	40	20%
Latcham	30	2	8	7%
Little Ireland	7	1	4	14%
Mudgley	34	3	12	9%
Panborough	36	6	24	17%
Sand	30	4	16	13%
Stone Allerton	122	12	48	10%
Stoughton Cross	12	2	8	17%
Theale	97	8	32	8%
Wedmore	578	45	180	8%
Westham	20	2	8	10%
West Stoughton	41	2	8	5%
Total	**1457**	**145**	**580**	**10%**

As the estimated peak capacity of 580kWp is based on 1457 households this has been reduced by a factor of 0.96 to reflect the 1398 households identified in the study area. This gives an estimated peak output of 557kWp and estimated annual yield of 527,479kWh per annum (assuming the annual yield is 947kWh per kWp of installed capacity before inverter losses).

Larger scale PV

The table below shows the larger scale installations in the study area. Yields from these installations have been estimated as above with the exception of the 1MW Wedmore Community Power Cooperative solar farm for which energy generation data has been provided[14].

[14] Between 2nd November 2013 and 29th April 2019 the solar farm generated 4.9GWh of electricity. In an average year the system is expected to generate 0.892GWh of electricity (892MWh, or 891,575kWh).

Installation	Installed capacity (kWp)	Project annual yield per kWp (kWh/kWp)	Projected annual yield (kWh/annum) before inverter losses
Wedmore CPC solar farm	1,000	See footnote 14	891,575
Middle School, Hugh Sexeys	30	947	28,410
Wedmore Primary School	20	947	18,940
Bowls Club and Tennis Club	12	947	11,364
Village Hall	4	947	3,788
Sports Pavilion	20	947	18,940
Solar farm - Theale	5,000	947	4,735,000
Solar farm	100	947	94,700
Tracking solar installation	30	1,231	36,933
Bagley Church (building)	4	947	3,788
Sub-total			**5,843,438**

Combining domestic roof-top and the larger-scale installations above gives the following estimated combined outputs:

PV Installation	Installed capacity (kWp)	Project annual yield per kWp (kWh/kWp)	Projected annual yield (kWh/annum)
Domestic roof-top installations	557	947	527,479
Larger scale installations	6,220	947 (1231 for the tracking solar array)	5,843,438
Combined output before inverter losses	6,777	N/A	6,370,917
Typical inverter losses (%)	N/A	N/A	14
Combined output allowing for inverter losses	**N/A**	**N/A**	**5,478,989**

Note

- Inverters are used to convert the direct-current (DC) output from a PV array into alternating-current (AC). Because this process is not 100% efficient an allowance has been made for 'inverter losses' using a typical figure of 14%.

Wind

One wind turbine with a rated capacity of 50kW has been operational in Wedmore parish since December 2012. In that time the turbine has generated 530,000kWh of electricity giving an estimated yield of 83,684kWh per annum[15] before allowing for inverter losses. Allowing for these the estimated yield is 71,968 kWh per annum.

Combined energy output from power generating renewables

The table below shows the combined estimated output from solar PV and wind. (As above the table includes an allowance for inverter losses).

Installation type	Installed capacity (kWp)	Projected annual yield (kWh/annum)
Domestic PV	557	527,479
Larger-scale PV	6,220	5,843,438
Wind turbine	50	83,684
Combined output (PV & wind) before inverter losses	6,827	6,454,601
Typical inverter losses (%)	N/A	14
Output allowing for inverter losses (kWh)	**N/A**	**5,550,957**

Reduction in CO_2 emissions from power generating renewables

Energy generated locally from roof-mounted PV, large-scale PV and the 50kW wind turbine displaces grid electricity and can therefore be treated as reducing CO_2 emissions.

Based on an emission factor of 0.28307kg CO_2 per kWh the solar and wind generation displaces 1571 tonnes CO_2 a year.

[15] Estimate assumes that the turbine has been operational for 76months.

Impact of local renewable electricity generation on average power consumption and CO_2 emissions

As with the baseline calculations above, the impact of local (renewable power generation) can be expressed as a daily average per household and per person.

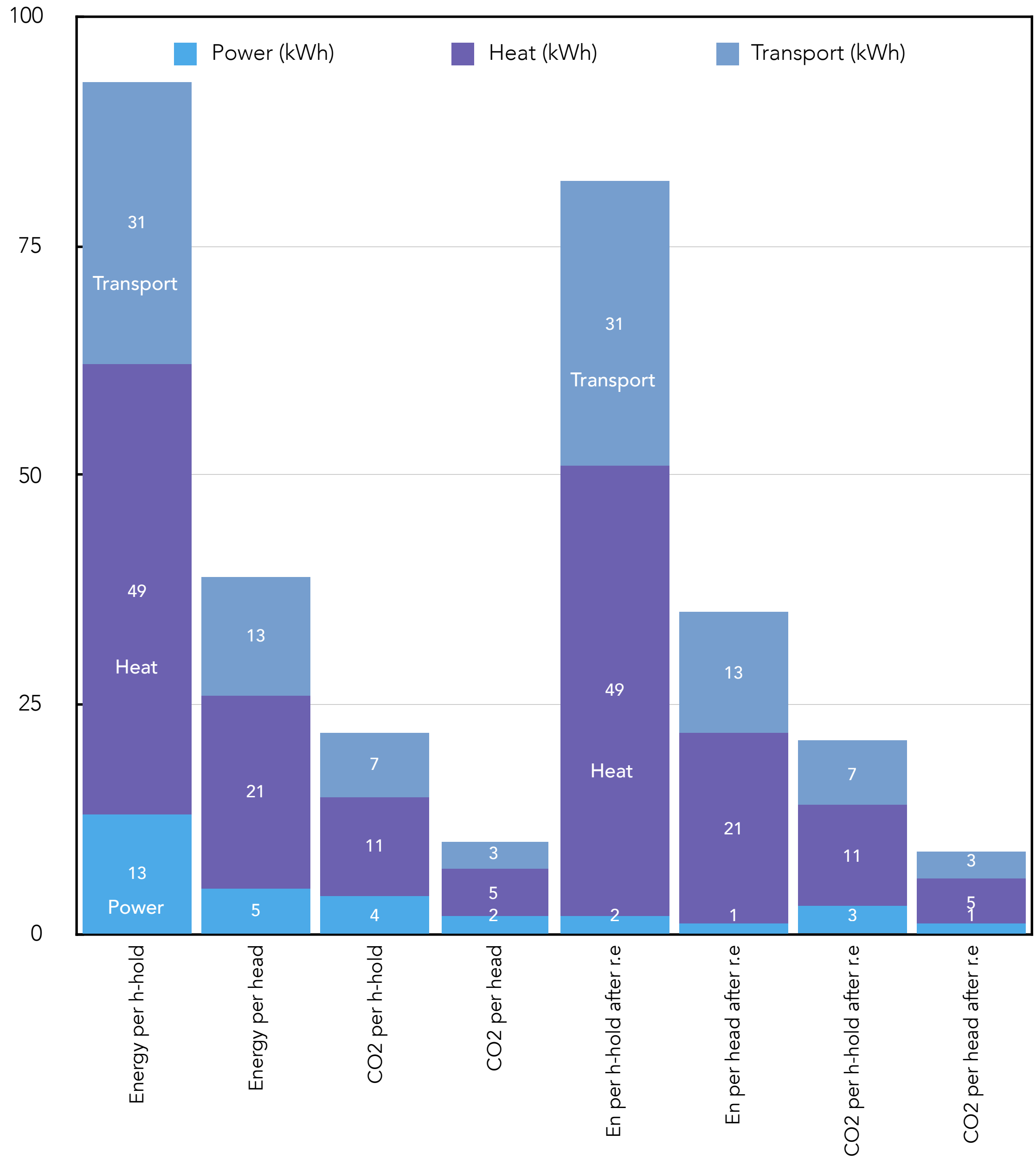
Daily energy use & CO2 emissions before and after inclusion of local r.e generation

	Baseline				With existing r.e. capacity			
	Energy use per household (kWh)	Energy use per person (kWh)	CO_2 emissions per household (kg)	CO_2 emissions per person (kg)	Energy use per household after r.e (kWh)	Energy use per person after r.e (kWh)	CO_2 emissions per household after r.e (kg)	CO_2 emissions per person after r.e (kg)
Power (kWh)	13	5	4	2	2	1	0.6	0.3
Heat (kWh)	49	21	11	5	49	21	11	5
Transport (kWh)	31	13	7	3	31	13	7	3

The effect of including local renewable power generation is to reduce average daily demand for power from 13 to 2kWh per household per day and from 5 to 1kWh per person per day.

Similarly, household CO_2 emissions from power usage fall from 4 to 0.6kg per household per day and from 2 to 0.3kg per person per day. The figures are shown graphically below.

Average energy use and CO2 emissions per day- baseline & with r.e.



Renewable heat

In this context renewable heat refers to:

- Air source heat pumps
- Ground source heat pumps
- Biomass boilers
- Solar thermal

Ofgem provide the following data on renewable heat installations accredited under the Renewable Heat Incentive (RHI) in the South West.

Total RHI accreditations per region up to Oct 2018[16]:

Location	ASHP	Biomass	GSHP	Solar thermal
South West England	4,914	1,701	1,618	1,777

Unfortunately, they do not provide anything more granular or a breakdown of the heat capacity by technology. Assuming there are approximately 5 million people living in the South West, pro-rata we could expect about 3 ASHP's to have been installed in the study area, about 1 solar thermal installation and slightly fewer biomass boilers and ground source heat pumps.

The study has identified one ground source heat pump system operating at Bagley Church. The 4kW system has been operational for 11 years and extracts heat from boreholes. It is assumed to have a heat output of 12kW[17].

Given that with the exception of Bagley Church the figures above are extrapolations, and the projected installation levels for renewable heat technologies are very low in comparison to what is a large heat demand across the study area, with the exception of appliances burning logs (which are included in the Baseline), they have been excluded from the calculations below.

[16] Domestic Renewable Heat Incentive - Quarterly report (issue 18)

[17] Assuming a coefficient of performance (COP) of 3, meaning for each unit of electricity used to operate the heat pump, 3 units of heat are emitted. The system is comprised of two 2kW heat pumps.

Section 5 - energy efficiency

The fastest, cheapest, and most effective way to reduce carbon emissions and reliance on fossil fuels is to reduce the need for energy in the first place and then to use it more efficiently, by changing behaviour and by switching to technology which produces the same output for less input.

Behaviour

Changing energy related behaviour can produce rapid reductions in energy demand at little or no cost. Research over the last 20 years into the impact of behavioural changes and how to stimulate these has shown that informing households that their energy consumption is being monitored, will for example, produce a small but measurable reduction in energy use, even without further intervention. And studies in the US have shown that providing information for householders comparing their energy consumption with that of their neighbours can produce longterm reductions in energy use of 2%.

Modest changes in the use of heating systems can also have a significant impact. Turning down a domestic heating thermostat by 1 deg C for example, can reduce heat energy consumption by 10%.

For the purposes of this exercise it has been assumed that behavioural measures would form part of a package of energy efficiency measures (including technical interventions below) to reduce energy demand. Reductions of 2% in electricity use and 5% in gas consumption ought to be achievable. Local intervention programmes might also push these reductions higher but as with other behavioural changes the challenge is engraining these so that the benefit are maintained in the long-term.

Technical measures

The effectiveness of energy efficiency measures at cutting energy use has been demonstrated beyond doubt. Measures such as roof, floor and wall insulation, draught-proofing, and energy efficient appliances are key to reducing energy demand locally and nationally.

The Committee on Climate Change regards energy efficiency as an essential part of the package of measures needed to cut carbon pollution in the UK. Critically, the less efficient our use of energy is, the more renewable energy generation capacity is required to eliminate fossil fuels.

So by how much could energy demand in Wedmore and the surrounding area be cut through energy efficiency? '***The power to transform the South West: How to meet the region's energy needs through renewable energy generation***' published in 2015 concluded that energy efficiency measures could reduce energy demand in the South West by 40%.

For comparison '***Zero Carbon Britain: Rethinking the Future***' proposed that energy demand in buildings and industry could be reduced by 52% (from 1050TWh to 510TWh) by combining a range of energy efficiency measures. And '***The 40% House***' considered what measures would be needed to reduce carbon emissions from housing by 60% in line with what was in 2005, the national carbon reduction target.

For the purposes of this exercise a reduction in energy demand of 40% through the concerted application of energy efficiency measures and behavioural change has been assumed.

One the challenges of improving energy efficiency is limiting the so-called 're-bound effect'. Reducing energy consumption through improved efficiency tends to lead to a reduction in energy running costs, the savings from which ***may*** be spent on other energy related activities which add to CO_2 emissions. For example, following the installation of wall insulation householders may choose to spend a proportion of the resultant energy savings on increasing the average internal temperature of the home, living at say 20 rather than 17 deg C.

A more extreme example would be using the financial saving from energy efficiency measures to purchase a flight. The nature and impact of the re-bound effect is very dependent on the individuals concerned but it has been shown to be real. Achieving a 40% reduction in energy demand through behavioural and technical measures may be achievable but it is likely to be challenging to maintain that level of saving over time and would require strong engagement and motivation to limit the impact of the rebound effect.

Cutting energy demand through energy efficiency - what does it mean in-practice?

Achieving a 40% cut in baseline energy demand means that every home in the study area needs to be made as energy efficient as technical measures allow.

