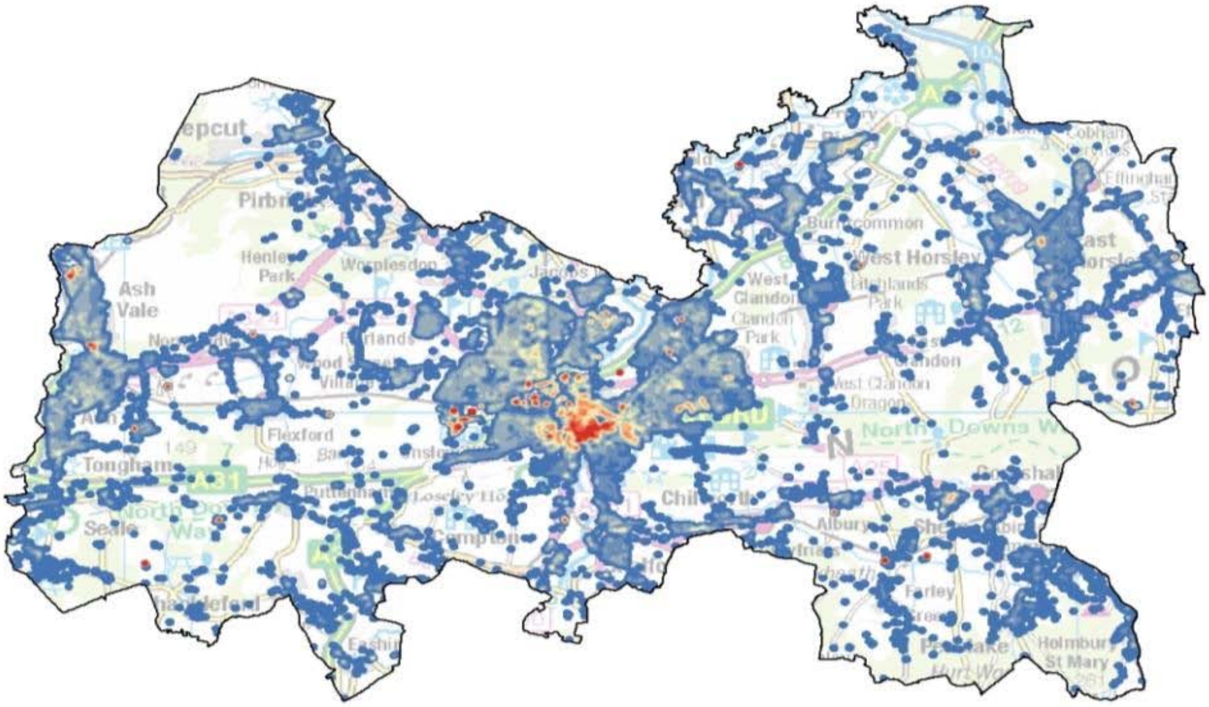
Guildford Borough Council
Renewable Energy Mapping Study



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Executive Summary

Overview

This report presents the output from the renewable energy mapping study undertaken by the Centre for Sustainable Energy on behalf of Guildford Borough Council. The findings will form part of the evidence base being used to support the development of the new Local Plan and will help the council to consider new policies which encourage the appropriate use of low and zero carbon energy generation across the Borough. The outputs will also provide the Council and other stakeholders with an indication of the range of sustainable energy resources that exist in the Borough and the opportunities and constraints that impact their use.

The scope of the work focuses on the supply of sustainable energy relating to buildings and stand-alone energy generation, but does not include energy relating to transport. The study specifically assesses opportunities and constraints relating to district heating systems using a heat mapping approach, large and medium scale wind power, solar PV farms and building-integrated renewable energy systems. Both existing and proposed developments are considered in the analysis.

Baseline energy demand and existing renewable energy generation

Existing energy use and associated emissions across Guildford Borough were first estimated to establish a baseline. Using Government local area statistics, total energy consumption across the industrial/commercial, domestic and transport sectors for 2012 was estimated to be 3,416 GWh. Figure 1 shows the sector split of total carbon dioxide emissions during 2012, with the total figure being 1,040 ktCO_2. This represents approximately 13% of the total for Surrey and 1.7% of the South East region's emissions. It is estimated that existing renewable heat and electricity generation capacity in the Borough currently results in carbon dioxide savings of no more than 0.3% of Guildford's total emissions.

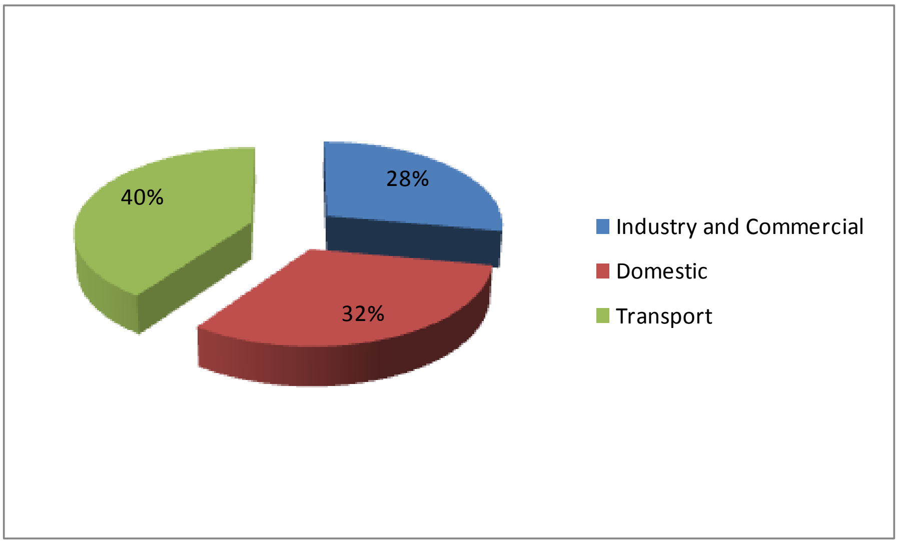

Figure 1: Local CO_2 emission estimates for Guildford Borough (2012 figures).

Heat mapping

Heat mapping is a process of using available datasets to make accurate estimates of heat demand from buildings within a given area, and presenting these visually on a map. The map can then be used to find areas of high heat demand which may be suitable for district heating, where one heat source is used to provide heat to a network of more than one property or building. This can be more efficient than each property having its own heating system, because heat generation is more efficient at larger scales and may sometimes be combined with electricity generation in the form of a Combined Heat and Power (CHP) system.

Analysis of the National Heat Map has identified areas and buildings with the highest heat demands across Guildford Borough including both residential and non-residential buildings. Potential future development sites, as identified in the draft Local Plan 2014, have also been overlaid to assess their proximity to existing heat loads, as new developments may sometimes act as a trigger for district heating projects which can then be designed to also serve adjacent buildings. Although a lack of data on heat load profiles for the new development sites has limited the extent to which these future heat loads can be assessed, the mapping identifies areas where significant existing and future heat loads are co-located – see Figure 2.

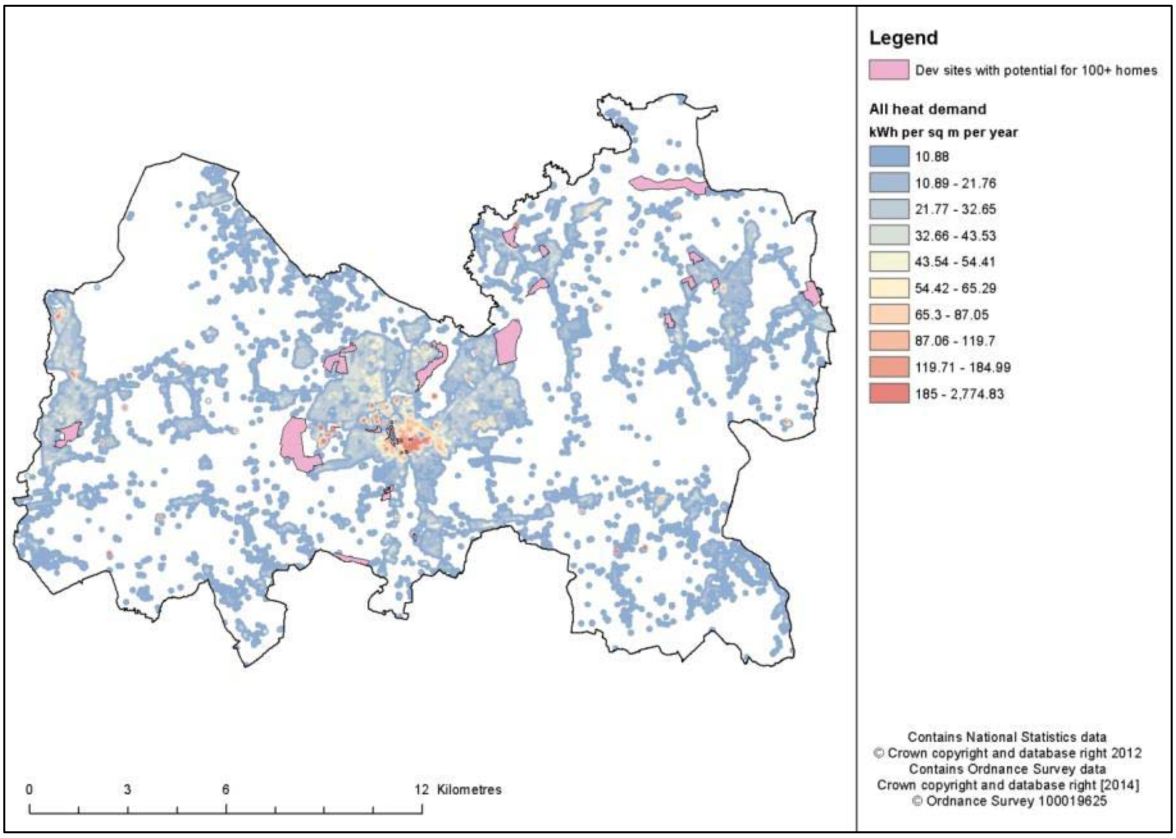

Figure 2: Large development areas with existing heat demand, whole borough

Further 'overlay' modelling has identified specific locations which may have increased potential for district heating by applying a set of criteria which considers co-location of areas with the highest heat densities, large residential heat loads and anchor loads (anchor loads are likely to have relatively high and stable heat demands and/or be in sectors more likely to participate in heat distribution projects such as hospitals, leisure centres or civic buildings). The analysis identified eight locations that met the overlay criteria and which were then considered in more detail. Of these, three areas were thought worthy of more detailed study:

- Central Guildford
- Royal Surrey County Hospital and surrounding area
- University of Surrey's Stag Hill Campus and adjacent industrial estates

These areas could be considered as heat 'priority areas' which are likely to have the most potential for viable district heating networks. This high level analysis provides a starting point for identifying areas with the greatest potential for district heating systems and can be used by planners and other stakeholders early on in the sustainable energy masterplanning process to assess strategically important developments sites. It can help to trigger timely and more in-depth feasibility studies once more detailed data becomes available for clusters of existing or future buildings previously identified within heat priority areas.

Onshore wind power and solar PV farms

The analysis shows that whilst opportunities for medium and large scale wind are somewhat limited within Guildford Borough, there are small areas in which wind development at this scale has potential. The potential for large scale wind is estimated to be 105 MW, equivalent to 42 large scale turbines which could annually generate electricity equal to 39% of the Borough's 2012 electricity consumption. The potential for Solar PV farms is much larger as site specific requirements are less restrictive but this has been reduced by 90% due to the likelihood of competing land use such as agriculture. The resulting resource is estimated to be 436 MW which could potentially equate to 60% of the Borough's 2012 electricity consumption.

However, both these renewable energy generation figures reduce significantly if designated areas such as Areas of Outstanding Natural Beauty (AONB), Special Protection Areas (SPA), Sites of Special Scientific Interest (SSSI), Areas of Great Landscape Value (AGLV) and green belt are introduced as planning constraints. For example, if all designations are treated as exclusion areas for these technologies, the net resource reduces to zero and 7 MW for large/medium scale wind and solar PV farms respectively – see Figure 3 below.