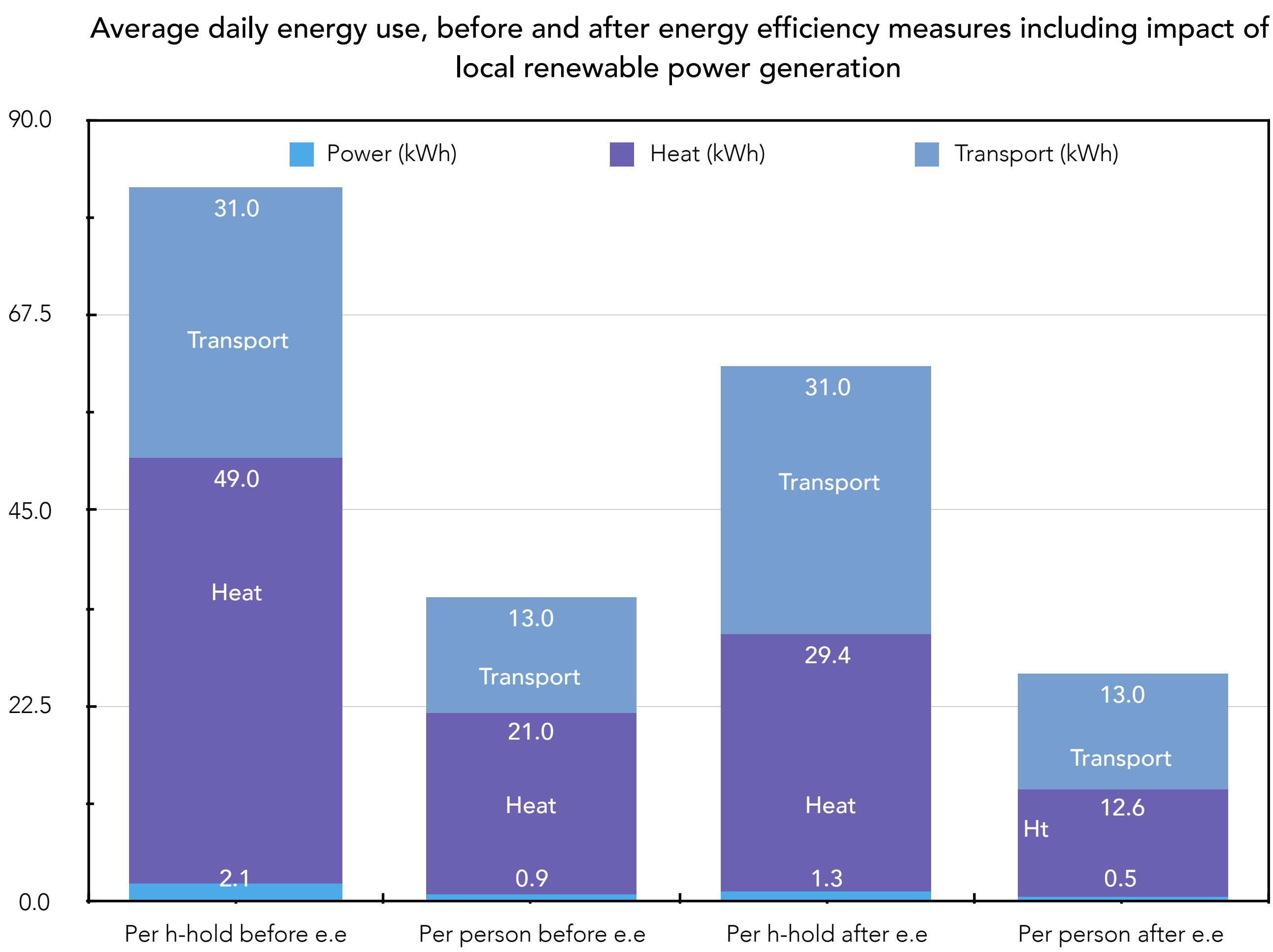
In addition to 'standard' measures such as loft and cavity wall insulation and draught-proofing, homes with solid walls will need to be insulated with external or internal wall insulation.

A study by the Centre for Sustainable Energy estimated that in the neighbouring district of Mendip 35% of homes have solid walls. If the distribution of property types is similar in Wedmore, approximately 490 homes will require solid wall insulation. The Energy Saving Trust[18] estimate external wall insulation costs around £13,000, and internal wall insulation around £7,400 per property.

[18] https://www.energysavingtrust.org.uk/home-insulation/solid-wall Figures based on a semi-detached property. Detached dwellings likely to be more expensive depending on the size of the dwelling.

Summary - the impact of energy efficiency on energy demand

The bar chart below shows the impact of a 40% reduction in energy demand through a combination of behavioural and technical energy efficiency measures. Figures take account of the impact of existing local renewable power generation listed in the previous section on the baseline requirement for power.



Transport - more efficient ways of moving people and goods

In the discussion above the average energy needed to move people in and around the study area was estimated to be about 13kWh per person per day. The 'passenger-kilometer' (p-km) is used to compare different modes of transport including their relative energy efficiency. A car carrying one person a 100km, delivers 100 p-km of transportation, and 400 p-km of transportation when it carries four people the same distance. Unlike 'miles per gallon' the lower the energy per 100 passenger-kilometers the better.

The graphic in Appendix 2 shows the energy requirement for different modes of passenger transport including aviation. The table below[19] pulls-out key figures. These are approximate and actual figures will be subject to the age, make and model of the vehicle and especially to driving style.

Mode of transport	Approximate energy requirement (kWh per 100 p-km)
Cycling	1
Walking	3.6
Electric scooter	4
Electric car (full - 5 people)	3-4
Coach (full)	6
Diesel high speed train	9
Average electric car	15-20
Average car (full)	16-23
Bus	32
Average UK car	80-114

Even allowing for the ranges shown it is possible to draw conclusions on how to reduce transport energy demand in Wedmore:

- The easiest way of improving the 'per person' energy efficiency of vehicle transport is to fill the vehicles.
    - Reducing the number of vehicles on the road brings the added benefits of reducing congestion as well as local air pollution.

[19] Source: David JC MacKay 'Sustainable Energy Without the Hot Air'. http://www.withouthotair.com/c20/page_128.shtml

- For short journeys encouraging people to cycle, walk or use electric bikes/scooters instead of driving produces a huge boost in efficiency. A bike is 80 to 100 times more energy efficient than a car per passenger-km.
- For longer journeys there is a similar uplift in efficiency from switching from cars to public transport.
- Electric cars are about four to five times more energy efficient than the average fossil fuel (petrol/diesel) car.
- Increasing the number of journeys on foot and bike would reduce the transport energy demand and car-sharing could make a significant further reduction.

There are two added benefits of switching to electric vehicles. Firstly, it eliminates exhaust pipe emissions which would significantly improve local air quality close to major thoroughfares. Secondly, it provides electrical energy storage, (the cars' batteries) which could help to smooth out peaks and troughs in energy demand and maximise the energy generated from renewable sources (discussed below). A further benefit is noise reduction - electric vehicles being much quieter than their petrol and diesel equivalents - making Wedmore a quieter place in which to live and work.

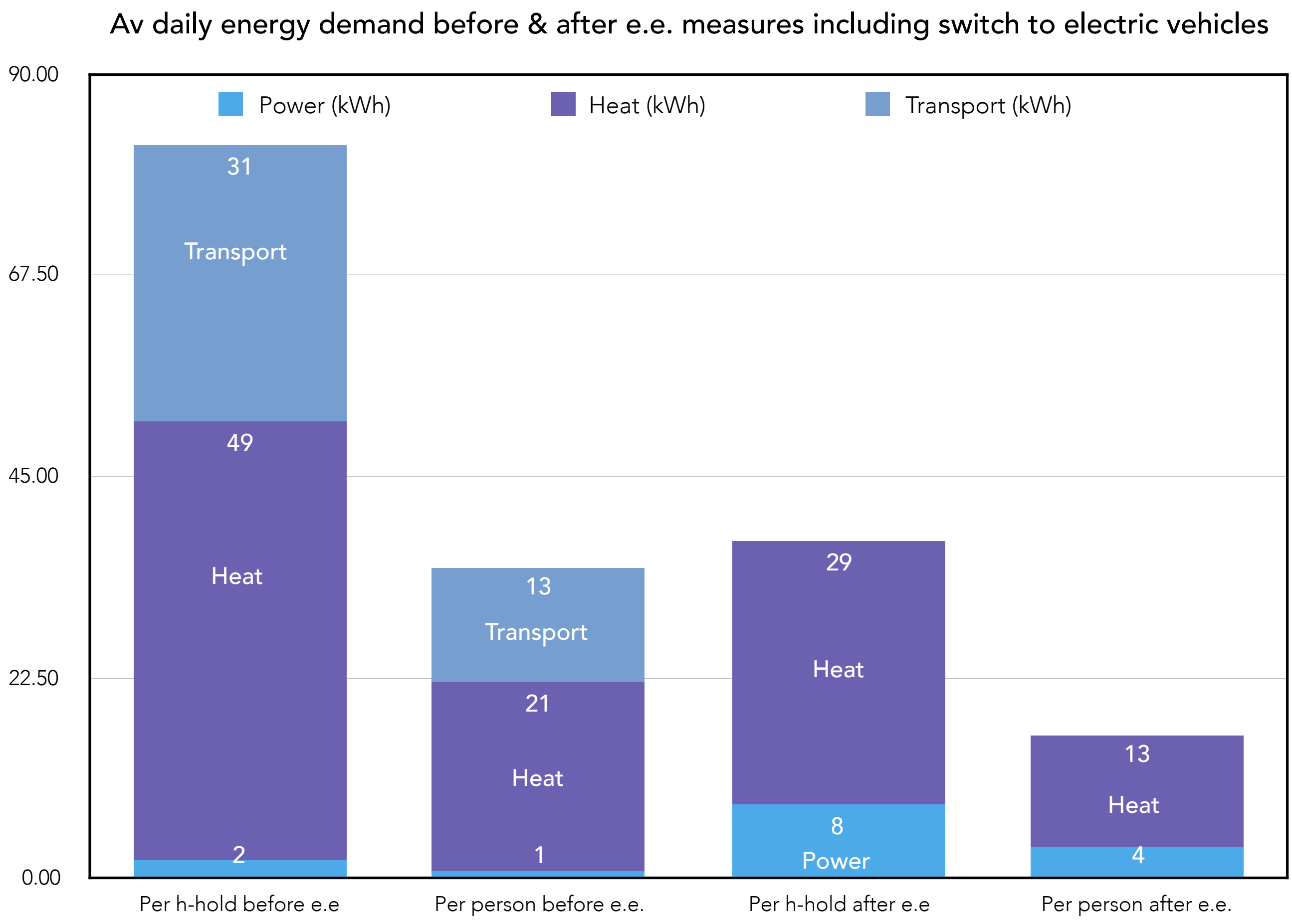
Whilst electric vehicles are much more efficient than fossil fuel cars they still require energy; and this needs to be added to the daily power requirement per household and per person in the calculations above.

The bar chart below shows the impact of switching to electric vehicles (EVs): firstly, the energy required for transport from burning petrol and diesel falls to zero and secondly, the electrical energy required to charge the EVs must be added to the power 'stack' of the graph.

The table and graph below shows the impact of electrifying cars when combined with other energy efficiency measures. The average daily power requirement increases as a result of the transition to electric cars. (As above, these figures take account of energy generated locally from existing solar PV and wind).

Av energy use per day before & after e.e. measures including switch to EVs

	Per household before e.e. measures	Per person before e.e. measures	Per household after e.e. measures	Per person after e.e. measures
Power (kWh)	2	1	8	4
Heat (kWh)	49	21	29	13
Transport (kWh)	31	13	0	0
Total	82	35	38	16



Notes

- Calculations in the table and graph above assume that all petrol and diesel cars are replaced by battery electric vehicles.

Section 6 - new renewable energy generation

New renewable power generation

Having considered how energy demand could be reduced through energy efficiency, and the **5,550,957kWh** of electricity generated annually from existing solar PV and wind, how could the remaining energy demand be met renewably?

Solar PV

The output of the solar PV panels is directly related to the intensity of the sunlight, which is in turn governed by latitude, the tilt and orientation of the panels, the time of day, time of year and cloud cover.

A simple way of estimating how much energy could be generated from solar PV is from the average roof area per person. For each person living in England, approximately 48m^2 of land is covered by buildings. Assuming that roughly a quarter of this is south-facing and increasing the area by 40% to allow for roof-tilt the average roof area per person is 16m^2.

Because PV panels are rectangular some of the roof space is unavailable, so the estimated area per person drops to 10m^2 per person. Ignoring any planning restrictions (such as Conversation Areas and listed buildings) what is the maximum theoretical domestic roof area available for solar PV?

10m^2 x 3318 (the population of the study area) = 33,180m^2

To avoid double counting the estimated area[20] of existing domestic (meaning residential) solar PV (2837m^2) is deducted from this figure to give a revised available area of 30,343m^2.

The ***average*** power of sunshine per square meter of south facing roof in the UK is approximately 110W/m^2. Taking the ***average*** efficiency of PV panels to be 20% the average power delivered by south-facing PV panels would be:

20% x 110W/m^2=22W/m^2

So the ***average*** power from PV roofs in Wedmore would be:

22W/m^2 x 30,343m^2 = 668kW

In an average day this would generate 668kW x 24 hours = 16,032kWh of energy.

This is equivalent to just under 5kWh per day per person[21].

[20] Based on a Sunpower SPR-E19-320 PV panel which has a peak output of 320W, and efficiency of 19.9% and panel area of 1.630m^2

[21] Based on a population of 3318 people in the study area.

Solar limitations

On paper solar PV could provide all (125%) of the daily per-person requirement for power in Wedmore which was estimated at 4kWh (allowing for ***existing*** renewable generation, the reduction in energy demand from energy efficiency and the switch to electric vehicles) with power to spare.

The calculation above is based on the ***average*** power of the sunshine on a south facing roof, i.e. it assumes that energy from the sun arrives evenly minute-by-minute throughout the course of a year. In reality the energy generated from a PV system comes mainly during the summer months and only during daylight hours, with most of that coming in the middle third of the day. So whilst roof-mounted PV could generate a lot of energy in total, to get the full benefit of this some way of storing the electricity generated in the day for use at night is needed plus other forms of power generation during the winter months when the solar resource is much smaller or non-existent. The role of electrical energy storage is discussed below.

Additional ground-mounted solar PV

Existing ground-mounted solar PV installations in the study area were listed above with the largest installation being a 5MW solar farm.

What contribution could additional field-scale PV make to the annual power requirements in Wedmore? The area required depends on the number of panels per square meter of field space, as well as the efficiency of the panels and intensity of solar radiation at the site in question.

The Wheal Jane solar PV farm in Cornwall covers an area of 3.88ha including the inverters, substation and security fencing, and has a peak output of 1.55MW.

This equates to a peak output of 0.04kW per m^2. Using the figure of 947kWh[22] of energy generated in a year for each kilowatt peak of installed PV one square meter of field scale PV (in Wedmore) would generate approximately 38kWh a year.

The estimated daily electrical energy consumption per person in Wedmore (after energy efficiency measures, existing PV capacity and electrification of cars) is 4kWh, which is 1,460kWh per year. So to meet the annual requirement ***per person*** from field scale solar would require about 38m^2 of field mounted PV (assuming no increase in roof-top PV from the current level).

A 2.34MW solar array at Wilmington Farm, installed by Bath and West Community Energy. Photo: Bath and West Community Energy.http://www.bwce.coop/projects/wilmington-farm/

Substituting fossil fuels in Wedmore would most likely be achieved using a combination of renewable technologies. But if field scale PV was the only option available meeting the power requirements of everyone

[22] The figure of 947kWh per kWp of installed capacity is higher than the peak capacity of the 1MW solar farm. The most likely reason for this is improvements in the efficiency of PV panels and inverters in the last 7 years.

in the study area would require approx 126,080m^2 (38 x 3318) of ground mounted PV. That is an area equivalent to about 12 football pitches[23].

An important difference between ground and roof-mounted PV is that the energy density of roof-mounted PV is significantly higher than ground arrays because the panels can be mounted closer together and there is no space requirement for security fencing, access paths and inverters.

A further issue is that land given over to ground-mounted PV is less available for food production, such as arable crops, (though the guidance has been amended such that only lower grade agricultural land can be used for PV). However, as demonstrated with the existing (1MW) community solar farm it is possible to design ground-mounted systems such that cattle and sheep can graze under and around the panels. The long life of ground-mounted PV systems, expected to be 20 years plus, coupled with the relative lack of disturbance during this time, also means that they can be designed to be diverse habitats which enhance biodiversity and ecological value.

Wind

On-shore wind

On-shore wind is a 'mature' technology, meaning it is well established, and has been installed and tested in the UK for over 30 years. According to RenewableUK[24] there are 7770 on-shore wind turbines in the UK with an operational capacity of 12,904MW (12,904,000kW).

On 1st April 2016 the Government ended public subsidies for on-shore wind-farms by closing the Renewables Obligation. The Government also amended the planning regulations to give local communities the final say over wind-farms. As a consequence applications for new on-shore wind turbines have reportedly[25] dropped by 94% despite the fact that (per unit of installed capacity) on-shore wind is the cheapest form of renewable energy and is, in some locations, cheaper than gas. As a result, without a change in policy the cumulative capacity of on-shore wind is expected to peak in 2020, with little additional capacity being added thereafter.

Leaving aside current policy, what contribution could onshore wind make to power demand in Wedmore? The power in the wind is proportional to the cube of the wind speed and the square of the rotor diameter. So the energy which could be generated depends on the annual average windspeed at the location in question, and the (tower) height and rotor diameter of the turbine(s).

Average windspeed increases with height above sea level. It is also reduced by buildings and natural obstructions such as trees and hedges. So to know how much energy could be generated by one or more turbines you need to know the exact location in mind and the characteristics of the windspeed at that position.

Preferably, the wind-profile (the variation in speed and direction over time) is measured over the course of a year, though a rough profile can be developed by monitoring for shorter periods. To maximise the yield from the specific

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[23] Based on the smallest Fifa approved football pitch which is of 90 X 120m in size. The population of Wedmore is taken as 3318 people.

[24] https://www.renewableuk.com/page/UKWEDhome/Wind-Energy-Statistics.htm

[25] https://www.independent.co.uk/news/uk/politics/onshore-wind-ban-lift-voters-renewable-energy-renewableuk-yougov-a8449381.html

location, the make and model of the turbine and tower height would be specified to match - as closely as possible - the wind-profile of the site.

In this case there is no specific location in mind, but a rough estimate of what wind turbines could contribute to the annual power demand in Wedmore can be developed using generic figures. The European Wind Energy Association estimate that on average a turbine with a rated output of 2.5 to 3MW would produce about 6 million kWh per year, or 16,427kWh per day.

This equates to about 5kWh per day per person in the study area. So to meet an average requirement of 4kWh per person per day would require 1 such turbine.

An alternative way of estimating the number of turbines required is in terms of 'typical' households. The same turbine would supply the power requirements of 1500 average households in Europe. Meeting the power requirements of 1398 households in Wedmore would require one such turbine which may also exceed the annual requirement.

These two approaches suggest that a single 2.5 to 3MW turbine would be sufficient to meet the average power requirements in Wedmore using wind energy alone. But as discussed above this would depend on the wind characteristics of the specific location in question, and the design of the turbine, as well as any planning restrictions on size and location.

Though the estimates of what could be achieved from wind are approximate they illustrate the difference in land-take required to meet the annual power requirement using wind and PV. In terms of footprint, wind is significantly more efficient than ground-mounted PV.

Off-shore wind

The parish of Wedmore may lack a coastline, but the 'The Power to Transform the South West' report examined the potential for off-shore wind to contribute to the power requirements in Somerset as a whole, and concluded that it could provide 29% of the county's needs.

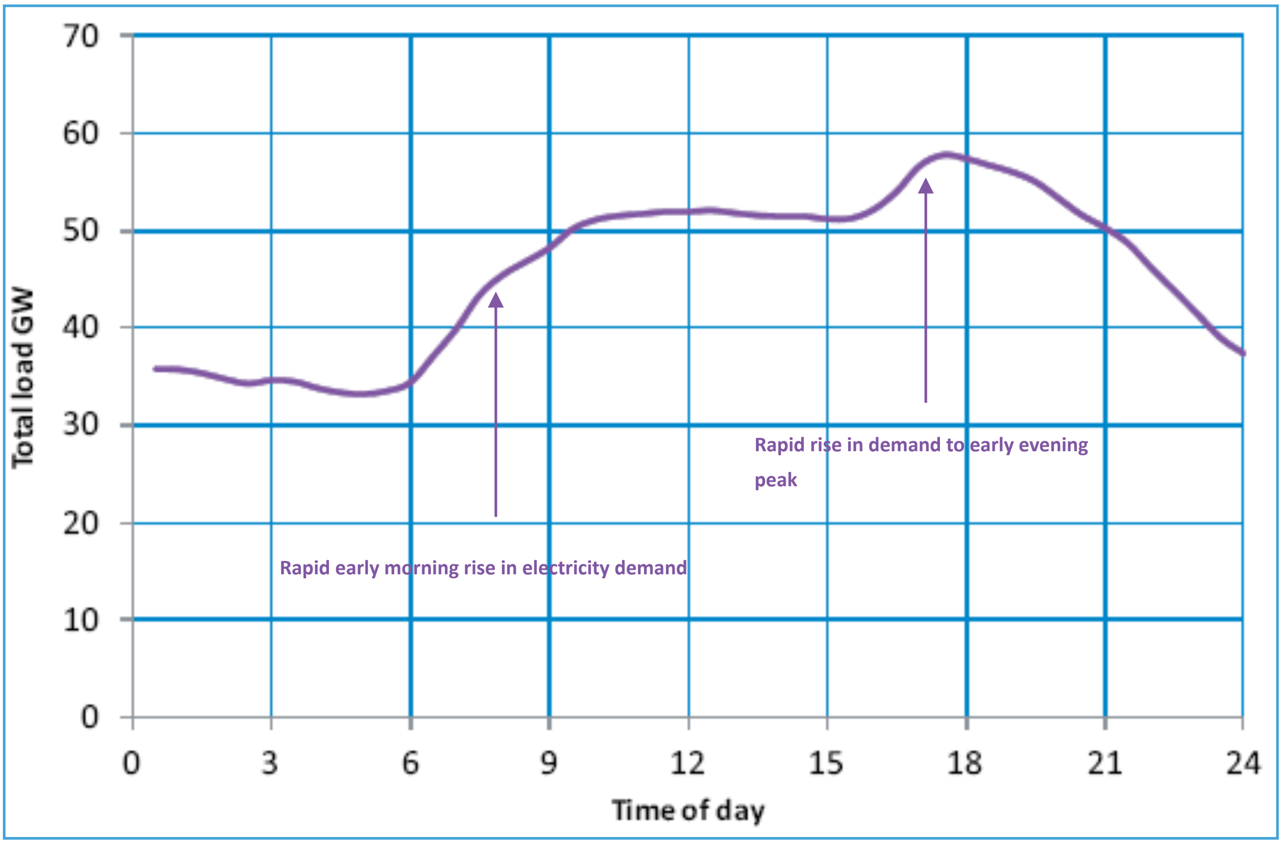
On a per head basis it could be assumed that it might contribute a similar amount to Wedmore which equates to about 2kWh per day per person.

Clearly, it is not suggested that Wedmore develop its own off-shore wind capacity, rather that it could source a proportion of it annual power needs from off-shore wind. With this in mind a number of community energy companies are looking at ways of enabling members to invest directly in off-shore wind projects, as they do now with PV and hydro generation.

Electrical energy storage

In any electricity distribution system (grid) the demand for and supply of electricity must match at all times in order to maintain the quality of the supply and specifically the voltage and frequency. Traditionally, this was achieved by increasing or decreasing the output from power stations, having additional generating capacity which can be brought on-stream at short-notice in reserve, getting industrial users to increase or reduce their demand for electricity and the use of hydro pumped-storage. In practice these are used in combination starting with the lowest cost measure at any moment in time.

Variation in national demand in for power in UK on 4th January 2010.



Source: http://www.publications.parliament.uk/pa/cm201213/cmselect/cmtran/239/239vw06.htm

Nationally, the type of storage with the greatest capacity is pumped hydro. This works by moving water between two reservoirs at different heights. When electricity is cheap, for example at night, water is pumped from the lower reservoir to the upper reservoir using electrically driven turbines. When additional power is required water is released from the upper reservoir, and flows down to the lower reservoir through the same turbines generating electricity as it does so.

The addition of a significant level of renewable generation to the UK's electricity mix has complicated the daily electricity demand profile (see graph above). Whilst PV farms and wind turbines ***could*** be turned off when supply exceeds demand, that would mean wasting renewable energy generation, with no guarantee it will be available when the reverse applies and demand exceeds supply. Part of the solution to this problem is electrical energy storage which enables surplus renewably generated electricity to be stored for later use[26].

In combination with smarter grids (national and regional distribution networks) and measures to manage the daily demand for power, electrical energy storage is widely regarded as key to accelerating the transition to fossil-free power in the UK and around the world.

[26] There are also localised effects to do with the frequency and voltage of the supply which electrical energy storage can address.

There are three main types of electrical energy storage[27]: i) bulk storage such as pumped hydro and compressed air, ii) distributed storage such as lithium-ion batteries, liquid air storage and pumped heat storage, and iii) fast/instantaneous storage which includes flywheels and super-capacitors.

In the last decade battery energy storage has come to the fore as a result of improvements in battery technology and the introduction of lithium-ion batteries in particular. Improvements in energy density have been coupled with a dramatic reduction in the cost per kilowatt hour of storage capacity over the last 7 years with reductions expected to continue.

The growth and availability of communications technology and the 'internet of things' is also creating opportunities for new and existing players in the energy market to use energy storage in new ways, for example by aggregating distributed storage to create larger blocks of capacity.

Electrical energy storage can be located at a power station, for example a wind-farm or ground-mounted PV array, at points on the grid such as substations or linked to individual buildings. A number of companies including Tesla now produce battery packs for use in homes, clusters of homes or non-residential buildings.

Battery electric vehicles can also be considered as a form of mobile electricity storage which, when connected to the distribution network through what is know as vehicle-to-grid, (V2G), can be used to supply energy as well as receiving energy to recharge the battery pack - though not at the same time.

As yet it is unclear what the optimum mix of these different types of electrical energy storage will be, though it is clear that as a greater proportion of the electricity supply is generated renewably more storage capacity will be required.

How much electrical energy storage would be needed in Wedmore?

'The Power to Transform' report estimates that to become fossil-free Somerset would require storage with a (power) capacity of 2,176MWe.

On a per capita basis that would equate to 13.42MW (13,417kW) of storage capacity in Wedmore or approximately 10kWe per household. For comparison the Tesla Powerwall provides 13.5kWh of electrical energy storage in each unit, with a power output of between 3.68 and 5kW[28], implying that storage equivalent to two Powerwalls per household would be required.

However, if battery electric vehicles are added to the mix, over time the suggested level of storage could easily be met by combining the capacity of their battery packs with some static battery storage in homes and potentially some larger-scale battery storage attached, for example, to community buildings.

As it stands the financial case for domestic battery storage is marginal, with payback periods often exceeding the expected live of the batteries. For households with a PV system claiming the Feed-in Tariff (FiT), the installation of a

[27] Though referred to as 'electrical energy storage' with the exception of super-capacitors the energy is stored in forms other than electrical charge, for example chemical energy in the case of lithium-ion batteries, then converted to electricity at the time of use.