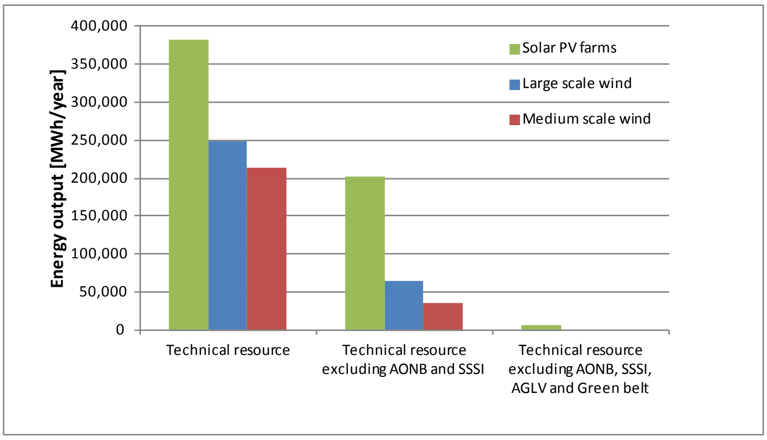

Figure 3: Estimated technical resource for wind and solar PV farms in Guildford Borough with various levels of potential constraints

It is important to note that wind power or solar PV farms are not automatically excluded from these designated areas by the planning system, but that certain designations may carry more weight than others meaning that the impact of the technologies will differ across the areas. The land designations considered each have their own set of criteria on what makes an area worthy of designation and justification is set out when each specific area is assessed by the designating body. Proposals within each location should be considered on a case-by-case basis and should be site-specific. The analysis therefore simply aims to identify areas where planning constraints are least likely to impact deployment of these technologies.

The results suggest that deploying larger scale wind power either now or in the future is likely to impact on landscape character and openness. Should Guildford wish to consider deploying such infrastructure, the significance of this impact, which would in part be dependent upon the designations in place at the chosen location, would need to be weighed against the benefits of long term local sustainable energy generation. Although the analysis also indicates that solar PV farms may offer more potential in terms of energy generation, deployment of a more significant amount of this technology may require similar concessions. It should be noted however that any change in land use from the deployment of either wind or solar PV is not permanent. Indeed, the installation of wind and solar PV systems for a period of 25 years, with easy restoration to the original land use state, might be seen by some authorities as a way of preserving the existing land use for future generations in the mid to long term.

Hydro power and water source heat pumps

In addition to the existing 35 kW hydro power scheme at the Town Mill adjacent to Yvonne Arnaud Theatre, the River Wey's course through Guildford Borough offers a number of opportunities for hydro generation as demonstrated by a 2010 Environment Agency report on opportunities for small scale hydro power on rivers in England and Wales. A total of 56 sites were identified having a combined capacity of 1.8 MW, with 17 of these estimated to be in the 50-500 kW range. The locations having the largest potential hydro generation capacities were found to be at Bowers Lock and Papercourt Lock.

Less is known about the potential for water source heat pumps. In the right locations, they have been shown to have the potential to provide efficient low carbon heating or cooling at scale as long as the buildings to be served are in close vicinity; as demonstrated by the Kingston Heights installation by the Thames, which incorporates a 2.3 MW water source heat pump for space and water heating of a mixed development. Future decarbonisation of the electricity grid will increasingly benefit heat pump technologies as their overall emissions reduce. Although no potential sites were identified within Guildford in the 2014 DECC water source heat map, this focused on matching large urban heat loads with high flow rivers, a combination which Guildford would appear to lack. However, the technical potential for heat generation on a river the size of the Wey is substantial at around 50 MW and may justify more detailed survey work to establish viability and the impact of scale for this technology.

Building-integrated renewable energy systems

An analysis was undertaken of the potential for building-integrated renewable energy technologies across Guildford Borough. Deployable potential was estimated using proportional data taken from other national studies on likely uptake rates for each technology considered independently. A lack of data however has limited the bulk of the analysis to the domestic sector. It does however generally consider installations on both existing and new development. Figure 4 summarises the technical potential developed in the analysis and a scenario for deployment using 'mid-scenario' uptake rates for the domestic sector.

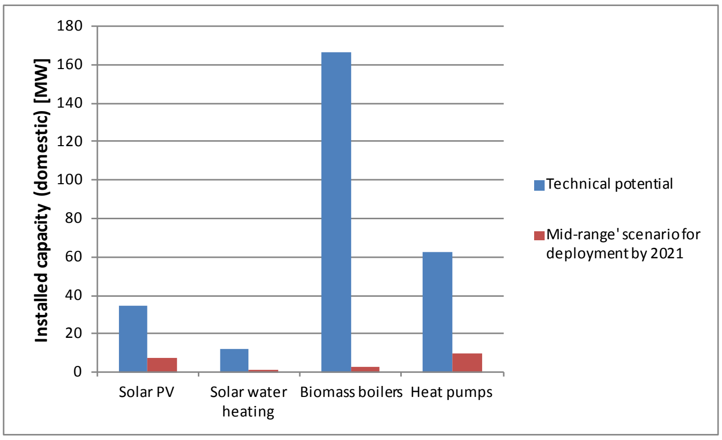

Figure 4: Comparison of technical resource and 2021 deployable potential for domestic installed capacity within Guildford Borough

Clearly the technical potential as expected is considerably higher than the deployable potential for each technology. Theoretically the full potential for solar and heat pump technologies is only constrained by the number of buildings where they can physically be installed and deliver adequate performance; the technical potential assessed in the analysis therefore makes an attempt to allow for some broad constraints without the need for detailed modelling. Biomass boilers however will be constrained by the availability of woodfuel which should ideally be locally obtained, and potentially by Guildford's Smoke Control Areas which only permit authorised fuels or exempt appliances. The scenarios for deployment shown should be considered as estimates only as a high number of uncertainties are apparent both in the source modelling and in the application of uptake rates to Guildford's building stock. However the modelling does illustrate the types of building-integrated technologies that Guildford can seek to encourage and strategically plan for as part of its overall approach towards achieving a low carbon, more sustainable and more secure range of local energy supplies.

MW or MWh? A note on units of energy:

In describing technologies that generate energy, this report mainly uses the terms megawatts (MW) and megawatt-hours (MWh). The key difference here is that the former refers to the generation capacity of the technology (i.e. its maximum instantaneous output or 'nameplate' rating), whilst the latter refers to the generation yield of the technology (i.e. the amount of energy it is likely to produce over a specified time period – normally a year). A domestic solar photovoltaic system, for example, might be rated at two kilowatts (its maximum instantaneous power output when light conditions are optimum), and over the course of a year it might typically generate 1,800 kilowatt-hours.

Depending on the scale of the energy plant, generation capacity is normally expressed in either watts (W), kilowatts (kW), megawatts (MW) or gigawatts (GW), with each unit increasing by a factor of 1,000. A wind turbine capacity of 2 MW, for example, can also be expressed as 2,000 kW (or 0.002 GW). Similarly, energy generation yield is normally stated in watt-hours (Wh), kilowatt-hours (kWh), megawatt-hours (MWh) or gigawatt-hours (GWh).

To convert from generation capacity to generation yield, an assumption needs to be made on the levels of generation at which the system will actually operate throughout the year; this will vary as it will not operate at its maximum generation capacity all the time. Industry-standard figures called 'capacity factors' are therefore used. The capacity factor takes into account the generation characteristics of a specific technology and can be defined as:

The actual energy yield produced over a period of time expressed as a proportion of the energy yield that would have been produced if the energy plant had operated at its full generation capacity continuously over the same period.

Capacity factors vary considerably between technologies; for example, solar PV may typically have a capacity factor of 0.1 whereas a large scale wind turbine may have one of 0.25. This effectively means that, in terms of energy yield, a 1 MW wind turbine is not directly comparable with a 1 MW solar PV farm. In this case, although both are capable of generating the same maximum output of 1 MW in ideal conditions, the wind turbine will typically produce more energy over the course of a year as the wind tends to blow during day and night, whereas the sun only shines during the day. The use of energy generation yields in MWh or GWh will therefore provide a more meaningful measure of renewable energy deployment than simply using generation capacities in MW or GW. Additionally, carbon savings are calculated directly from generation yields rather than generation capacities.

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1 Introduction

This report presents the output from the renewable energy mapping study undertaken by the Centre for Sustainable Energy on behalf of Guildford Borough Council. The findings will form part of the evidence base being used to support the development of the new Local Plan and will help the council to consider new policies which encourage the appropriate use of low and zero carbon energy generation across the Borough. The outputs will also provide the Council and other stakeholders with an indication of the range of sustainable energy resources that exist in the Borough and the opportunities and constraints that impact their use.

The need for such a study and the importance of its subject matter broadly stems from two key national drivers relating to planning and climate change:

- Firstly there is a responsibility on all local authorities to contribute towards Government targets in reducing carbon emissions and increasing renewable energy generation. The Government's current targets are to reduce the UK's carbon emissions by 80% (below 1990 levels) by 2050 and ensure that 15% of our total energy consumption (including electricity, heat and transport) comes from renewable energy sources by 2020.

- Secondly, local planning authorities are required to align their key policy documents and strategies with the 2012 National Planning Policy Framework (NPPF). This strongly supports the transition to a low carbon future and encourages the use of renewable resources. It also states that local authorities should have a positive strategy to promote energy from renewable and low carbon sources and should consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure the development of such. It also states that local authorities should identify opportunities where development can draw its energy supply from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers.

Guildford Borough Council currently has a target to reduce carbon emissions from its own operations, against a 2008-09 baseline, of 43% by 2019-20, with an interim target of 34% by 2014-15. Good progress is being made against these targets through renewable energy installations and energy efficiency measures, but with stretching targets some of the measures identified in this report might well need to be considered to help meet these aspirations. It also has a Carbon Management Plan that drives its own programme of energy efficiency and renewable technology deployment.

Previous work on the potential for renewables includes the 2007 Guildford Town Centre Sustainable Energy Feasibility Study[1], which examined the potential for providing combined heat and power (CHP), renewables and other energy efficiency measures on major development sites in Guildford Town Centre. The following analysis aims to update and broaden this study.

2 Scope of study

The scope of the work focuses on the supply of sustainable energy relating to buildings and stand-alone energy generation, but does not include energy relating to transport. The study first establishes a baseline energy demand and total emissions inventory for Guildford Borough and then examines a number of topics using a range of data sources, GIS tools and other desk-based methodologies. The study specifically assesses opportunities and constraints relating to:

[1] www.guildford.gov.uk/media/4268/Executive-Summary-p1-10/pdf/Executive_Summary_p.1-10.pdf

- **Heat mapping** – drawing on the National Heat Map to identify locations with the highest spatial heat densities which may hold potential for district energy networks
- **Large scale stand-alone renewable energy generation** – assessment of opportunities for wind power, solar photovoltaic farms, hydro power and water-source heat pumps. The study does not consider stand-alone energy generation technologies which use biomass such as woodfuel or waste.[2]
- **Building-integrated renewable energy systems** – integration of low or zero carbon energy generation systems within existing buildings and future development.

3 Baseline energy demand and existing renewable energy capacity

3.1 Baseline energy demand

Estimating existing energy use and associated emissions across Guildford Borough is important to establish a baseline from which to measure future changes and monitor progress towards relevant targets. Using Government local area statistics[3], total energy consumption across the industrial/commercial, domestic and transport sectors for 2012 was estimated to be 3,416 GWh. Figure 5 shows the sector split of total emissions during 2012, with the total figure being 1,040 ktCO2.[4] This represents approximately 13% of the total for the County of Surrey and 1.8% of the South East region's emissions.

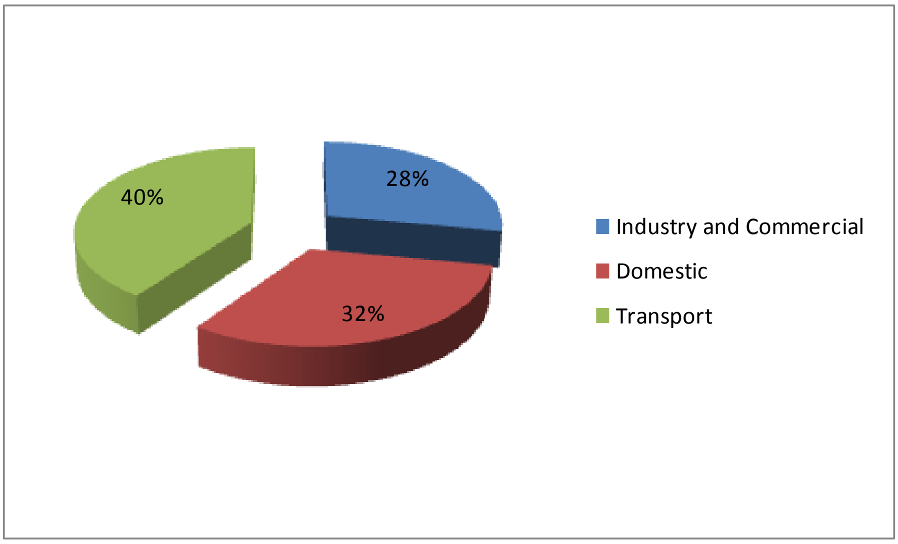


Figure 5: Local CO_2 emission estimates for Guildford Borough (2012 figures).