[28] https://www.tesla.com/sites/default/files/pdfs/powerwall/Powerwall%202_AC_Datasheet_en_GB.pdf 3.68kW is the continuous output and 5kW the maximum output

battery can, (depending on how it is installed) reduce FiT payments[29], further reducing the financial case. There are instances where larger-scale storage is financially viable where it can be used to generate revenue by provide grid support services such as frequency response, or STOR[30] (short-term operating reserve).

However, as the unit cost of battery storage falls, and if and when the government changes the regulations on how battery storage is treated, so as not to penalise those claiming the FiT, the financial case in favour of battery storage is expected to improve.

The contribution from renewable electricity generation

Allowing for demand reduction from energy efficiency measures and the increased power demand for electric vehicles, what contribution could roof-mounted PV (plus storage) and on-shore wind make to the daily demand of power in the study area?

The graph below suggests that in average terms, on-shore wind and roof-mounted solar would significantly exceed the daily requirement for power in Wedmore. The inclusion of more ground-mounted PV would further increase the total amount of electricity generated daily. However, several caveats apply here.

The graphs show ***average*** figures and assume that annual demand for and supply of electricity is spread evenly across the year; in reality both vary hourly, daily and seasonally. Also, the capacity of roof-mounted solar PV is based on a theoretical maximum which ignores any planning restrictions due to Conservation Areas and listed buildings, both of which will limit the available roof area. And the projected output from the wind-turbine also assumes there are no planning constraints which might govern the size or location of a turbine, and that existing planning constraints applicable to on-shore wind are lifted. Nonetheless, it does show that meeting daily power requirements using existing technologies (even without additional ground-mounted PV) is possible.

Balancing peaks and troughs in supply and demand

The inclusion of electrical energy storage would help to smooth-out the peaks and troughs in the output from wind and solar but it is unlikely this would be of sufficient capacity to cope with all the periods when solar output is low or zero (mid-winter, and at night for example) and when there is a prolonged lull in wind-speed meaning that local demand would be greater than supply.

How could these gaps be plugged? One option would be to install more renewables at other locations, and of different types, small-scale hydro for example, to diversify the mix. Adding more storage, and storage of different types, in combination with measures to manage demand, by controlling for example when appliances turn on and off are also likely to be part of the solution.

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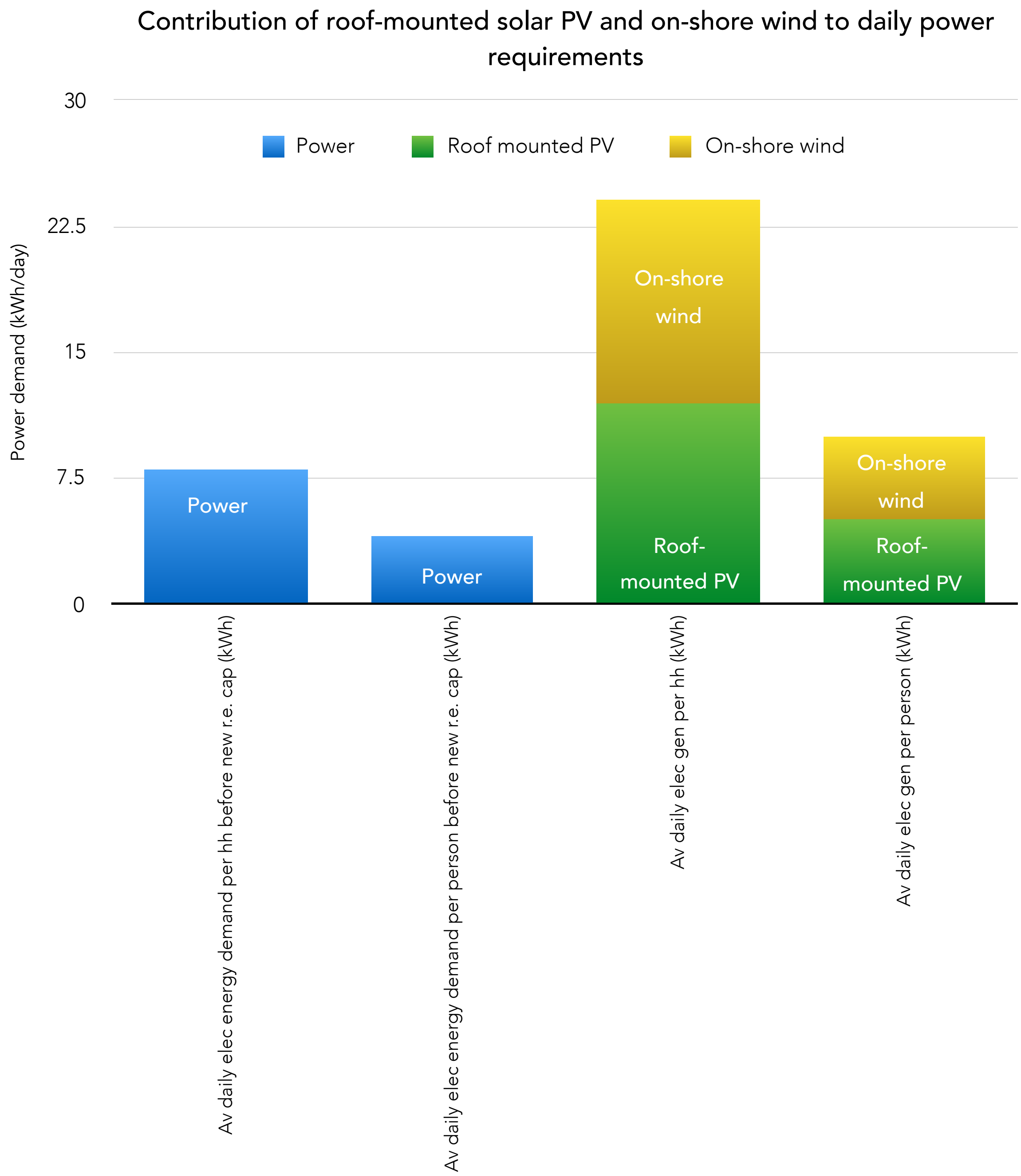
[29] The BRE have produced a useful guide on batteries and solar power, available here: http://www.bre.co.uk/filelibrary/nsc/Documents%20Library/NSC%20Publications/88031-BRE_Solar-Consumer-Guide-A4-12pp.pdf

[30] Both the National Grid and Distribution Network Operators (DNOs) contract to third parties to provide a range of grid balancing and support services. Some operators now aggregate storage capacity at different locations to provide these services, meaning that the storage can be used to generate revenue.

At a national scale greater connectivity with other parts of Europe, allowing the UK to export and sell excess energy when supply is greater than demand, and buy additional energy when the reverse applies, will also make an important contribution[31]. And forms of renewable electricity generation such as 'green gas' which can be turned on and off quickly and on demand may form part of the solution. Research on just how much additional capacity will be needed to supplement renewable power plus storage, in combination with measures such as 'smart grids' is on-going.



[31] Exporting and importing power to and from our European neighbours already takes place daily to balance supply and demand. See https://www.electricitymap.org/?page=country&solar=false&remote=true&wind=false&countryCode=GB-ORK for nearly live data. At present is is unclear how Brexit will affect this aspect of energy trading.

Renewable heat

Solar thermal

Solar thermal or solar water heating is a very well established technology which has been available commercially in the UK for over 40 years. A good quality solar system will, over the course of a year, generate about 50% of the energy required to provide domestic hot water[32].

Solar thermal panels covert about 50% of the energy they receive from sunlight into hot water. The amount of hot water that could be generated in Wedmore from solar thermal can be estimated using the area of south-facing roof-space worked out above.

Estimated area of south facing roof[33]: 30,343m^2.

Average power of sunshine per square meter of south facing roof in the UK: 110W/m2.

Allowing for efficiency of solar thermal panels (50%) this is reduced to: 50% x 110W/m2 = 55W/m2

So if all south facing roofs in Wedmore had solar thermal the average power would be:

55W/m^2 x 30,343m^2 = 1669kW

In an average day[34] this would generate 1669kW x 24 hours = 40,056kWh of energy (heat).

This is equivalent to 12kWh per day per person.

Limitations of solar thermal

Twelve kilowatt hours per day per person is about 60% of the heat required per person from burning gas (also 21kWh/day/person), before applying reductions from energy efficiency measures. And it is just under the daily requirement after energy efficiency measures (13kWh per person per day).

But as with solar PV there are limitations.

- To compare the potential contribution from solar thermal to other forms of renewable energy average figures have been used. The major share of the energy generated by solar thermal is during the summer months. Only a small fraction is produced in the winter which is when the demand for heat is greatest.
- Covering all the south facing roofs with solar thermal would produce much more hot water than is actually needed during the summer months and result in a lot of wasted heat.
- By opting for solar thermal we take roof space which could be allocated for PV panels.

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[32] Though this percentage can be increased through careful use.

[33] Excluding roof-space already assumed to have roof-mounted PV.

[34] As above this calculation assumes that the solar panel generates energy continuously - this allows comparison with other renewable measures.

- The heat produced by solar thermal systems is defined as 'low-grade' energy, and needs to be distinguished from higher temperature heat which can be used for other applications. Nor is it as valuable or useful as high-grade electrical energy.

Solar thermal could make a significant contribution to the heat required for hot water in Wedmore. However, as south facing roof space is at a premium and could also be used to generate electricity with solar PV it is likely that only a small proportion of the available space would be given over to solar thermal as a whole.

Biomass

The term 'biomass' is often used interchangeably with 'bioenergy'. In this context it refers to heat generated by burning wood in the form of logs, wood-chips or pellets to generate heat for space heating and hot water.

Wood heating is used extensively in Scandinavia, Germany and Austria in urban as well as rural areas. The use of wood in this way is treated as a form of renewable energy, because the process of burning wood replicates part of the naturally occurring 'carbon cycle'. The proviso being that the wood must come from a managed source and be continuously replenished by new planting[35].

In the last three years air quality and the detrimental impact of emissions from petrol and diesel vehicles and solid fuel heating appliances (including wood burners) has become a much more prominent issue. Much of the concern about health relates to emissions of nitrogen dioxide (NOx) and particulates - microscopic particles produced as part of the combustion process. Urban areas with a higher density housing, roads and vehicles tend to be most susceptible but less densely populated and rural areas are by no-means exempt, particularly close to major roads and slow moving traffic.

For wood-burning appliances such as wood burners and boilers the emission of particulates and other pollutants depends amongst other things on:

- The design and age of the appliance - whether it has been designed to be 'low-emission' or 'DEFRA compliant' and certified for use in smoke-controlled areas.
- The quality of the fuel - whether it is free from paints, stains and preservatives, and most importantly the moisture content of the fuel[36].
- The temperature at which the stove/appliance is operating - particulates emissions are higher when stoves are operating at lower temperatures.

In response to public concern about air quality, and as part of its Clean Air Strategy the Government has said it will outlaw the sale of all but the cleanest stoves by 2022, encourage the sale of 'cleaner' wood (including wood with a moisture content below 20%), and could introduce 'no-burn' notices which give Council's the power to block people from using their stoves when air quality is poor.

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[35] The carbon cycle. Trees convert carbon dioxide into carbon via photosynthesis as they grow. When they die the process is reversed. The carbon breaks down and combines with oxygen in the air to form carbon dioxide. This also happens when wood is burned.

[36] The moisture content of woodfuel should be below 20%. Higher levels of moisture will tend to increase smoke and emissions as well as reducing the energy content of the fuel.

Guidance currently produced by the Government suggests that it still regards wood-fuel as a form of renewable heat at both the small and large scales. Whether this position is tenable in the long-term and whether we reach a point in time when either it is regarded as socially unacceptable to burn wood or other solid fuels in rural areas, or the Government seeks to restrict or ban the burning of solid fuels is unclear.

Assuming that air quality does not prevent the use of wood as a form of renewable heat, how much of the current heat demand in Wedmore could be met by switching from gas to wood? 'The Power To Transform' report estimated that biomass could contribute 15% to the heat requirements in Somerset. Applying this percentage in Wedmore gives the following breakdown:

Current domestic demand for heat from gas in Wedmore (before energy efficiency measures): 13,489,464kWh per annum.

Proportion of gas consumption assumed to be for cooking[37]: 3%

Balance of current demand for heat from gas: 13,084,780kWh per annum[38]

Actual energy requirement for heat assuming average efficiency of gas boilers is 85%: 11,122,063

Proportion of heat to come from biomass: 15%

Heat required from biomass to meet 15% of annual demand: 1,668,309kWh per annum

Assumed efficiency of the wood burner/appliance[39]: 80%

Energy required from biomass allowing for efficiency of wood burners: 2,085,386kWh per annum

Annual energy content per unit of area for wood (from forestry residues, short-rotation wood, thinnings etc): 10.3 MWh/ha.a

Annual energy content per unit of area for wood[40] (from short-rotation willow coppice): 46MWh/ha.a

Area of wood (from forestry) required for heat production: 202ha roughly 2 square kilometres

Area of short-rotation willow coppice required for heat production: 45 ha roughly 0.5 square kilometres

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[37] Source: United Kingdom Housing Energy Fact File. Department of Energy and Climate Change (2013). Jason Palmer and Ian Cooper.

[38] Heat demand includes losses due to boiler inefficiency. I.e. actual heat demand will be lower.

[39] 80% of the energy produced is useful heat, 20% is wasted including heat lost up the flue.

[40] Source: Biomass Energy Centre. Potential outputs of biofuels per hectare per, annum. These figures are approximate and depend on the geographical location, cultivation inputs and techniques, harvesting and processing etc. The energy content is dependent on the moisture content of the fuel. In both cases it is assumed that this is 30% moisture content.

These figures are based heat demand in the study area ***before*** a reduction in heat demand from energy efficiency measures. Assuming this can be reduced by 40% the land area required drops to:

- **Area of wood (from forestry) required for annual heat production after e.e. measures:** 1.2 square kilometres
- **Areas of short rotation willow coppice required for annual heat production after e.e. measures:** 0.3 square kilometres

To put these areas in context 1.2sq km of woodland is equivalent to a square 1.1km (0.7 miles) on the sides, and 0.3sq km of short-rotation coppice a square 0.55km (0.34 miles) on each side.

The area of willow is smaller than the area of woodland because of the higher energy content. However, according to the Biomass Energy Centre the crop yield depends on the inputs and short-rotation willow may require more intensive inputs including the use of artificial fertilisers to achieve these yields year on year.

Heat pumps - extracting solar energy from the air, ground and water

Almost every household owns at least one heat pump in their fridge or freezer. And heat pumps in the form of air conditioning are increasingly standard features in new cars and some new homes.

Heat pumps use the physical characteristics of a 'working fluid' which is a refrigerant, to move heat from one place to another; in a fridge that is from the inside to the outside of the insulated box in which the food is stored. The same principle can be used to extract solar energy, in the form of heat stored in the air, ground or water to provide heat for hot water and space heating.

As well as moving heat from one place to another heat pumps also raise the temperature of the heat energy being transferred or 'pumped'. A ground source heat pump extracts heat from the ground at say 11 deg C and can raise the temperature to between 30 to 65 deg C. Similarly, an air source heat pump extracts heat from the air which is drawn into the appliance by a fan, and then used to provide space heating and domestic hot water.

Heat pumps are regarded as a form of renewable energy because for each unit of electrical energy used to operate the appliance, 2.5 to 5 units of useful heat can be extracted. Because this 'extra' heat is solar energy[41] ultimately replenished by the sun, it is treated as renewable heat.

This ratio of electrical energy 'in' to useful heat 'out' is known as the Coefficient of Performance (CoP)[42]. Another way of thinking about this is that a heat pump with a CoP of 3 to 4 is 300 to 400% efficient. This lift in efficiency means that for each unit of useful heat we need we require 3 to 4 times less energy from a heat pump than from say a gas boiler

[41] Some ground source heat pumps use bore holes deep enough for some of the heat energy to be derived from geothermal activity.

[42] Manufacturers will also describe this as the 'SCOP' - seasonal coefficient of performance.

producing an equivalent amount of useful heat. (Please see the footnote[43] for a comparison of CO_2 emissions in new dwellings.)

An important characteristic of heat pumps is that the CoP and efficiency of the system decreases as the temperature difference between the heat 'in' and 'out' goes up. For this reason heat pumps are best suited to properties which are well insulated and distribute heat using a low temperature system such as low temperature radiators or underfloor heating.

Because heat pumps are best suited for producing and delivering low temperature heat they are not particularly 'responsive' meaning they need to run continuously for long periods unlike say gas boilers which produce high temperature heat and can be turned on and off to provide an injection of heat on demand.

What could heat pumps contribute in Wedmore?

For this exercise it is assumed that 15% of the heat demand in Wedmore ***after*** energy efficiency measures (which is currently served by gas), is displaced by biomass as shown above.

What would be required to meet the remainder of the demand presently served by gas, plus heat from oil, solid fuels other than wood, and Economy 7 (storage heaters), with heat pumps?

The figures are as follows:

(Note: In converting from gas, oil and solid fuel boilers to heat pumps we have to take account of the efficiency of the boilers being replaced by heat pumps. To do this the average efficiency of a gas, and oil boiler has been taken as 85% and that of a solid fuel appliance as 80%. Newer boilers and solid fuel appliances should have higher efficiencies than this, but these figures allow for the age range of systems in use).

Current domestic demand for heat from gas in Wedmore (before energy efficiency measures): 13,489,464kWh per annum

Proportion of gas consumption assumed to be for cooking: 3%

Balance of current demand for heat from gas: 13,084,780kWh per annum

Actual heat demand in homes with gas boilers allowing for boiler efficiency of 85%: 11,122,063

Domestic demand for heat from gas after applying energy efficiency measures (assuming 40% reduction in demand): 6,673,238kWh per annum

[43] How do heat pumps compare with gas boilers in terms of CO_2 emissions? The carbon factors used in SAP 2012 (the methodology for calculating emissions in new dwellings) are 0.216kg CO_2 per kWh for gas and 0.519kg CO_2 for electricity. Thus, the carbon factor for electricity is 2.4 times higher per kWh than gas. Provided the Coefficient of Performance of a heat pump is 2.4 or greater, the CO_2 emissions from switching to heat pumps will be equal to or better than a gas boiler. One further point to consider is that the carbon factor for electricity in the UK is set to fall year on year until it is effectively zero. The carbon factor for natural gas is unlikely to fall much below the figure shown.

Proportion of heat demand met by new biomass[44] (15%): 1,000,986kWh per annum

Residual heat demand from homes with gas heating: 5,672,252kWh

Residual heat demand from homes using oil heating (before energy efficiency measures): 9,119,893kWh

Residual heat demand from homes using oil heating (after energy efficiency measures): 5,471,936kWh

Residual heat demand in homes with oil boilers after energy efficiency measures and allowing for boiler efficiency: 4,651,146kWh

Residual heat demand from homes using solid fuel heating (coal, and smokeless fuel) before energy efficiency measures: 1,885,624kWh

Residual heat demand from homes using solid fuel heating (coal, and smokeless fuel) after energy efficiency measures: 1,131,374kWh

Residual heat demand from homes using solid fuel heating (coal, and smokeless fuel) after energy efficiency measures and allowing for boiler efficiency: 905,099kWh

Residual heat demand from homes using Economy 7 heating before energy efficiency measures: 284,430kWh

Residual heat demand from homes using Economy 7 heating after energy efficiency measures: 170,658kWh[45]

Balance of residual heat demand to be met using heat pumps = displaced heat from gas, oil, solid fuel and Economy 7

Balance of annual heat demand to be met using heat pumps = 11,399,155kWh

Assumed average Coefficient of Performance (CoP)[46]: 3.0

Electrical energy required annually to run heat pumps to meet residual heat demand: 3,799,718kWh per annum

Average energy required to run heat pumps per day per household[47]: 7kWh

Average energy required to run heat pumps per day per person: 3kWh

The figures above show the average energy required to operate heat pumps which are displacing other fuels namely, gas, oil, solid fuels (other than wood), and providing a more efficient and controllable alternative to Economy 7.

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[44] Biomass boilers displacing gas.

[45] Electric resistive heating is 100% efficient so an allowance for 'boiler' efficiency is not required.

[46] A CoP of 3 means that one kilowatt hour of electricity will produce 3 kilowatt hours of heat - on average across the year.

[47] As above this calculation is the average across all households in the study area.

Combining this demand with the energy required for existing wood-burning appliances, and new biomass boilers displacing 15% of the homes currently on gas gives revised figures for average consumption per household and per head as follows:

Electrical energy required to run heat pumps: 3,799,718kWh per annum

Energy required for *new* biomass appliances (displacing gas) allowing for appliance efficiency[48] and *after* energy efficiency measures: 1,251,233kWh per annum

Energy required for *existing* biomass appliances after energy efficiency measures: 97,907kWh per annum

Annual energy requirement for heat pumps, new biomass and existing biomass (after energy efficiency measures): 5,148,858kWh per annum

Average energy required for heating per household per day: 10kWh

Average energy required heating per person per day: 4kWh

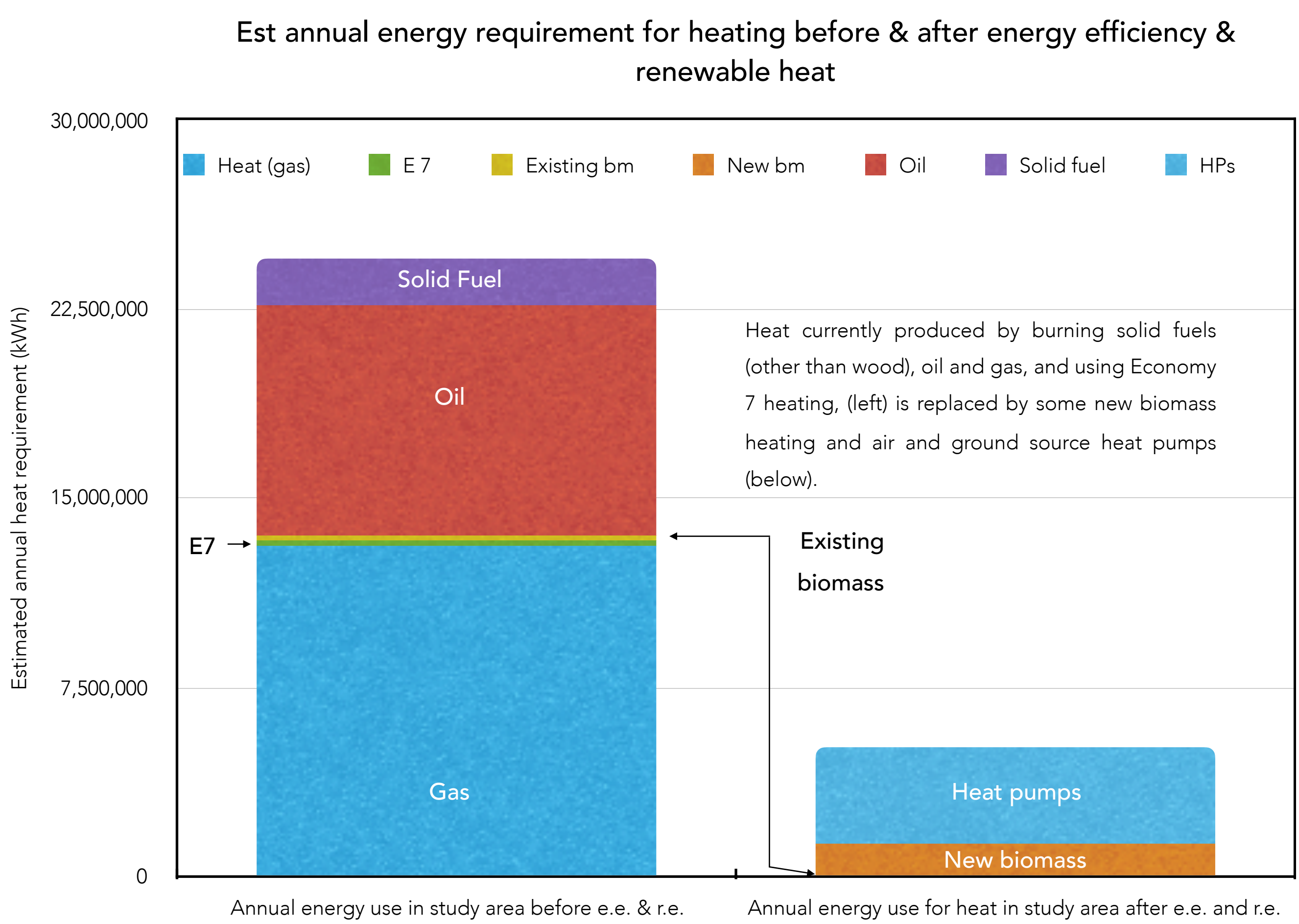
Notes

- To allow comparison with other energy demands and with renewable energy generation these averages assume that the annual demand for heat is spread evenly across the year. In reality the major part of this demand will be occur in the heating season (i.e. the winter months).
- Heat pumps offer a step change in efficiency from 90-95% in the case of an efficient ***new*** gas boiler, and 100% with electric (resistive) heating, to 300-500%. But they are only suitable in properties where a full package of energy efficiency measures have been installed. In solid wall properties this means internal or external wall insulation.
- Field trials of heat pumps also show that to realise their full potential they must be sized correctly, fitted with appropriate controls, and operated as designed, i.e. run for long periods rather than intermittently as with a gas boiler. Problems in any of these areas will significantly reduce efficiency and increase energy consumption.
- One further point to note is that by switching from gas, oil and coal to heat pumps the daily requirement for power that will need to be met renewably increases. This is shown in the summary below.

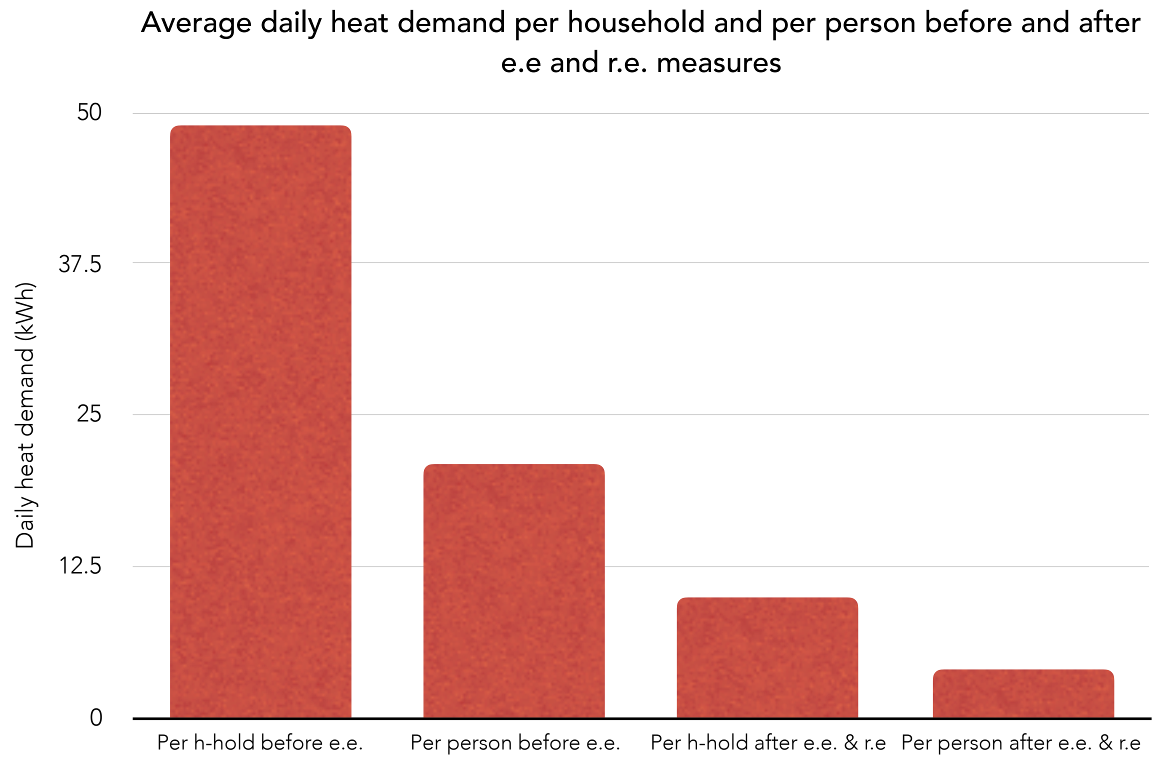
[48] Assumes that on average wood burners are 80% efficient

Renewable heat - summary

The impact across the whole study area of replacing gas, solid fuel, oil and Economy 7 heating with some new biomass and heat pumps is shown in the graph below.