Table 1 presents a sub-set of this data for 2012 which shows building-related (i.e. non-transport) energy consumption across the Borough, mostly based on metered data, split between domestic and industrial/commercial users.

[2] Strategic planning for waste management is dealt with by Surrey County Council, being the minerals and waste planning authority for Surrey. The County Council is also leading on the development of biomass hubs within their own estates.
[3] See: www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2010
[4] See: www.gov.uk/government/statistics/local-authority-emissions-estimates. Note that this figure does not include emissions and removals from the landuse, landuse change and forestry sector (LULUCF) which in this case would reduce the total by 9 $ktCO_2$. For more information see: http://unfccc.int/methods/lulucf/items/3060.php

Sector	Electricity (GWh/year)	Gas (GWh/year)	Other Fuels (GWh/year)	Total (GWh/year)	CO_2 Emissions (kT/year)
Domestic	267.9	832.7	39.31	1,140.0	331.9
Industrial/commercial	371.1	357.4	47.62	776.0	290.7
Total	**639.0**	**1,190.1**	**86.93**	**1,916.00**	**622.6**

Table 1: Guildford Borough energy consumption statistics (non-transport)

According to DECC's updated energy and emissions projections (2014) for final energy demand[5], the figure for natural gas consumption in the domestic sector under a 'reference' scenario is likely to decrease slightly over the next decade due mainly to energy efficiency initiatives, although other changes in factors such as comfort levels and electricity consumption (where homes are being heated to higher temperatures and incorporate higher numbers of power-hungry devices) may reduce or reverse the effect on overall carbon emissions.

3.2 Existing renewable energy capacity

An accurate figure for the amount of existing renewable energy generation capacity across the Borough is not currently known although sub-regional data regarding the Feed-in Tariff[6] scheme suggest that there was at least 3.9 MW of solar PV, 2 kW of wind and 35 kW of hydro installed between April 2010 and September 2014.[7] It is estimated that this combined capacity would generate approximately 3.3 GWh per year. This equates to annual savings of 1,600 tonnes of CO_2, or around 0.2% of the Borough's total CO_2 emissions for 2012.

Similar data was identified for the Renewable Heat Incentive[8] scheme, which identified 0.2 MW of heat pump and biomass installed capacity (April 2014)[9]. The source data from Table 1 also indicates that 2.5 GWh of energy was consumed within the Borough using 'bioenergy and wastes' in 2012, although it is not known how this figure is split between heat, power or transport end uses and so it is not possible to discern which fossil fuels were displaced or the implied emission savings. However, these figures are relatively small and it is estimated that their impact on the Borough's total annual CO_2 emissions is in the order of 0.1%.

[5] www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014
[6] www.gov.uk/feed-in-tariffs/overview
[7] www.gov.uk/government/statistical-data-sets/sub-regional-feed-in-tariffs-confirmed-on-the-cfr-statistics
[8] www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/renewable-heat-incentive-rhi
[9] www.gov.uk/government/statistics/rhi-and-rhpp-deployment-data-april-2014

4 Heat mapping

4.1 Using the National Heat Map to search for district heating opportunities

4.1.1 What is heat mapping?

Heat mapping is a process of using available datasets to make accurate estimates of heat demand from buildings within a given area, and presenting these visually on a map. The map can then be used to find areas of high heat demand which may be suitable for district heating.

4.1.2 What is district heating?

District heating is a technology which uses one heat source to provide heat to more than one property. Instead of each property having its own heating system separate from any other property, a group of properties connected to a district heating system all receive heat (in the form of hot water or steam) from a central source, via a network of insulated pipes. This can be more efficient than each property having its own heating system, because heat generation is more efficient at larger scales. The heat source of a district heating system can be a basic boiler, or it can be a Combined Heat and Power (CHP) system. CHP produces both heat and electricity, so with a CHP district heating system, as well as a network of pipes distributing heat, there is also a network of wires to distribute electricity (or one main user which takes all of the electricity generated).

4.1.3 Using the National Heat Map

This report uses data from the National Heat Map, which was produced by CSE for the Department of Energy and Climate Change[10]. The National Heat Map shows heat demand across England at a range of scales from national to local. Behind the heat map is a database of modelled heat demand for every address in the country (and actual heat demand for buildings which have Display Energy Certificates).

For this report , with DECC's permission, we have taken address-level modelled heat demand from the National Heat Map for the Guildford Borough area and used a Geographic Information System (GIS) to analyse the spatial distribution of heat demand. All addresses in the study area, with their associated heat demand, were mapped using their OS Grid coordinates. A heat demand density map has been produced covering the study area – this is a map layer which gives the estimated heat demand per unit of land area (typically kWh heat / square metre), based on the address-level heat demand data.

Areas with high concentrations of heat demand have higher spatial density values. This is easy to understand when seen on a map - Figure 6 shows an example heat density map[11] over the address points from which it originates. The address points (in black) are scaled so that those with higher heat demand are bigger. Heat density (the coloured base-map) is shown from blue to red, with blue areas being low density and red areas high density. Areas in which there are more and/or larger point heat demands close together have higher heat densities.

[10] See http://tools.decc.gov.uk/nationalheatmap/

[11] This is an example area which is not within Guildford Borough

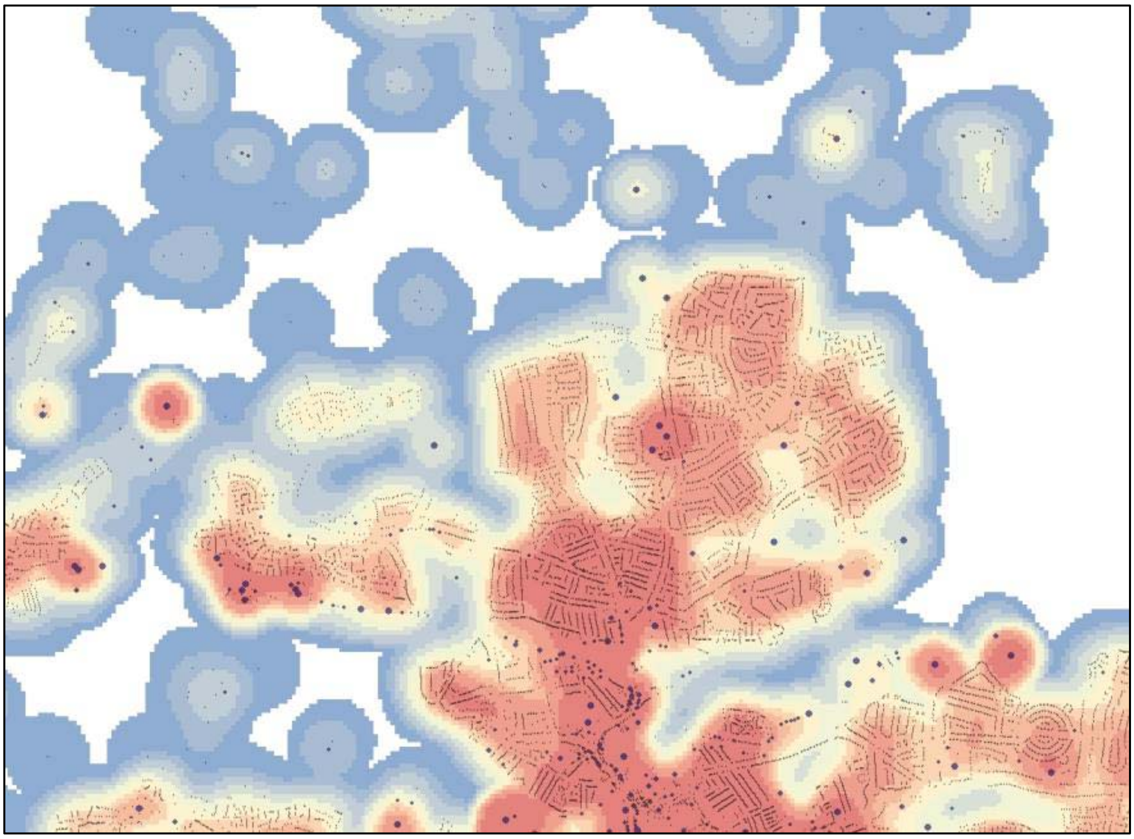


Figure 6: Example of heat density map

4.1.4 Viability of district heating

There is a cost to establishing and running a district heating system; a large part of the cost is laying pipes, due to the need to dig up roads, which is expensive. An energy centre, which houses the heat source, also needs to be established; this could be located within one of the buildings in the network or it could be in its own separate building. Cost varies widely depending on the number and type of buildings connected and the area covered. Installing district heating in a new development is cheaper than installing it in an existing development because pipes can be laid at the same time as other infrastructure when the roads are built.

Properties connected to a district heating network normally pay the heating network operator for units of heat delivered. Therefore the economics of a district heating system are dependent on the amount of heat provided per metre of pipe; the higher the amount of heat delivered per metre of pipe, the better. The amount of heat delivered per metre of pipe is known as the linear heat density.

Linear heat density is the critical factor in heat distribution economics, but this can only be calculated at the stage when a route has been defined. For the purposes of this report we are identifying areas which contain buildings which could be candidates for becoming part of a district heating system. Potential pipe routes are not suggested in this report, and so linear heat density cannot be calculated.

As a proxy for linear heat density, spatial heat density (along with other factors) is used to find parts of the study area most likely to contain high concentrations of heat demand, which are then investigated in more detail. Spatial density is the amount of heat per area (for example, per square metre).

4.2 Heat demand across Guildford Borough

In this section maps are used to illustrate heat demand across the borough, based on current infrastructure. Figure 7 shows heat demand from all sources. Heat demand is concentrated in Guildford town centre, with some peripheral areas such as the Royal Surrey County Hospital and the University of Surrey also having high heat demand. There are some isolated points of high heat demand, including the Spectrum Leisure Complex, which can be seen just to the north west of the centre of Guildford town, on the south side of the A3. The rest of Guildford Urban Area and Ash and Tongham have moderate heat demand, while scattered areas within the green belt have lower demand.

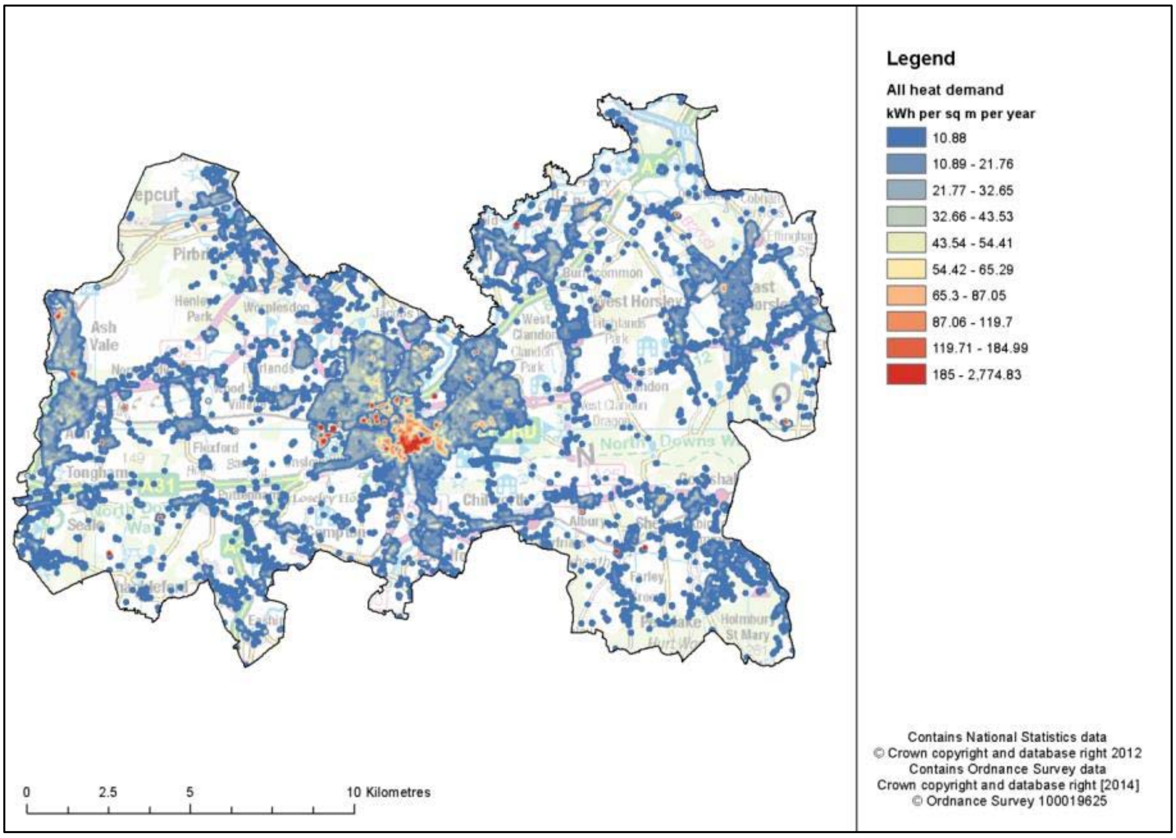


Figure 7: Heat demand from all sources across Guildford Borough

Figure 8 shows Guildford Urban Area. There are concentrations of heat demand in the centre and in some areas around the centre . Figure 9 shows heat demand in Ash and Tongham Urban Area: higher heat demand can be seen in Ash town centre, Ash Vale town centre, Ash Green and Wyke.