The graph below shows the impact of energy efficiency and renewable energy on the daily average energy requirement for heat per household and per person in the study area.



Cooking

The calculations above have assumed that in homes with gas heating 3% of the annual usage is for cooking, and in homes without gas, cooking is with electricity. Electricity for cooking is treated as part of the annual requirement for power and has not been itemised in the baseline figures.

Over the last 20 years there has been a reduction in energy use for cooking. This reflects changes in lifestyle, and appliances, e.g. greater use of microwave ovens, as well as other efficiency improvements. More recently this trend has levelled off, though further reductions in demand may be achievable with the introduction of more efficient appliances such as electric induction hobs.

Breaking these figures down by consumption per household and per person gives the following figures:

Current demand for gas in homes with gas heating: 13,489,464kWh per annum

Proportion of gas consumption assumed to be for cooking: 3%

Energy required for cooking (using gas): 404,684kWh per annum

Average energy per day per household for cooking: 0.8kWh

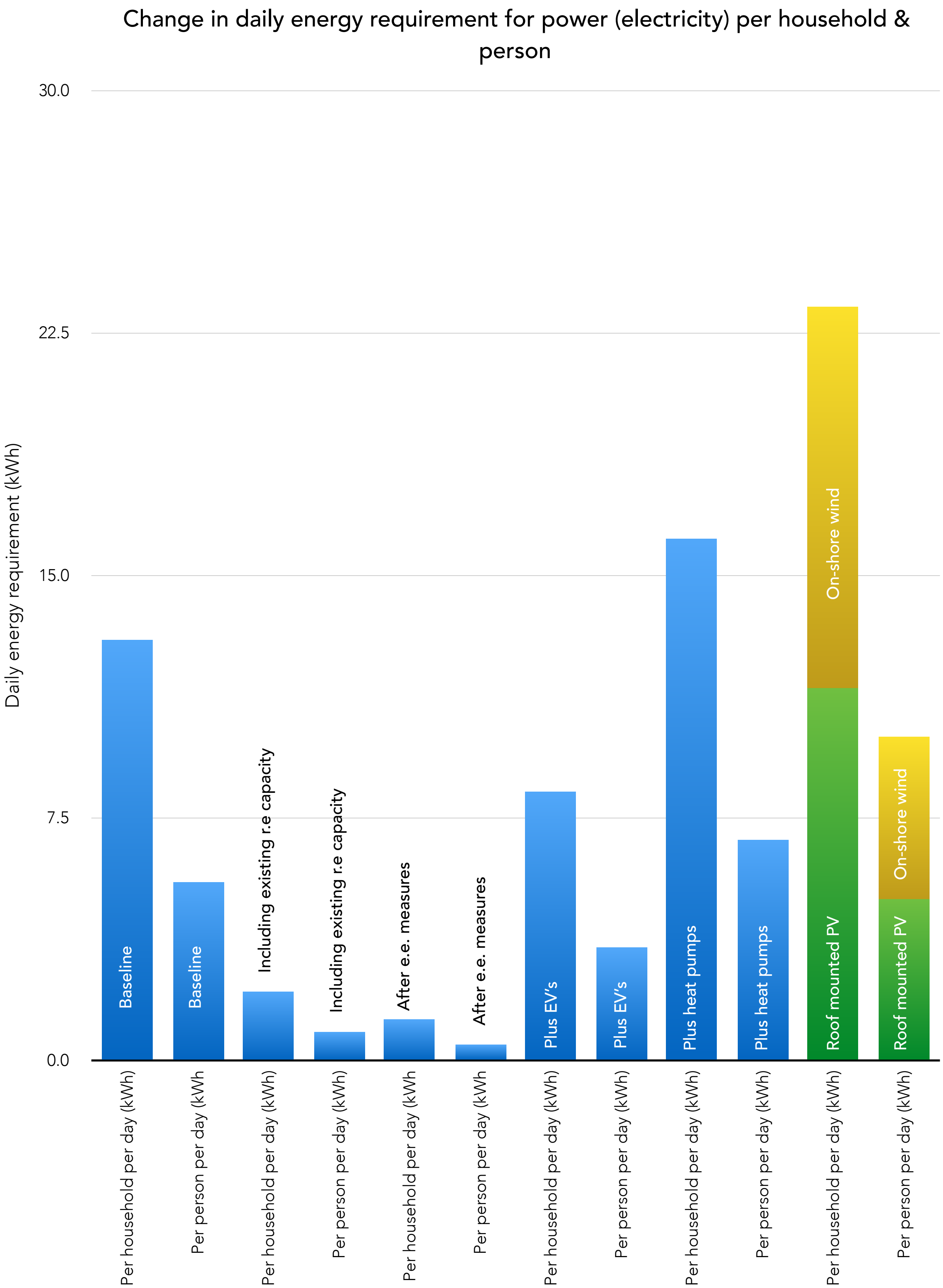
Average energy per day per person for cooking: 0.3kWh

In a scenario where gas is no-longer used for heating it is assumed that all cooking is done electrically, with the energy required added to the daily power requirement.

Impact of heat pumps and cooking on daily power requirement

The graphs above show what happens to the total and daily heat requirement from moving away from gas, solid fuel, oil and Economy 7 to using heat pumps and some new biomass for heating.

This change to renewable electric heating and in the transition from cooking with gas to electricity adds to the daily requirement for power which is illustrated in the graph below.


Change in daily energy requirement for power (electricity) per household & person
Daily energy requirement (kWh)
30.0
22.5
15.0
7.5
0.0
Baseline
Baseline
Including existing r.e capacity
Including existing r.e capacity
After e.e. measures
After e.e. measures
Plus EV's
Plus EV's
Plus heat pumps
Plus heat pumps
Roof mounted PV
On-shore wind
Roof mounted PV
On-shore wind
Per household per day (kWh)
Per person per day (kWh
Per household per day (kWh)
Per person per day (kWh)
Per household per day (kWh
Per person per day (kWh
Per household per day (kWh)
Per person per day (kWh)
Per household per day (kWh)
Per person per day (kWh)
Per household per day (kWh)
Per person per day (kWh)

Moving from left to right the graph shows the impact on the daily power requirement of:

- Existing renewable energy capacity
- Reducing demand through energy efficiency measures
- Converting the fleet of petrol and diesel cars to battery electric power
- Substituting 85% of gas heating, plus solid fuel, oil and Economy 7 with heat pumps

And the contribution of new roof-top solar PV and an on-shore wind turbine.

Section 7 - conclusions

This report has considered how much energy is required to provide, heat power and transport in the parish of Wedmore, how this could be reduced by reduced through energy efficiency measures and how the remaining requirement could be met renewably.

This section presents general and specific conclusions based on the findings of the study.

General conclusions

i. The estimate of annual and daily energy demand for heat, power and transport has been based on local data where available and as well as estimates from regional and national data.

ii. The study suggests that it would be possible to meet these requirements renewably by combining:

- Significant (40%) reductions in demand for heat and power through behavioural change and energy conversation and efficiency measures.
- A switch from petrol and diesel cars to battery electric vehicles.
- A significant increase in existing renewable power generation in the area.
- The decarbonisation of heat through energy efficiency, and substitution of gas, oil, Economy 7, and solid fuel heating with biomass (wood) and the use of heat pumps.

iii. It is clear that changes of this type and scale require a change in national and local planning policy, incentives for renewable energy generation and electrical energy storage. New financial models will also be required to fund deep energy efficiency improvements such as internal and external wall insulation and renewable and very low carbon heat.

Baseline - energy demand and CO_2 emissions

i. Baseline energy consumption has been estimated using two data sets published by BEIS. The fuel mix in homes not on mains gas has been estimated from published research.

ii. The results give estimates of average consumption which has been presented as daily consumption per household and per person in the study area to allow comparison between different types of energy use and between energy demand and generation.

iii. Average figures are intended to be indicative of the area as a whole. They are not a substitute for measuring actual consumption by recording meter readings, measuring fuel use in the case of oil or solid fuel heating systems, or using a smart meter to monitor usage.

iv. Average power consumption in the study area appears to be slightly higher than the national average. This may be due to marginally higher than average levels of occupancy and homes which are a little larger than the average nationally.

v. In the absence of local energy data for private vehicles (cars) this has been estimated from national statistics. Actual energy use will depend heavily on vehicle size and weight, the type of driving (urban, motorway etc) and driving style.

vi. Averaging the energy demand in the study area across all households area gives a daily energy consumption of about 93kWh per household of which about 33% is for transport, 53% heat and 14% for power. Estimating CO_2 emissions on the same basis gives daily baseline emissions per household of 22kg of which 32% is transport, 50% heat and 18% power.

vii. Whilst actual energy demand and emissions for individual households will vary according to size, heating system, number of vehicles etc, the results highlight the relative contribution of heat and transport and importance of addressing these in terms of energy efficiency, and renewable energy generation.

The impact of existing renewable power generation on baseline power demand

i. Existing solar PV installations - ground and roof-mounted, and a 50kW wind turbine already make a very significant contribution to the daily power requirement in Wedmore.

ii. On average this installed capacity is estimated to reduce daily demand for power from 13 to 2kWh per household per day and from 6 to 1kWh per person per day.

Energy efficiency - reducing demand for heat and power

i. Energy efficiency remains the fastest and most cost-effective means of reducing energy demand and cutting CO_2 emissions. Generally speaking it is also more cost effective to use less energy than to build new infrastructure to generate more energy.

ii. This report assumes heat and power demand can be cut by 40% through a combination of behavioural and technical energy efficiency measures. Whilst lower than some projections (which suggest a 52% reduction) achieving and then sustaining this level of demand reduction will be very challenging.

iii. The most difficult part of this is likely to be reducing heat demand in older solid-wall properties particularly those in Conservation Areas or which are listed, where the options for improvement may be technically more difficult or restricted by planning requirements.

iv. Despite the challenges, energy efficiency is one area where there is scope for local and community engagement, and intervention to understand local needs and accelerate up-take and progress.

Transport - from petrol and diesel to electric power

i. The average electric car is 4 to 5 times more efficient than a petrol and diesel car at converting chemical energy into movement. This hugh efficiency benefit coupled with the fact that the electricity used to charge the battery will increasing come from renewable sources means that battery electric vehicles are one of the big and potentially quick wins in terms of reducing dependence on fossil fuels and carbon pollution. Locally electric vehicles bring other benefits such as zero tail-pipe emissions and reduced noise.

ii. Research from across the EU suggests that drivers are most likely to consider switching to an electric car if:

- Public charging infrastructure is visible and obvious
- They have the opportunity to see, and preferably try an EV, and,
- They have access to finance. (At present electric vehicles are more expensive to buy than petrol and diesel equivalents, but as with conventional cars increasingly they are being leased rather than purchased. In terms of the total cost of transportation, electric vehicles are close to that of equivalent petrol and diesel cars and expected to become cheaper imminently).

iii. The transition to EV's should be one area where local engagement and actions can stimulate take-up alongside measures to encourage walking, cycling and car sharing.

Renewable power

i. As discussed above, existing solar PV and wind generation in the area is already making a very significant contribution to daily power requirements in Wedmore.

ii. The study has considered how residual power demand could be met following improvements in energy efficiency and the switch to EV's.

iii. There are any number of ways new PV generation could be combined with other types of generation such as wind and hydro, and even anaerobic digestion. For the purposes of this exercise three technologies were considered: an expansion of roof-top PV, new ground-mounted PV and on-shore wind.

iv. Whilst theoretical outputs from roof-top PV and ground-mounted PV can be estimated with reasonable confidence based on location, the energy generated by a wind turbine is dependent on the exact location, wind profile and size and characteristics of the turbine installed. For these reasons the estimates for wind energy generation are more generic than those for PV.

v. The estimates calculated here suggest that meeting the residual power requirement for Wedmore would require about 12 football pitches worth of new ground-mounted PV, or one 2.5 to 3MW wind turbines[49].

vi. By combining new and existing roof-top solar with a single 2.5-3MW turbine the residual daily power requirement could be significantly exceeded.

vii. In the case of on-shore wind, it has been assumed that existing planning requirements which make it all but impossible to get permission for an on-shore turbine are lifted. (Planning implications are discussed further below).

viii. One striking finding is the difference in land area required to meet Wedmore's power needs between ground-mounted PV and a wind turbine. This is likely to be an important consideration going forward, given competing pressures on land use.

[49] Assuming no increase in roof-mounted PV.