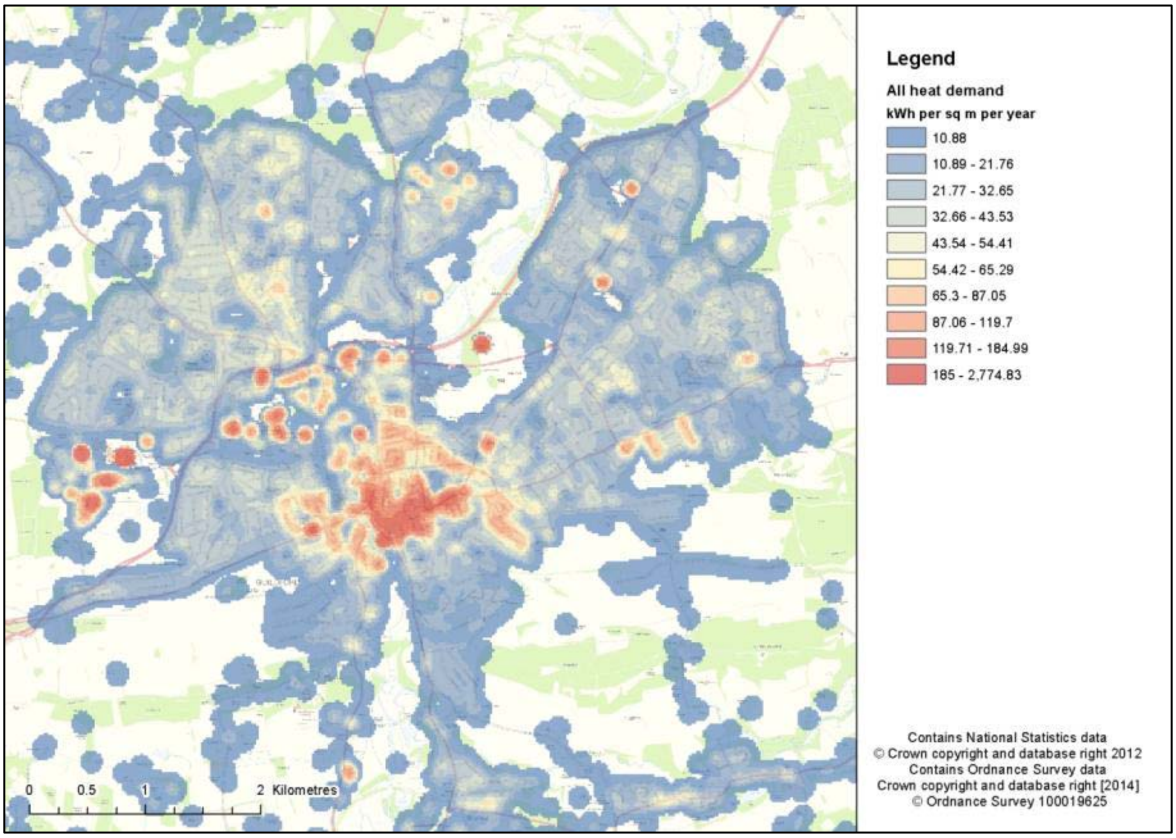


Figure 8: Heat demand in Guildford Urban Area

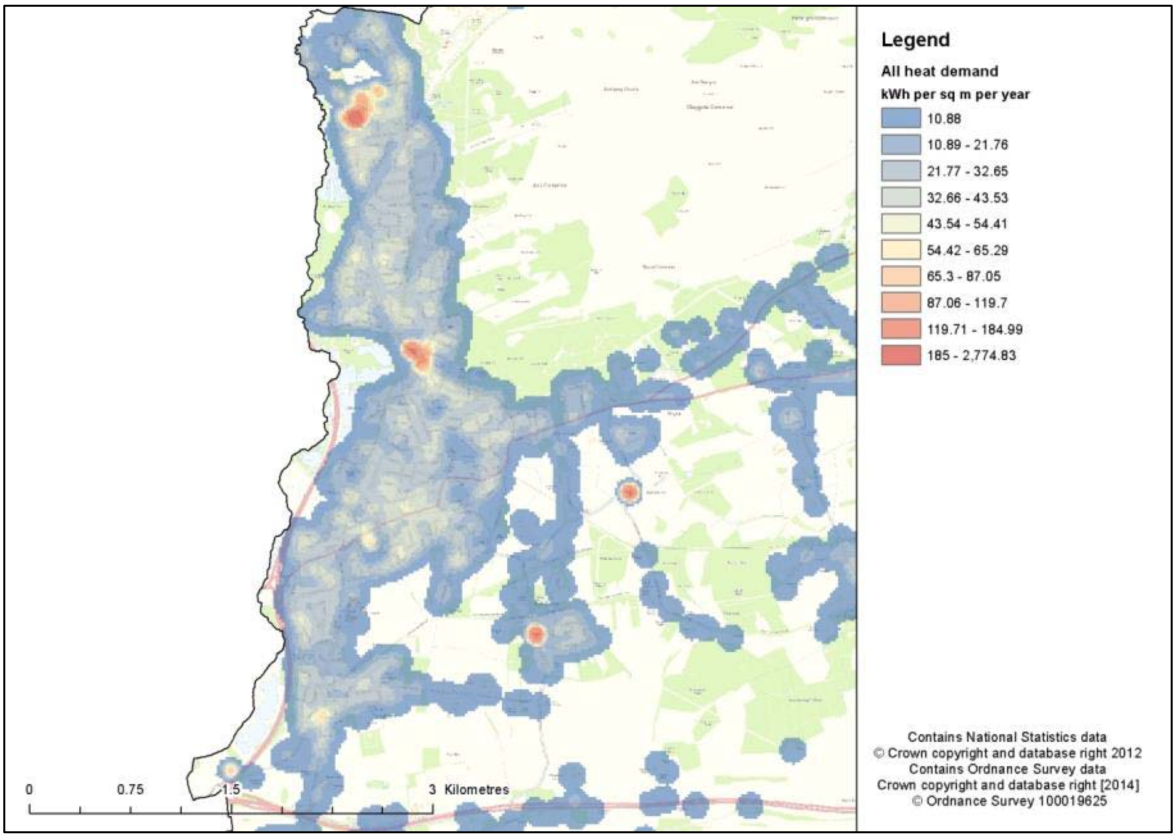


Figure 9: Heat demand in Ash and Tongham Urban Area

Figure 10 shows residential heat demand across the borough and Figure 11 shows non-residential heat demand. Residential heat demand covers a larger area but is less concentrated, while non-residential heat demand is concentrated into a few hotspots in the centre of the borough and dispersed points elsewhere.

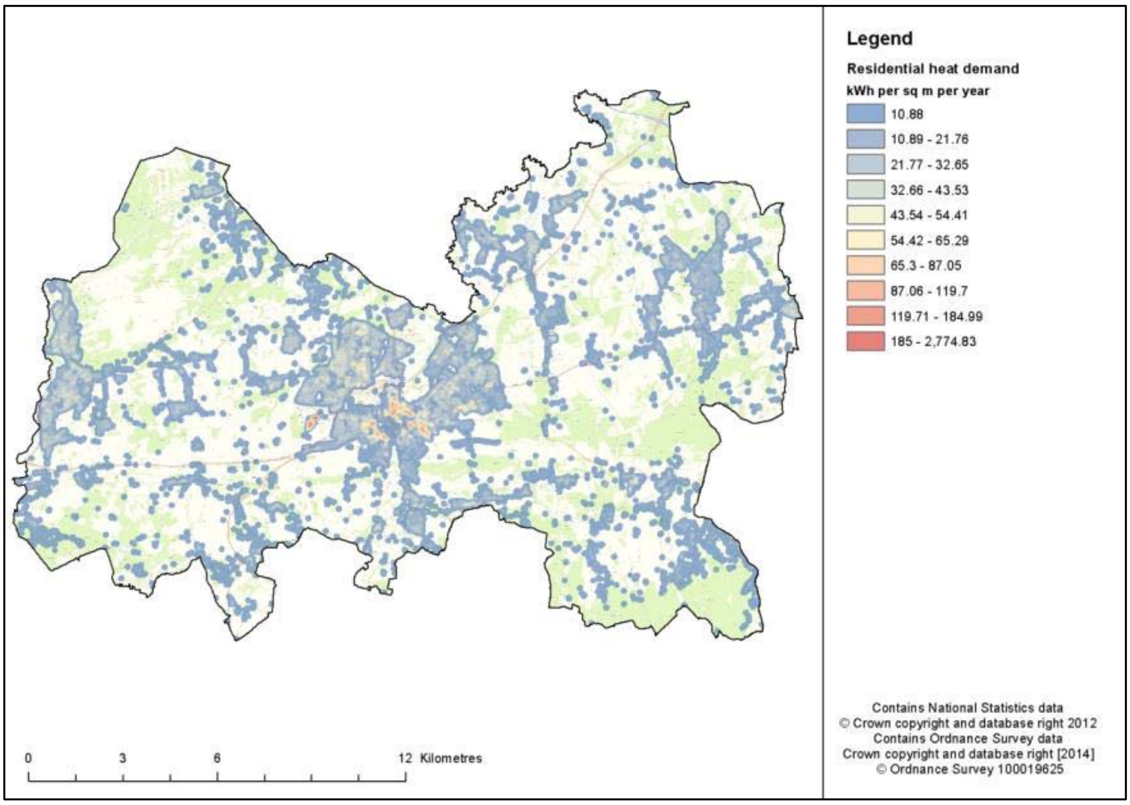


Figure 10: Residential heat demand across the borough

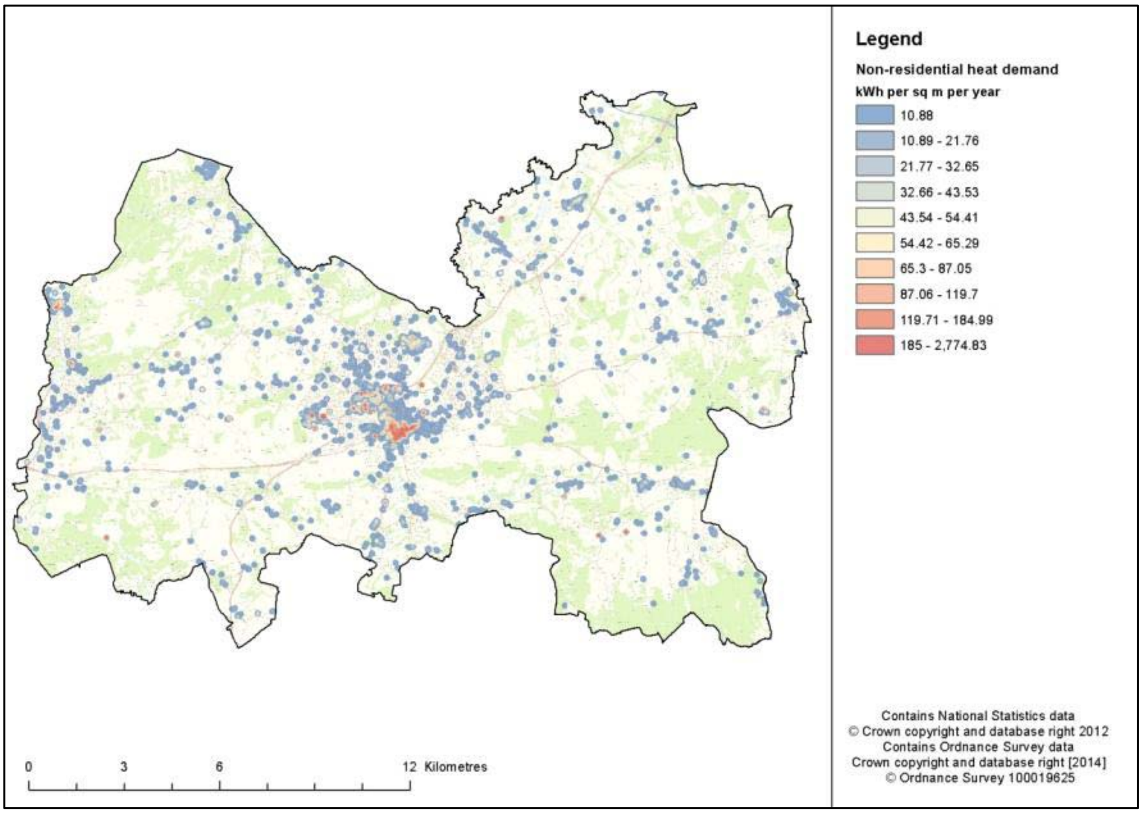


Figure 11: Non-residential heat demand across the borough

4.3 Identifying areas with potential for district heating

4.3.1 Overlay analysis

With a large area to explore, a useful way of identifying areas which are mostly likely to be suitable for district heating is to find areas which satisfy three conditions favourable to district heating, relating to: overall heat demand; presence of potential anchor loads; and groups of dwellings with high heat demand (normally blocks of flats). These conditions are:

- Areas must be within the 10% of land area with the highest heat demand density.
- Areas must be within 200m of residential buildings with an annual heat demand of more than 100,000kWh per year (these could in theory be single dwellings but in practice only blocks of flats tend to have heat demand this high).
- Areas must be within 200m of potential anchor loads. Anchor loads are defined as the following types of buildings, which are likely to have relatively high and stable heat demands and/or be in sectors more likely to participate in heat distribution projects. These categories are from the National Heat Map:
    - Hotels
    - Health (hospitals, health centres, etc)
    - Education (schools, colleges)
    - Government buildings (e.g. local authority offices)
    - Public buildings (buildings with a floor area of over 1,000sq m that are occupied (in part or in whole) by public authorities or institutions providing public services, which are frequently visited by the public and must therefore have a display energy certificate). This includes local authority-owned leisure centres.

The National Heat Map uses data from a variety of sources which classify commercial buildings into different types. The categories are reasonably wide, so not all buildings in the above categories will actually be suitable as anchor loads. However, they provide a good basis for establishing the area of search. When these areas are established, buildings identified as anchor loads are checked for suitability. Figure 12 to Figure 14 show the locations of these areas on the map.

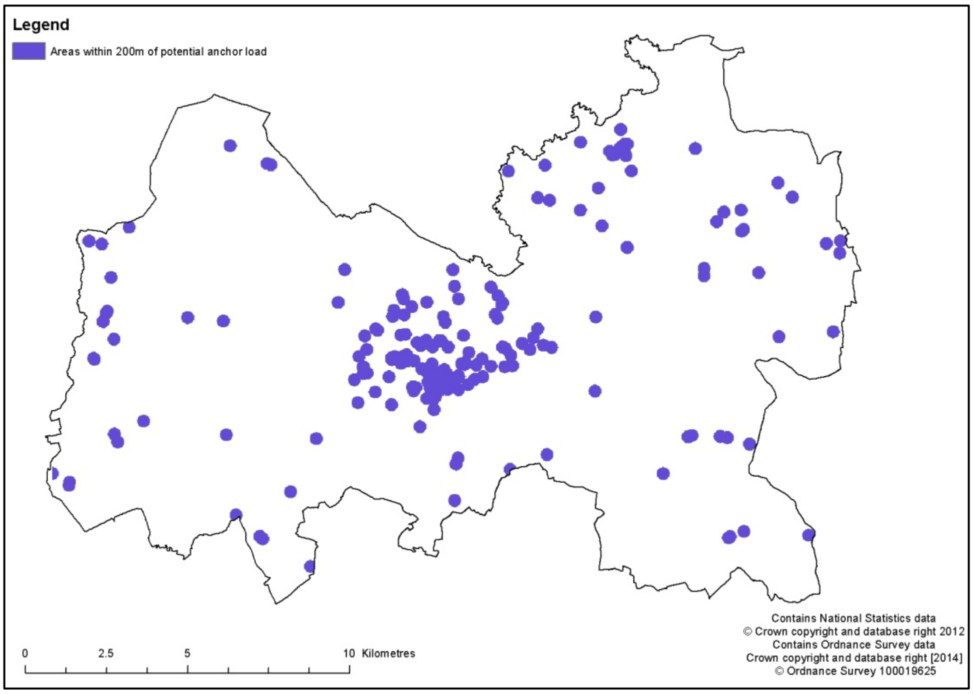


Figure 12: Areas within 200m of an anchor load

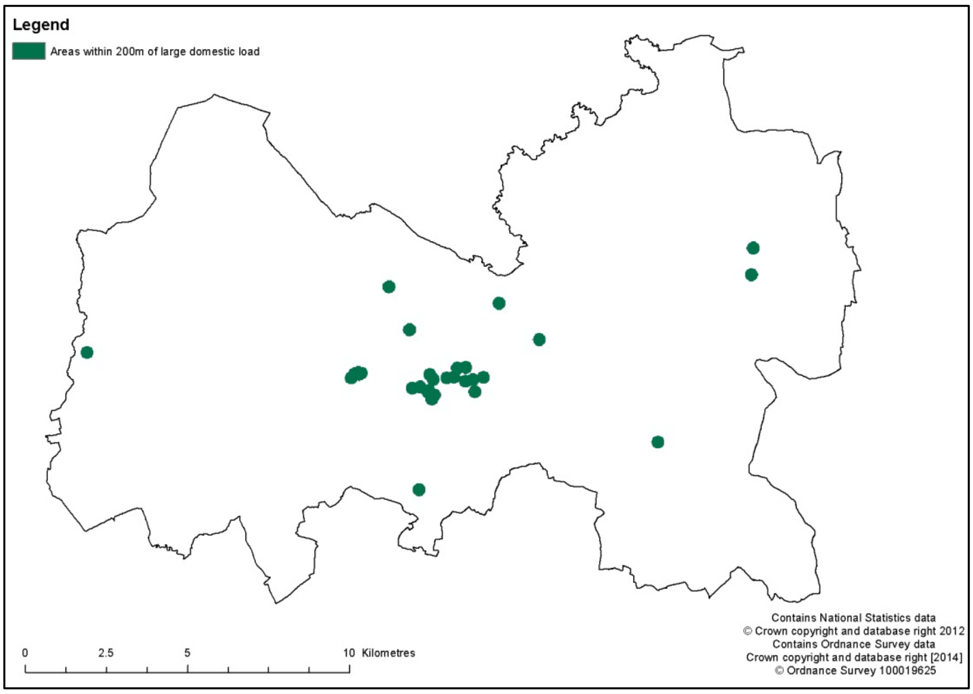


Figure 13: Areas within 200m of a large domestic load

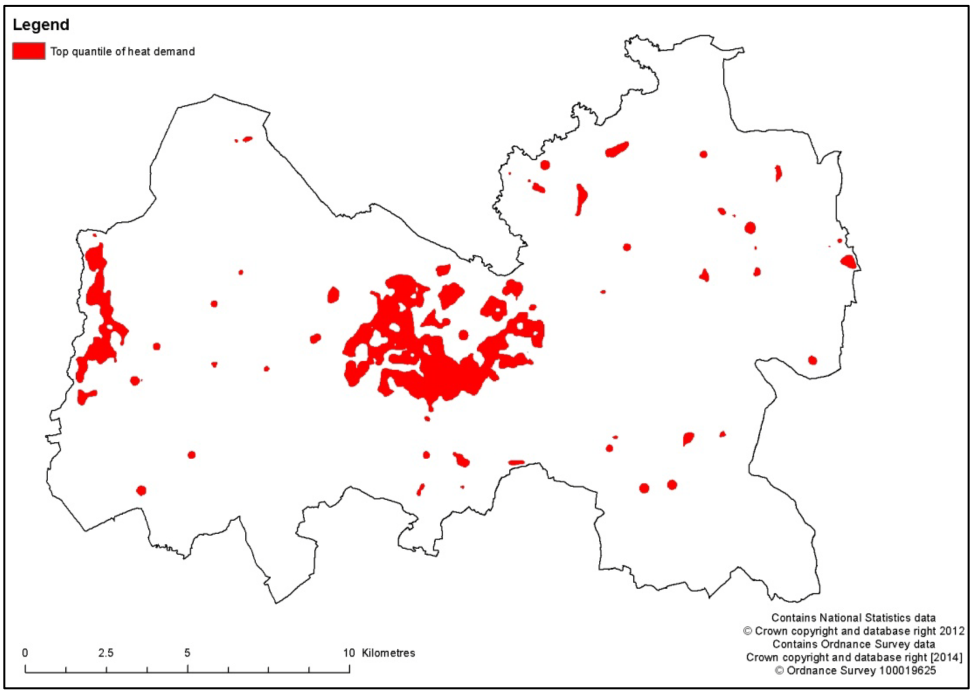


Figure 14: Areas within the top 10% of heat demand by land area

These three criteria are overlaid to identify places where all of the conditions are true. The resulting locations identified are shown in Figure 15. These locations and the areas surrounding them[12] were then examined using address data from the National Heat Map, Ordnance Survey maps and Google Streetview to find out more about the types of buildings there and their suitability (for example, high heat demand can be caused by dense

[12] As the criteria include areas that are up to 200m away from anchor loads and large domestic blocks, at least a 200m radius outside each area is also examined.

terraced housing, which is less suitable than larger loads due to the number of connections which would be required). The results of this initial survey are shown in Table 2.

It is important to note that the results of this initial survey show the boundaries of where all three conditions specified above overlap, but this boundary should not be interpreted as the limit of the area which is suitable for district heating. The areas are identified by finding places *within 200m of* an anchor load or large domestic block, and so anchor loads or domestic blocks which would form part of the district heating system may be located up to 200m outside of the red boundaries shown in Figure 15. The red lines should therefore not be thought of as the limit of the area where district heating is a possibility, because some of the buildings connected to a district heating network will be outside of the lines.

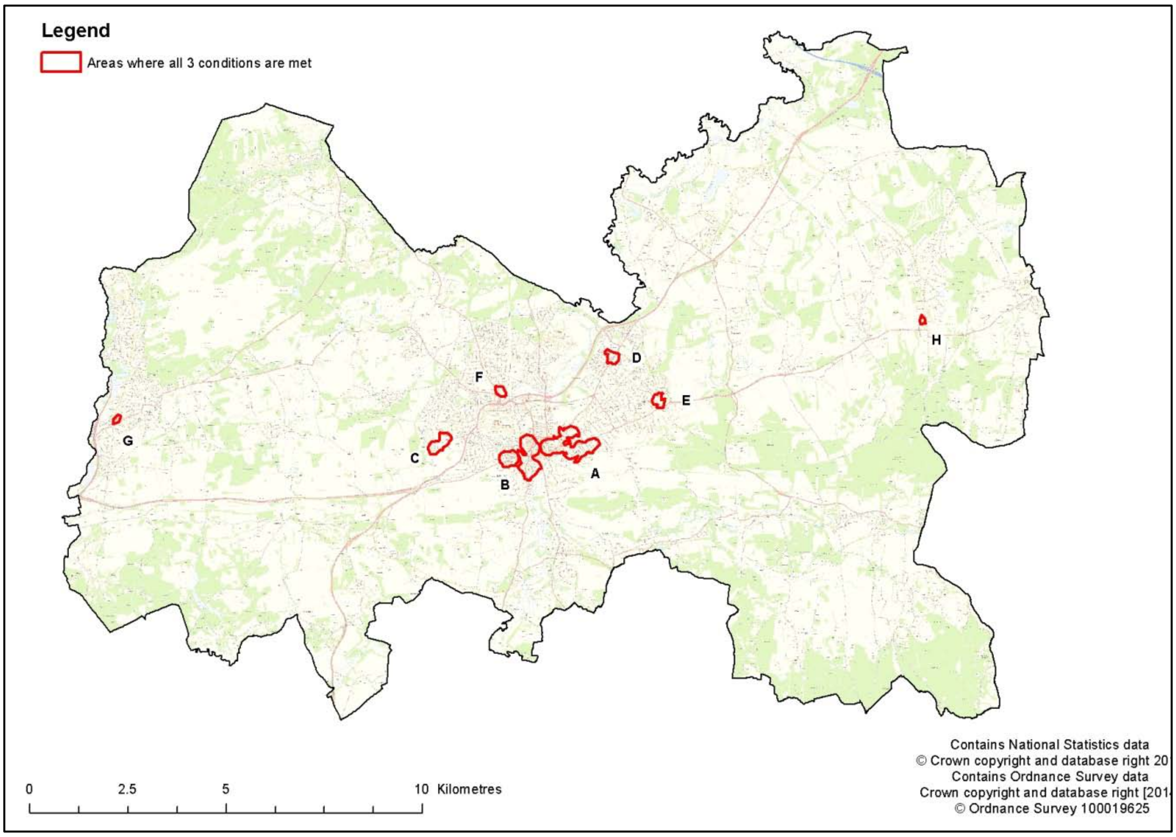


Figure 15: Result of overlaying all three criteria

Area reference in map[13]	Narrative
A	Guildford town centre including shopping area and several large heat loads.
B	Central Guildford including Farnham Road Hospital and Guildford County School.
C	Area around the Royal Surrey County Hospital.
D	Burpham area: anchor loads are small; not suitable.
E	Bushy Hill area: there is a large school but this is the only anchor load (and schools are not ideal as anchor loads because of lack of demand in holidays). The residential block identified is low rise and apart from this there is nothing that looks like a suitable load. Not suitable.
F	Woodbridge Hill area: High heat demand caused by nearby offices (Avaya House on Cathedral Hill). Anchor load is identified as a hotel in the heat map database but this is not visible on Streetview. Some low rise flats.
G	Area around Alexandria Road, Ash. Has Japonica Court which is low rise sheltered housing flats. Anchor load identified is a school, which is not suitable.
H	Area to the south of East Horsley: Contains a large amount of low-rise flats. Anchor load is not suitable.