Renewable heat

i. Of the three categories of energy use, heat, power and transport, heat is the most difficult to decarbonise as it requires bespoke interventions in each property which can be disruptive, time-consuming and expensive. However, it is simply not possible to decarbonise the energy system without improving energy efficiency and finding renewable and very low carbon alternatives to burning fossil fuels.

ii. The approach taken here has been to assume that a proportion (15%) of homes currently heated with gas are converted to wood (biomass heating) and the remainder, plus homes which currently use oil, solid fuel and Economy 7 are converted to heat pumps.

iii. Five to ten years ago biomass was regarded as the main alternative to gas in both urban and rural areas. But recent concerns about the health impacts of air pollution including that from wood-burning have called this into question. Whether wood-fuel heating has role to play in Wedmore will depend in part on local attitudes as well as Government guidance and local regulations.

iv. It is unlikely that all homes in Wedmore could be upgraded to a high-enough energy efficiency standard to be suitable for heat pumps, so without biomass some other form of low-carbon/renewable heating will be required. The low density of homes in rural areas probably means that heat networks are unlikely to be feasible - at least in the short-term - as an alternative to individual heating systems. One option may be 'green' or synthetic gas produced as a bi-product of anaerobic digestion, but at this stage it is difficult to say if and how this might be deployed in Wedmore. A further option in settlements located over former mine workings may be to extract heat from these in combination with individual heat pumps, though this would still require significant improvements in the energy efficiency of connected buildings.

v. For the remaining 85% of homes in the area it has been assumed that they will be converted to heat pumps. Because heat pumps produce lower temperature heat than gas, oil or solid fuel boilers they should only be installed in well-insulated dwellings - underlining the importance of energy efficiency improvements.

vi. The high efficiency of heat pumps (300-500%) would dramatically reduce the average daily requirement for heat across the study area, though it does add to the daily requirement for power needed to generate the heat which will need to be met renewably.

vii. As with the switch to electric vehicles heat pumps should be seen as one of the big wins in terms of decarbonising heat across the area provided the thermal efficiency of dwellings can be improved.

Timescales - how quickly to net zero emissions?

i. There is considerable debate at the moment about how quickly the UK should achieve net zero emissions. The Committee on Climate Change announced[50] in 2019 that the UK as a whole should seek to achieve net zero emissions by 2050, but climate campaigners such as Extinction Rebellion argue that that science necessitates we

[50] https://www.theccc.org.uk/2019/05/02/phase-out-greenhouse-gas-emissions-by-2050-to-end-uk-contribution-to-global-warming/

get to this point no later than 2025 and local councils including Sedgemoor[51] have passed motions declaring a climate emergency and calling for carbon neutrality or 'net zero carbon' by 2030.

ii. In terms of the measures which need to be taken locally in Wedmore, they will be broadly similar whatever the target date, the key difference being how quickly they are deployed. In both cases we have to reduce the amount of energy required in the first place and then meet this requirement without adding to carbon emissions.

iii. Of the three categories of energy use explored in this report, heat, power and transport, increasing renewable generation capacity and switching away for internal combustion engine (ICE) cars are likely to be the two where most progress can be made most quickly. However, because it is the most difficult of the three, there is a risk that the hard decisions and interventions needed to decarbonised heat continue to be postponed nationally and locally. It is not possible to get to zero emissions without decarbonising heat.

iv. How quickly Wedmore can move to decarbonise its use of energy will be as much a local as national decision.

Planning - constraints and implications

i. The interventions in this report have been based what is technically possible rather than what is allowable under the planning system. In reality some of the measures suggested here will be constrained due to planning requirements. For example it is unlikely that roof-top PV will be allowable on listed buildings or dwellings in a Conservation Area if the south-facing roof faces the public realm. In practice these constraints mean that additional measures, and generating capacity will be required elsewhere.

ii. It is also clear that some aspects of the planning system will need to change. The difference in land-take between ground-mounted PV and wind mean it is very hard to see how a de-facto ban on new on-shore wind generation can be compatible with a serious commitment to decarbonise the energy system.

iii. Given this it may make sense for groups such as Green Wedmore to a) lobby for a change in planning policy on wind and b) undertake provisional work on increasing local wind generation on the assumption that current policy will have to change at some point.

[51]https://www.climateemergency.uk/blog/sedgemoor/ Resolution to 'work towards carbon neutrality in Somerset by 2030'.

Appendix 1 - baseline energy consumption and emissions

Defining the study area

The following settlements were included in the baseline assessment of energy demand and CO_2 emissions.

- Wedmore
- Blackford
- Theale
- Sand
- Westham
- Heath House
- Little Ireland
- Panborough
- Mudgley
- Clewer
- Cocklake
- Crickham
- Bagley
- Chapel Allerton
- Stone Allerton

Estimating energy consumption

BEIS provide two sets of data which can be used to calculate domestic energy demand in a given geographical area; consumption by postcode area and by Lower Super Output Area (LSOA). The most up-to-date information for both data sets is for 2017.

BEIS present postcode data is presented as 'experimental' and state that this excludes some meter points with very low or very high consumption. Lower Super Output Area, more established approach, is a statistical area of approximately constant population, of about 1,500 people. Unlike energy demand by postcode, this does not provide an exact fit with the geographical boundary of this study.

For these reasons both postcode and LSOA data were used estimate domestic energy demand per household, to provide a comparison and sense check of the outputs. Figures for the number of households and population from the Housing Need Assessment[52] were then used to estimate energy consumption in the study area.

The methodology below is presented as two parts; first calculations based on the number of households derived from the number of standard, domestic, electricity meters (assumed to be equivalent to the number of households) from the BEIS postcode data, and second outputs scaled according to the number of households identified in the Housing Need Assessment (2018).

[52] Wedmore Housing Need Assessment - Approved Final Report, November 2018.

Estimated electricity consumption from postcode data

The following postcodes were taken as being representative of the settlements listed above and used to estimate consumption gas and electricity consumption:

Settlement	Postcode
Blackford	BA22 7EB
Blackford	BA22 7EE
Blackford	BA22 7EF
Panborough	BA5 1PN
Panborough	BA5 1PR
Panborough	BA5 1PS
Panborough	BA5 1PT
Panborough	BA5 1PU
Panborough	BA5 1PW
Stone Allerton	BS26 2NB
Stone Allerton	BS26 2ND
Stone Allerton	BS26 2NG
Stone Allerton	BS26 2NH
Stone Allerton	BS26 2NJ
Stone Allerton	BS26 2NL
Stone Allerton	BS26 2NN
Stone Allerton	BS26 2NP
Stone Allerton	BS26 2NQ
Stone Allerton	BS26 2NR
Stone Allerton	BS26 2NS
Stone Allerton	BS26 2NW
Chapel Allerton	BS26 2PB
Chapel Allerton	BS26 2PD
Chapel Allerton	BS26 2PG
Chapel Allerton	BS26 2PH
Chapel Allerton	BS26 2PJ
Chapel Allerton	BS26 2PQ
Wedmore	BS28 4AA
Wedmore	BS28 4AB
Wedmore	BS28 4AD
Wedmore	BS28 4AE
Wedmore	BS28 4AG
Wedmore	BS28 4AH
Wedmore	BS28 4AL
Wedmore	BS28 4AN
Wedmore	BS28 4AP
Wedmore	BS28 4AR
Wedmore	BS28 4AS
Wedmore	BS28 4AT
Wedmore	BS28 4AU
Wedmore	BS28 4AW
Wedmore	BS28 4AX
Wedmore	BS28 4AY
Wedmore	BS28 4AZ
Wedmore	BS28 4BA
Wedmore	BS28 4BB
Wedmore	BS28 4BE
Wedmore	BS28 4BG
Wedmore	BS28 4BH
Little Ireland	BS28 4BJ
Wedmore	BS28 4BL
Wedmore	BS28 4BP
Wedmore	BS28 4BQ
Wedmore	BS28 4BT
Wedmore	BS28 4BW

Wedmore	BS28 4BX
Wedmore	BS28 4BY
Wedmore	BS28 4BZ
Wedmore	BS28 4DA
Wedmore	BS28 4DB
Wedmore	BS28 4DF
Wedmore	BS28 4DH
Wedmore	BS28 4DN
Wedmore	BS28 4DQ
Wedmore	BS28 4DT
Wedmore	BS28 4DU
Wedmore	BS28 4DX
Wedmore	BS28 4EA
Wedmore	BS28 4EB
Wedmore	BS28 4ED
Wedmore	BS28 4EE
Wedmore	BS28 4EJ
Wedmore	BS28 4EL
Wedmore	BS28 4EP
Wedmore	BS28 4EQ
Cocklake	BS28 4HB
Cocklake	BS28 4HD
Cocklake	BS28 4HE
Cocklake	BS28 4HF
Wedmore	BS28 4HG
Cocklake	BS28 4HH
Cocklake	BS28 4HL
Cocklake	BS28 4HN

Cocklake	BS28 4HW
Clewer	BS28 4JF
Crickham	BS28 4JS
Crickham	BS28 4JT
Crickham	BS28 4JU
Crickham	BS28 4JX
Crickham	BS28 4JY
Crickham	BS28 4JZ
Blackford	BS28 4NB
Blackford	BS28 4ND
Blackford	BS28 4NE
Blackford	BS28 4NG
Blackford	BS28 4NH
Blackford	BS28 4NJ
Blackford	BS28 4NL
Blackford	BS28 4NN
Blackford	BS28 4NP
Blackford	BS28 4NQ
Blackford	BS28 4NR
Blackford	BS28 4NS
Blackford	BS28 4NT
Blackford	BS28 4NU
Blackford	BS28 4NX
Blackford	BS28 4NY
Blackford	BS28 4NZ
Wedmore	BS28 4SA
Theale	BS28 4SL
Theale	BS28 4SN

Theale	BS28 4SR
Theale	BS28 4SU
Theale	BS28 4SW
Theale	BS28 4SX
Theale	BS28 4SY
Bagley	BS28 4TD
Bagley	BS28 4TE
Bagley	BS28 4TF
Bagley	BS28 4TG
Mudgley	BS28 4TH
Mudgley	BS28 4TU
Mudgley	BS28 4TX
Mudgley	BS28 4TY
Mudgley	BS28 4TZ
Heath House	BS28 4UG
Heath House	BS28 4UH
Heath House	BS28 4UJ
Heath House	BS28 4UN
Heath House	BS28 4UP
Heath House	BS28 4UQ
Heath House	BS28 4UW
Westham	BS28 4UX
Westham	BS28 4UY
Westham	BS28 4UZ
Sand	BS28 4XF
Sand	BS28 4XG

Postcode level standard electricity consumption was obtained from the Department of Business Energy and Industrial Strategy (BEIS) for 2017 (source: https://www.gov.uk/government/statistics/postcode-level-electricity-statistics-2017-experimental)

For the postcodes listed above the results are:

- Number of meters listed = 1080
- Estimated annual consumption electricity (kWh) = 5,114,853

Estimated Economy 7 tariff electricity consumption from postcode data

BEIS provide data for electricity consumption using the Economy 7 tariff within the following postcode areas. (Other areas are assumed not to have Economy 7 meters or consumption which is too low to be recorded):

- BA5 1PN
- BS28 4NS
- BS28 4SR
- BS28 4TE

In these postcodes:

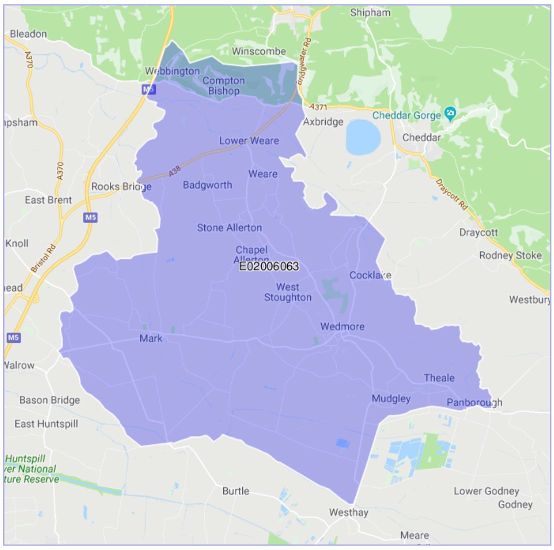
- Number of meters listed = 29
- Estimated annual consumption electricity (kWh) = 217,053

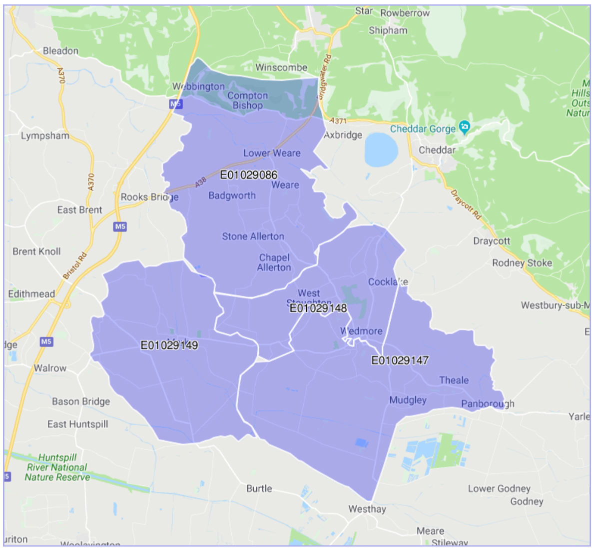
Exclusions:

- The estimated consumption is the sum of total domestic consumption for the postcodes listed above.
- The number of meters is the total within the listed postcodes for meters that have a consumption ***between*** 100kWh and 100,000kWh ***and*** a domestic meter profile.