Table 2: Description of areas identified by overlay analysis

4.3.2 Areas around largest loads

In addition to the overlay analysis, a second approach is taken whereby the map is scanned for the largest head loads and the highest heat density, and the area around these examined. Often, a large heat load will be isolated, with no others around it, such as in the case of some industrial installations. Likewise, an area with high heat density may be composed of many small heat loads, which is not ideal for district heating.

This process identified one additional site, the University of Surrey's Stag Hill campus, which had not been identified by the overlay analysis due to the student residences on site not being identified as blocks of flats (that is, sharing the same XY coordinates). The University has many large heat loads. Further investigation revealed that the Stag Hill campus already has a district heating network, which supplies around 60% of the campus' heat demand.

4.4 Further investigation of areas with potential for district heating

4.4.1 Central Guildford

The analysis above identified two areas in central Guildford; areas A and B (see Figure 15, Table 2, and Figure 16). They are very close together and can be treated as one area. This covers a large area in the centre of Guildford, from the Farnham Road Hospital and Guildford County School in the west, to Guildford High School in the north, Albury Road in the east, and the junction of Portsmouth Road and Lawn Road in the south. The river and the railway line run from top to bottom through the western side of the area which could limit district heating pipe runs, or make installing pipes more expensive. The railway station is likely to be redeveloped in the near future which could increase its heat demand.

Potential anchor loads in and around the area are shown on Figure 17 and Table 3.

At this point it should be emphasised again that the red boundaries on the maps indicate the area where all of the conditions described in section 4.3.1 are true (as shown in Figure 16 to Figure 20). This does not mean that it is only this area that has potential for district heating; the conditions include areas that are *up to 200m away* from anchor loads and large domestic blocks, so there could be anchor loads or large domestic blocks outside of the red boundaries. For this reason in this section buildings up to 200m outside of the red boundaries are

[13] Reference letter is assigned in order of the size of the area, largest first

included and investigated in more detail, and using this information at the end of the section the boundaries are re-drawn to show a priority area for district heating .

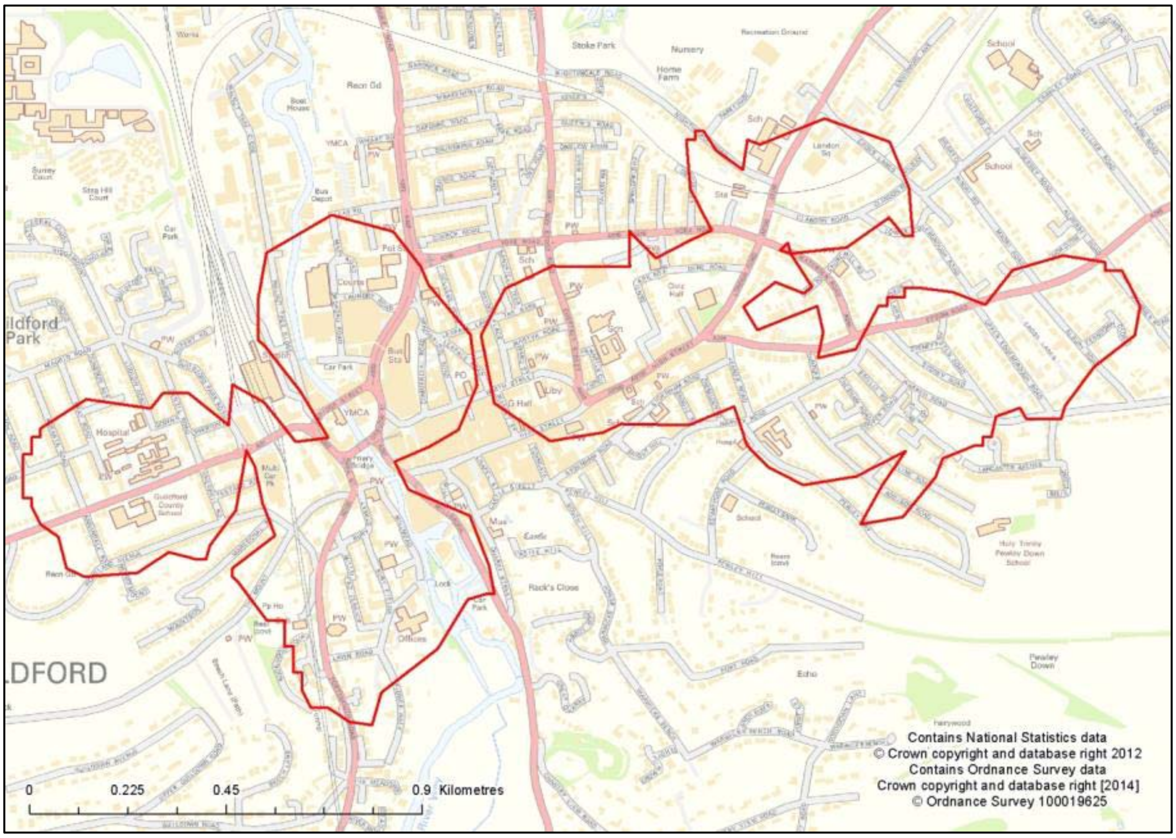


Figure 16: Central Guildford area showing areas resulting from overlay analysis, where all 3 conditions are met

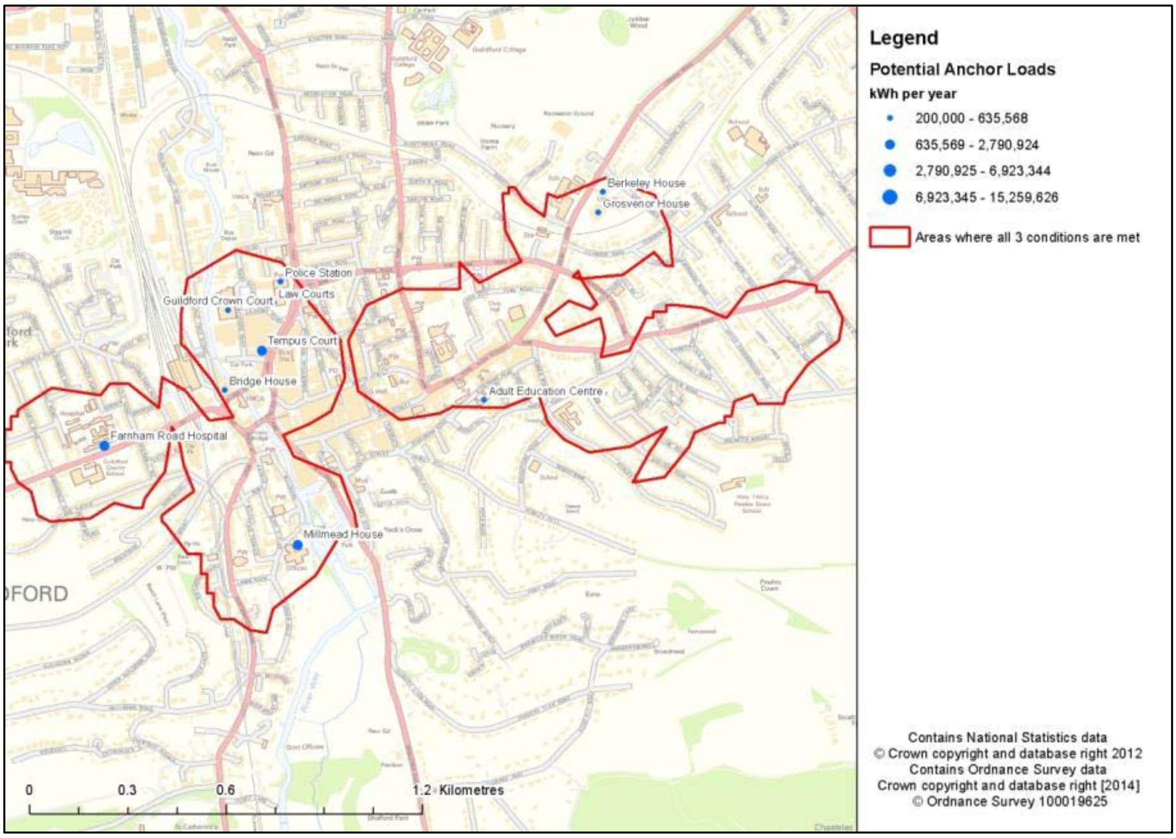


Figure 17: Anchor loads in central Guildford area

Potential Anchor Load	Annual heat consumption (MWh)	Source[14]
Adult Education Centre, Sydenham Road	200	Estimated
Tempus Court, Onslow Street	894	Estimated
Law Courts, Mary Road	534	DEC
Guildford Borough Council, Millmead House, Millmead	724	DEC
Bridge House, Walnut Tree Close	597	DEC
Berkeley House, London Square	542	DEC
Grosvenor House, London Square	482	DEC
Farnham Road Hospital, Farnham Road	2,511	DEC
Guildford Crown Court, Bedford Road	208	Estimated
Guildford Police Station, Margaret Road	268	Estimated

Table 3: Anchor loads in central Guildford area

There are also a number of large blocks of flats in the area. These are shown in Figure 18 and Table 4.

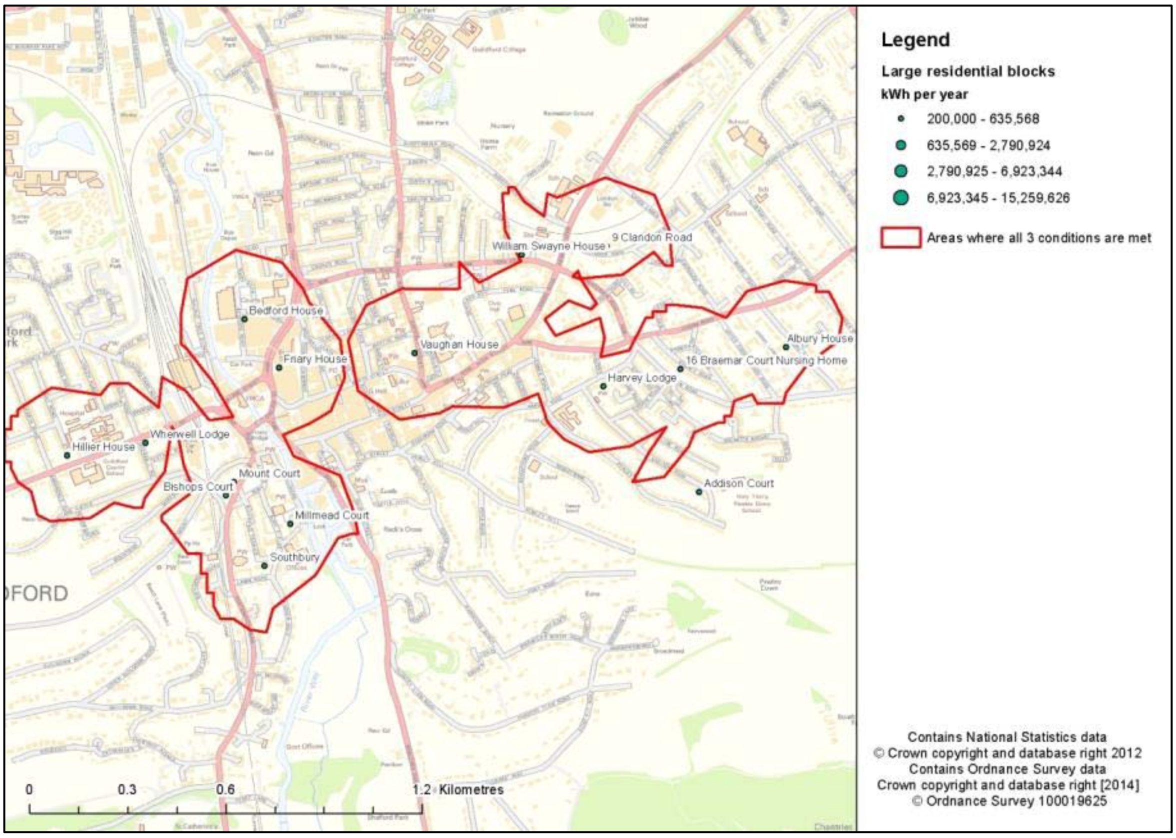


Figure 18: Large domestic loads in central Guildford area

14 This can be either estimated by modelling or from a Display Energy Certificate (DEC)

Large domestic blocks	Annual heat consumption (MWh)	Number of properties	Source
16 Braemar Court Nursing Home	256	19	Estimated
9 Clandon Road	219	16	Estimated
Addison Court	278	36	Estimated
Albury House	215	26	Estimated
Bedford House	220	68	Estimated
Bishops Court	328	40	Estimated
Cavendish House	227	22	Estimated
Friary House*	271	61	Estimated
Harvey Lodge	240	26	Estimated
Hillier House	365	37	Estimated
Millmead Court	232	27	Estimated
Mount Court	329	40	Estimated
Southbury	255	24	Estimated
Vaughan House	431	50	Estimated
Wherwell Lodge	216	15	Estimated
William Swayne House	227	16	Estimated

* Friary House already has its own heat network which could be joined up to a larger one

Table 4: Large domestic loads in central Guildford area

Finally, there are a number of large loads that are neither anchor loads nor residential properties. These are three retail sites and one office block, all with annual heat demand above 1GWh. These are shown in Figure 19 and Table 5.

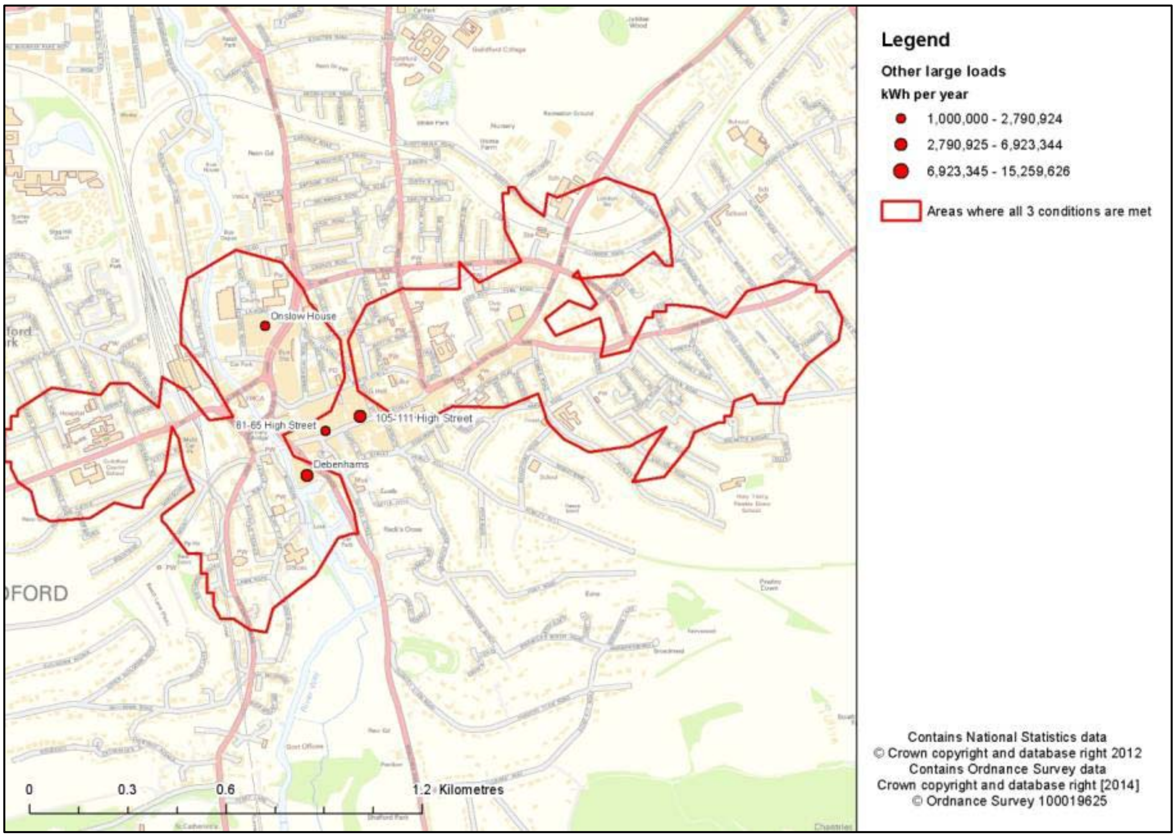


Figure 19: Other large loads in central Guildford area

Other large loads	Annual heat consumption (MWh)	Source
Onslow House	1,378	Estimated
61-65 High Street	1,557	Estimated
Debenhams	3,866	Estimated
105-111 High Street	5,108	Estimated

Table 5: Other large loads in central Guildford area

Figure 20 shows anchor loads, large domestic loads, other large loads, and all other heat loads, plus heat density, for the area identified in the overlay analysis, plus 200m around the edge. Heat density is high in parts due to smaller heat loads (mainly retail) being clustered together.

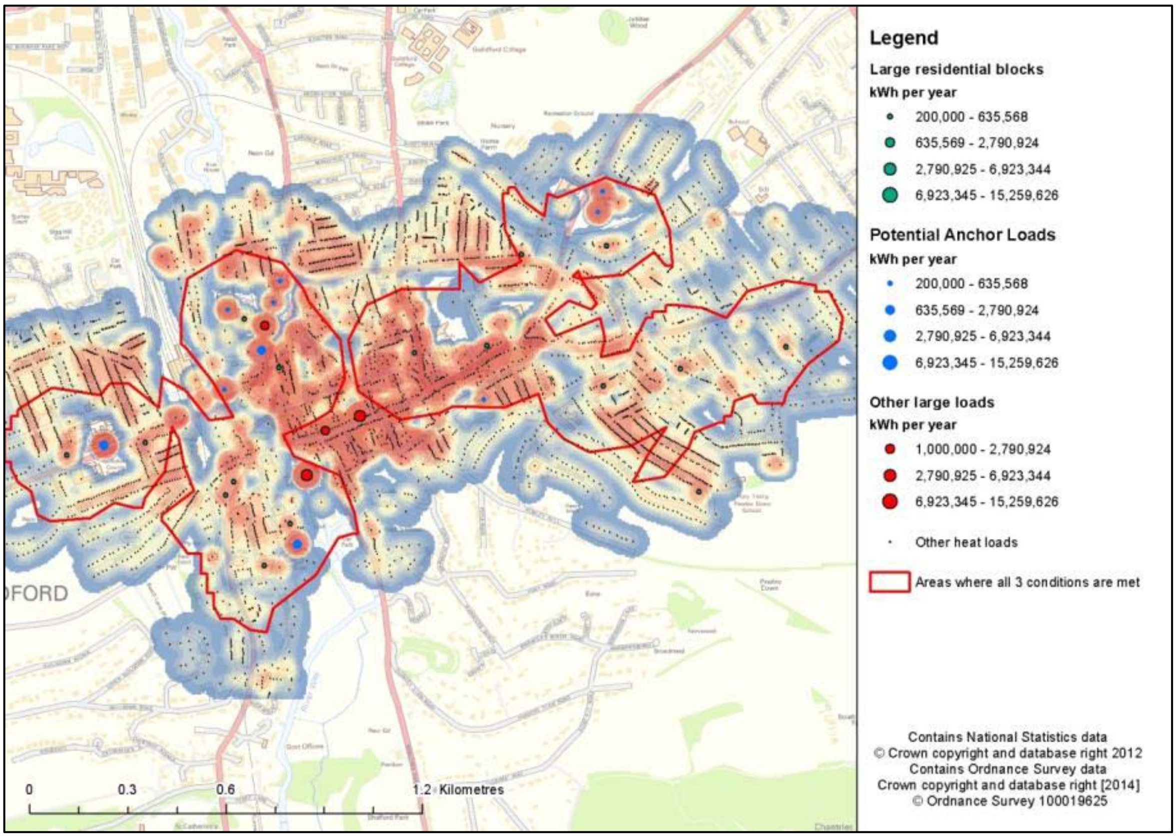


Figure 20: Central Guildford area, showing all load types and heat density

Having examined the area in more detail, a priority area for district heating can now be outlined, smoothing out and expanding the jagged outline in the maps above and taking into account the topography of the area. Important topographical features in the central Guildford area from the point of view of district heating are the river and the railway line. It can be complicated and therefore costly to run pipes under or over these features and so the priority area has been split into three: a western section to the west of the railway line, a central section between the railway line and the river, and the largest section to the east of the river. The re-drawn area is shown in Figure 21, along with a number of development sites identified in the draft Local Plan which are within 200m of these priority areas. If a district heating system was developed in these priority areas, the new development could then be connected as it is built.

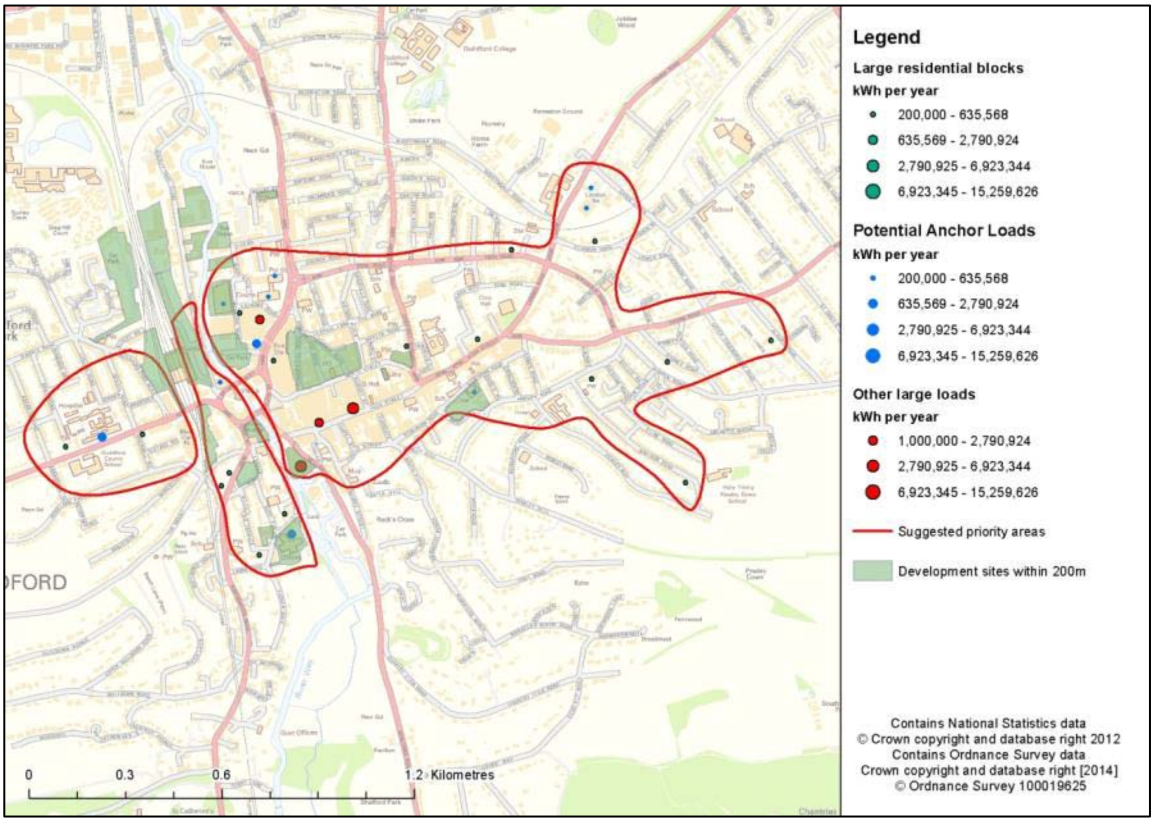


Figure 21: Suggested priority areas in central Guildford with development sites (within 200m of priority areas) overlaid

4.4.2 Royal Surrey County Hospital and surrounding area

The area around the Royal Surrey County Hospital is smaller than the central area and has fewer heat loads. It has therefore been illustrated in just one map, Figure 22. The anchor loads have been labelled; these are the hospital (the two points represent two different parts of the hospital where heat demand has been measured separately due to both parts having separate Display Energy Certificates), the Medical Research Centre, and the Leggett Building, which is the university's Postgraduate Medical School. Details of anchor loads are shown in Table 6.