Estimated electricity consumption by Lower Super Output Area (LSOA)

The Middle Super Output Area covering Wedmore and the surrounding locality is show in the left hand map (screen shot from Energy Map) below. This divides into four Lower Super Output Areas (shown right).





These are:

iv. E01029086 - Stone Allerton

v. E01029149 - Mark

vi. E01029148 West Stoughton and Wedmore

vii. E01029147 - Latcham

The second E01029149 has been excluded from the summary as it largely falls outside the study area.

For the three remaining Lower Super Output Areas BEIS give the following data[53] for 2017:

- Number of meters: 2308
- Annual electricity consumption (kWh): 12,488,924

Estimating gas consumption

Estimated gas consumption from postcode data

The postcode areas identified above were checked against the BEIS database[54]. Those listed as having gas meters are shown in the table below.

[53] https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-electricity-consumption

[54] https://www.gov.uk/government/statistics/postcode-level-gas-statistics-2017-experimental

In postcodes with gas meters BEIS give the following data:

- Number of meters: 575
- Total estimated annual domestic gas consumption (kWh): 10,312,543

Settlement	Postcode	Listed on BEIS domestic gas database
Clewer	BS28 4JF	Yes
Cocklake	BS28 4HL	Yes
Wedmore	BS28 4AB	Yes
Wedmore	BS28 4AD	Yes
Wedmore	BS28 4AE	Yes
Wedmore	BS28 4AG	Yes
Wedmore	BS28 4AH	Yes
Wedmore	BS28 4AL	Yes
Wedmore	BS28 4AN	Yes
Wedmore	BS28 4AP	Yes
Wedmore	BS28 4AR	Yes
Wedmore	BS28 4AS	Yes
Wedmore	BS28 4AT	Yes
Wedmore	BS28 4AU	Yes
Wedmore	BS28 4AW	Yes
Wedmore	BS28 4AX	Yes
Wedmore	BS28 4AY	Yes
Wedmore	BS28 4AZ	Yes
Wedmore	BS28 4BA	Yes
Wedmore	BS28 4BB	Yes
Wedmore	BS28 4BE	Yes
Wedmore	BS28 4BG	Yes
Wedmore	BS28 4BH	Yes
Wedmore	BS28 4BL	Yes
Wedmore	BS28 4BP	Yes
Wedmore	BS28 4BQ	Yes
Wedmore	BS28 4BW	Yes
Wedmore	BS28 4BX	Yes
Wedmore	BS28 4BY	Yes
Wedmore	BS28 4BZ	Yes
Wedmore	BS28 4DA	Yes
Wedmore	BS28 4DB	Yes
Wedmore	BS28 4DF	Yes
Wedmore	BS28 4DN	Yes
Wedmore	BS28 4DQ	Yes
Wedmore	BS28 4DT	Yes
Wedmore	BS28 4DU	Yes
Wedmore	BS28 4DX	Yes
Wedmore	BS28 4EA	Yes
Wedmore	BS28 4EB	Yes
Wedmore	BS28 4ED	Yes
Wedmore	BS28 4EE	Yes
Wedmore	BS28 4EJ	Yes
Wedmore	BS28 4EL	Yes
Wedmore	BS28 4EQ	Yes
Wedmore	BS28 4HG	Yes

Postcode areas with domestic gas meters

Estimated gas consumption by Lower Super Output Area

For the Lower Super Output Areas of E01029086 - Stone Allerton, E01029148 West Stoughton and Wedmore, and E01029147 - Latcham, BEIS provide the following data:

- Number of meters: 871
- Annual gas consumption (kWh): 15, 962 475

Estimating demand for heat in homes not on mains gas or using Economy 7

In homes which are not on mains gas or listed as using Economy 7 the consumption of fuels for heating and hot water is not metered so consequently has to be estimated.

There are two parts to this, firstly, estimating the number of homes using oil and solid fuel, and within this the split between wood and coal as the primary fuel, and secondly, the energy consumption per household.

Estimating the number of homes using oil or solid fuel for heating

The number of homes using oil or solid fuel for heating is estimated by taking the number of standard electricity meters within the postcode study area. On the assumption that each domestic property has one electricity meter this is taken to be equivalent to the total number of homes in the study area. The number of gas and Economy 7 meters is deducted from this number to leave the total number of homes assumed to use oil or some form of solid fuel for heating and hot water.

The figures are as follows:

Split between fuels used for heating in homes in the study area	Number	Notes
Number of electricity meters in the postcode study area (based on standard electricity tariff)	1080	Figure from BEIS consumption data by postcode for 2017
Number gas meters in the postcode study area	575	As above
Number of Economy 7 meters in the postcode study area	29	As above
Estimated number of homes assumed to be on other fuels	476	Total number of electricity consumption meters (standard tariff) minus number of gas and Economy 7 meters

For homes *not* on gas or Economy 7 the split between those using oil and those using solid fuel is taken from research by the University of Exeter[55] which found that in areas not on mains gas approximately 4.5 homes used oil for every home using solid fuel (excluding homes using Economy 7).

Applying these ratios the figures are as follows:

Estimated number of homes using oil and solid fuel for heating and hot water	Number	Notes
Estimated number of homes assumed to use fuels *other* than gas or Economy 7 for heating and hot water	476	Calculated estimate. See notes in the table above.
Estimated number of homes using oil for heating and hot water	389	Estimate assumes that 4.5 homes use oil for every home using solid fuel
Estimated number of homes using solid fuel for space heating and hot water	87	As above

Estimating the split between wood and coal use in homes using solid fuel

National statistics[56] have been used to estimate the split between homes using wood as the primary source of heat and those using coal. These suggest that 7.5% of homes use wood and 92.5% use coal (which is taken to include smokeless fuels).

Using this breakdown the figures are as follows:

Estimated split between homes wood and coal for heating and hot water	Number	Notes
Estimated number of homes in the study area using wood for heating and hot water	7	Based on national statistics. See text.
Estimated number of homes in the study area using coal for heating and hot water	80	As above

[55]http://geography.exeter.ac.uk/staff_profile_images/Hoggett2011_Heat_in_Homes.pdf derived from NS/DECC 2010 This suggests that 35.3% of homes not on mains gas use Economy 7 for heating and 52.9% use oil and 11.8% use solid fuel. Based on figures provided by BEIS, the actual number of homes using Economy 7 in this study is much lower than 35.3%. The ratio (split) between homes using solid fuel and oil in Exeter's research has been applied in this case. Approximately this is 4.5 homes using oil for every home using solid fuel.

[56] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/517572/Summary_results_of_the_domestic_-wood_use_survey_.pdf

Summary of estimated breakdown of fuel type for heating and hot water for homes in the study area

The results above are summarized in the table below:

Estimated number of homes in the study area using specified fuels for domestic heating and hot water	Number	Notes
Mains gas	575	
Economy 7	29	
Heating oil	389	
Wood	7	
Coal	80	
Total	1080	Equals total number of domestic properties in the study area based on BEIS data for consumption by postcode.

Estimating energy consumption per household

Using the statistics above for the number of meters and total annual consumption (for all meters) the average consumption per household can be estimated, and figures compared for estimates derived from postcode and Lower Super Output Area (LSOA) data. The results are summarised as follows:

By postcode		By Lower Super Output Area (LSOA)	
Standard electricity consumption			
Number of meters	1080	Number of meters	2308
Total consumption (kWh/annum)	5,114,853	Total consumption (kWh/annum) including E7	12,488,924
Estimated average consumption per meter (household) (kWh/annum/meter)	4736	Estimated average consumption per meter (household) (kWh/annum/meter)	5411
Economy 7		N/A	
Number of meters	29		
Total consumption of electricity using Economy 7 (kWh/annum)	217,053		

By postcode		By Lower Super Output Area (LSOA)	
Estimated average electricity consumption (E7) per meter (household) (kWh/annum/meter)	7485		
Estimated annual average consumption per meter (household) including standard electricity and E7 (kWh/annum/meter)	4937	Estimated annual average consumption per meter (household) including standard electricity and E7 (kWh/annum/meter)	5411
Gas consumption			
Number of meters	575	Number of meters	871
Total consumption (kWh/annum)	10,312,543	Total consumption (kWh/annum) including E7	15, 962 475
Estimated average consumption per meter (household) (kWh/annum/meter)	17,935	Estimated average consumption per meter (household) (kWh/annum/meter)	18,327

Heat consumption in households using oil or solid fuel is assumed, on average, to be similar to those using mains gas.

Scaling the number of households and population according to the Housing Need Assessment

As discussed above whilst consumption data by postcode and by LSOA provide two means of estimating energy demand by household neither provides an exact fit with the study area.

Based on BEIS data by postcode there are estimated to be 1080 households in the study area[57]. According to the Housing Need Assessment (2018) there are 1398 households in the parish of Wedmore and a population of 3318[58].

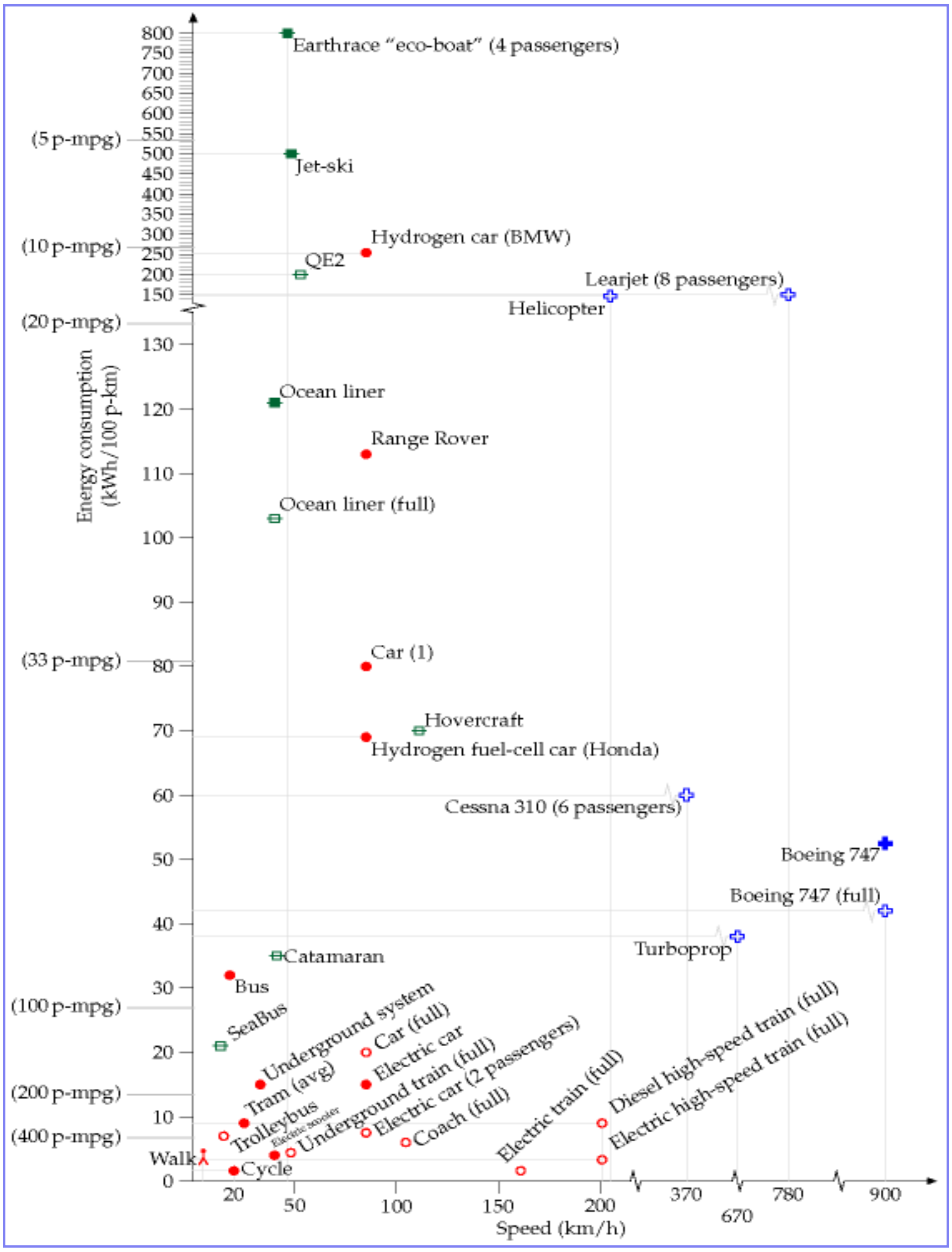
57 BEIS caveat this data by stating that it is 'experimental'.

58 Population figure taken from 2011 Census.

Taking the revised number of households the breakdown of fuel type by number of households can be scaled as follows:

Fuel type	Number of households based on BEIS postcode data	Number of households scaled based on Wedmore Housing Need Assessment	Notes
Mains gas	575	744	Scaling assumes that the ratio of different fuel types estimated from the BEIS postcode data remains unchanged.
Economy 7	29	38	
Heating oil	389	503	
Wood	7	9	
Coal (including smokeless)	80	104	
Total	1080	1398	

Appendix 2 - energy use by transport mode



Energy requirements of different forms passenger transport. Source: Sustainable Energy Without the Hot Air. David JC MacKay. http://www.withouthotair.com/c20/page_128.shtml The vertical coordinate shows the energy consumption in kWh per 100 passenger-km. The horizontal coordinate indicates the speed of the transport. The "Car (1)" is an average UK car doing 33 miles per gallon with a single occupant. The "Bus" is the average performance of all London buses. The "Underground system" shows the performance of the whole London Underground system. The catamaran is a diesel-powered vessel. Equivalent fuel efficiencies in passenger-miles per imperial gallon (p-mpg) are indicated on the left hand side. Hollow point-styles show best-practice performance, assuming all seats of a vehicle are in use. Filled point-styles indicate actual performance of a vehicle in typical use.