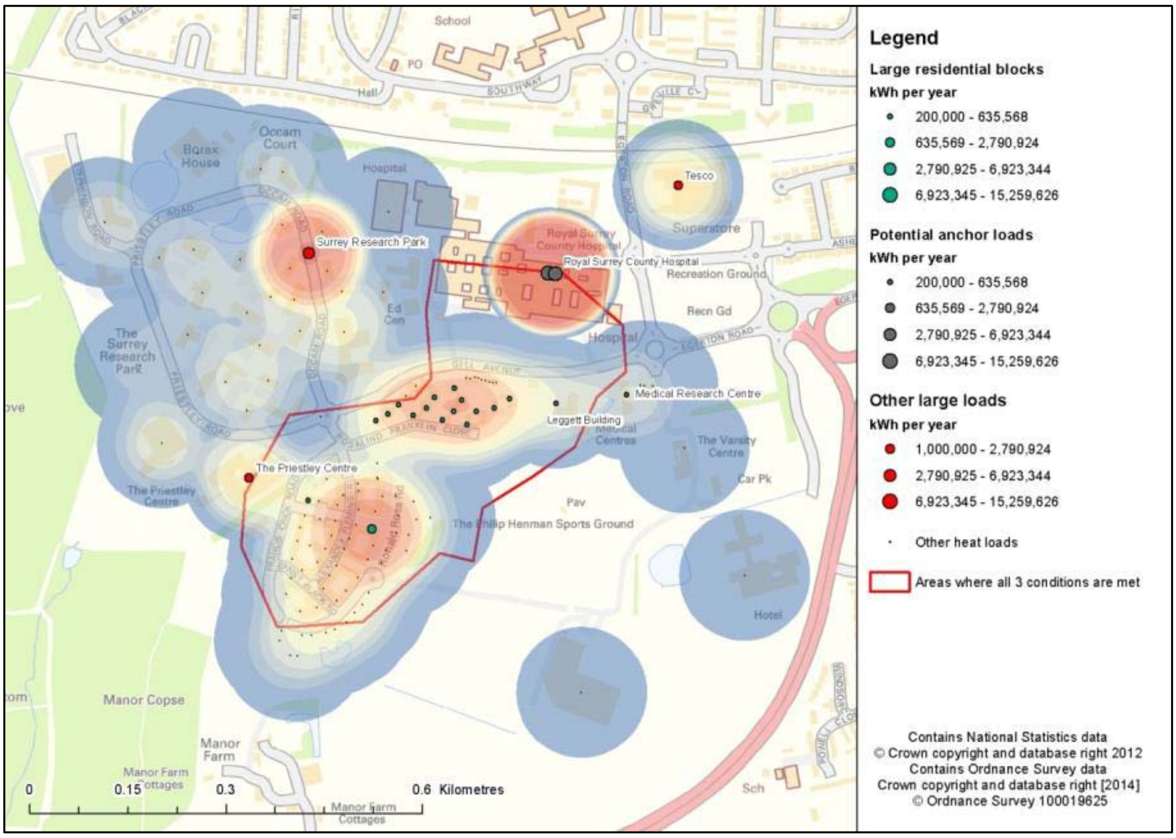


Figure 22: Royal Surrey County Hospital and surrounding area

Potential Anchor Load	Annual heat consumption (MWh)	Source[15]
Post Graduate Medical School (Leggett Building)	488	DEC
Florence Desmond Day Hospital, Royal Surrey County Hospital	15,260	DEC
H P R U Medical Research Centre	327	DEC
Royal Surrey County Hospital	15,050	DEC

Table 6: Anchor loads in Royal County Hospital area

There are several residential blocks comprised of various student residences. These have not been labelled due to space; most of the small points inside the red lines are blocks of student accommodation. Some of these are shown as 'large residential blocks', in cases where the heat demand of all points with the same XY coordinates sums to 200,000kWh per year or more. The cluster in the middle are blocks in the Rosalind Franklin Close accommodation complex, while the cluster south of this is Manor Park Student Village. Details of large domestic blocks are shown in Table 7.

[15] This can be either estimated by modelling or from a Display Energy Certificate (DEC)

Large domestic blocks	Annual heat consumption (MWh)	Number of properties	Source
Block A, Rosalind Franklin Close	421	36	Estimated
Block B, Rosalind Franklin Close	222	19	Estimated
Block C, Rosalind Franklin Close	421	36	Estimated
Block E, Rosalind Franklin Close	234	20	Estimated
Block F, Rosalind Franklin Close	234	20	Estimated
Block G, Rosalind Franklin Close	421	36	Estimated
Block H, Rosalind Franklin Close	234	20	Estimated
Block J, Rosalind Franklin Close	280	24	Estimated
Block K, Rosalind Franklin Close	234	20	Estimated
Block L, Rosalind Franklin Close	280	24	Estimated
Francis Harrison House	421	36	Estimated
Manor Park Village	269	23	Estimated
Block F Manor Park Village	2,299	Unknown	DEC
Ted Adams House	409	35	Estimated
Wealden House	222	19	Estimated
West Sussex House	421	36	Estimated

Table 7: Large domestic loads in Royal County Hospital area

Other large loads shown on the map (and also shown in Table 8) are a Tesco superstore, The Priestley Centre (part of Surrey Research Park) and another building which in the address data underlying the National Heat Map is called simply Surrey Research Park. Here it may be the case that the address data has several addresses recorded at a single XY coordinate, but that in reality the addresses belong to different buildings. Therefore heat demand may be more spread out over the Research Park than it appears in the map.

Other large loads	Annual heat consumption (MWh)	Source
Surrey Research Park	4,980	Estimated
Tesco	1,145	Estimated
The Priestley Centre	1,023	Estimated

Table 8: Other large loads in Royal County Hospital area

The suggested priority area in this zone is shown in Figure 23.The draft Local Plan shows a large development site near to this priority area – this is Site 60, shown in Figure 24. If built, this development would have around 140 dwellings. Currently there is not enough information available about the site to calculate heat density, but if this site was suitable for district heating, the system could be connected to the priority area.

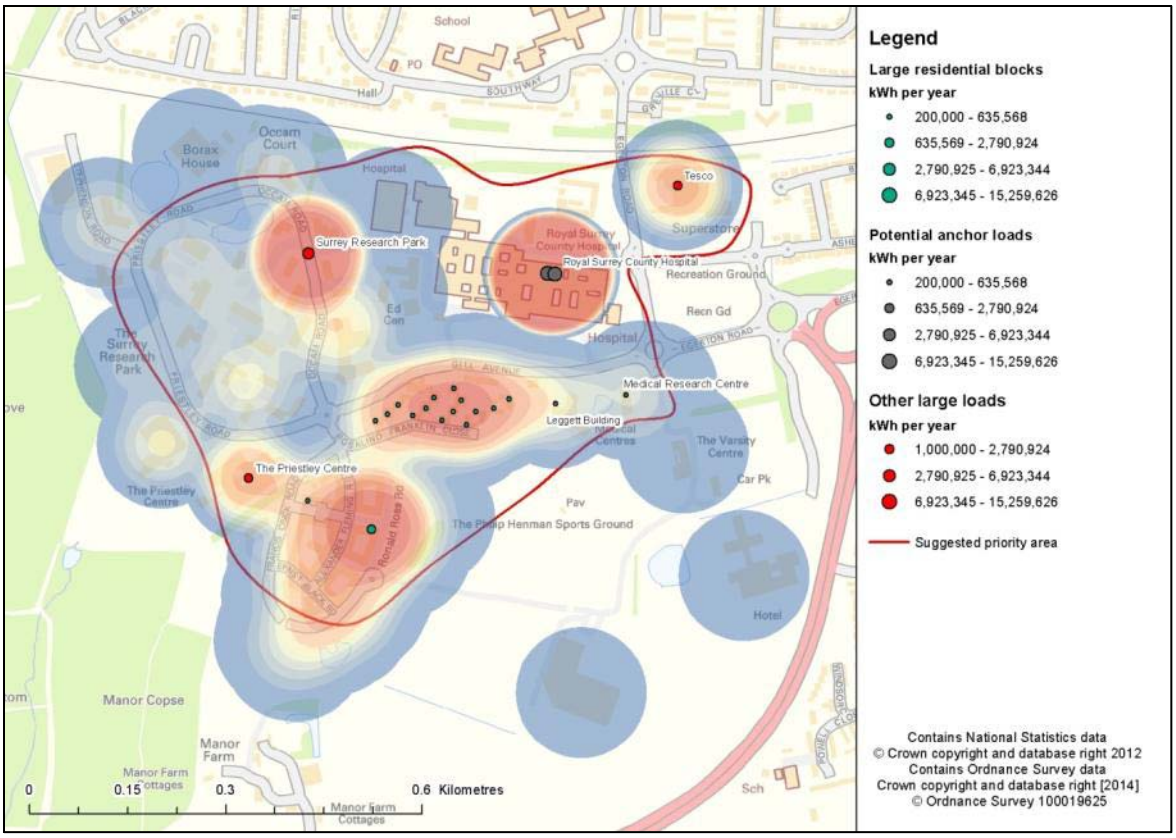


Figure 23: Royal Surrey County Hospital and surrounding area: suggested priority area

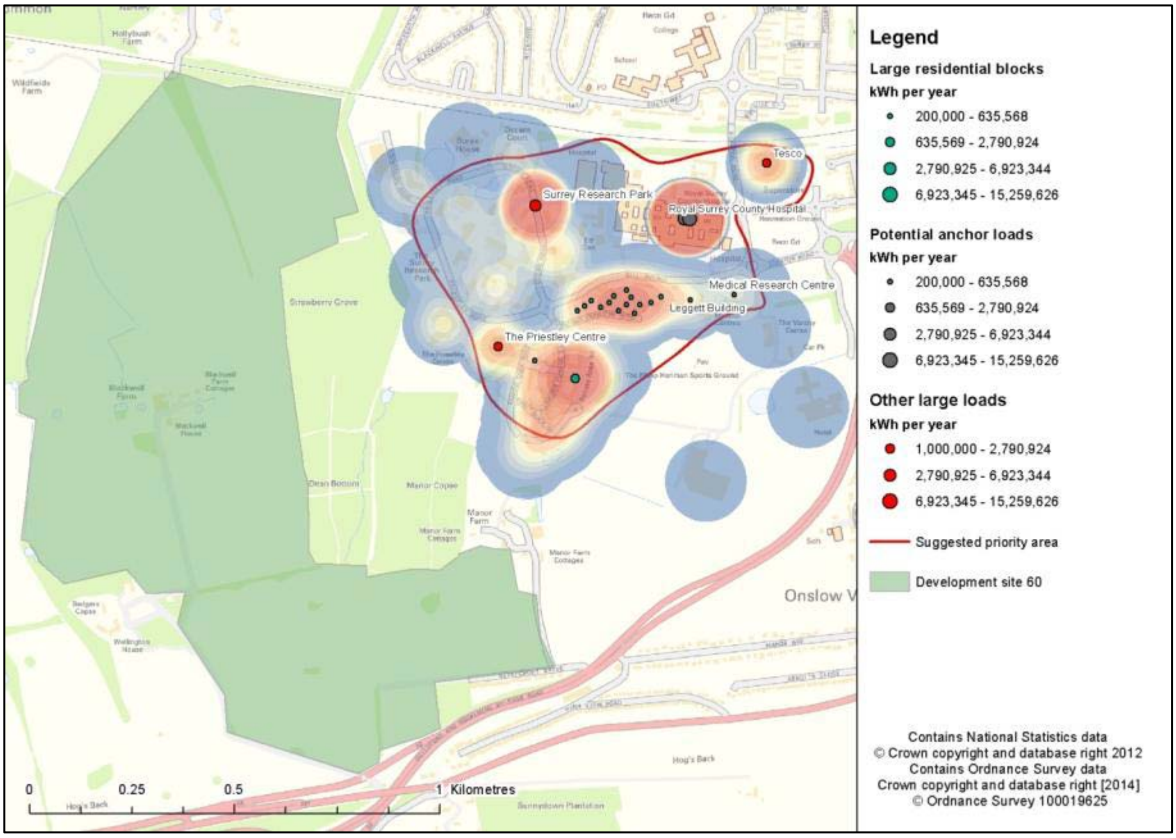


Figure 24: Royal Surrey County Hospital suggested area with nearby development site

4.4.3 University of Surrey

The University of Surrey's Stag Hill campus is to the north west of Guildford town centre. It has high heat demand, but it already has a district heating system which supplies approximately 60% of its heat demand.

North of the Stag Hill campus is Guildford Business Park, Cathedral Hill Industrial Estate, and Midleton Industrial Estate. These areas have some buildings with high heat demand. Both sites are shown in Figure 25. The area of high heat demand at Cathedral Hill is Avaya House.

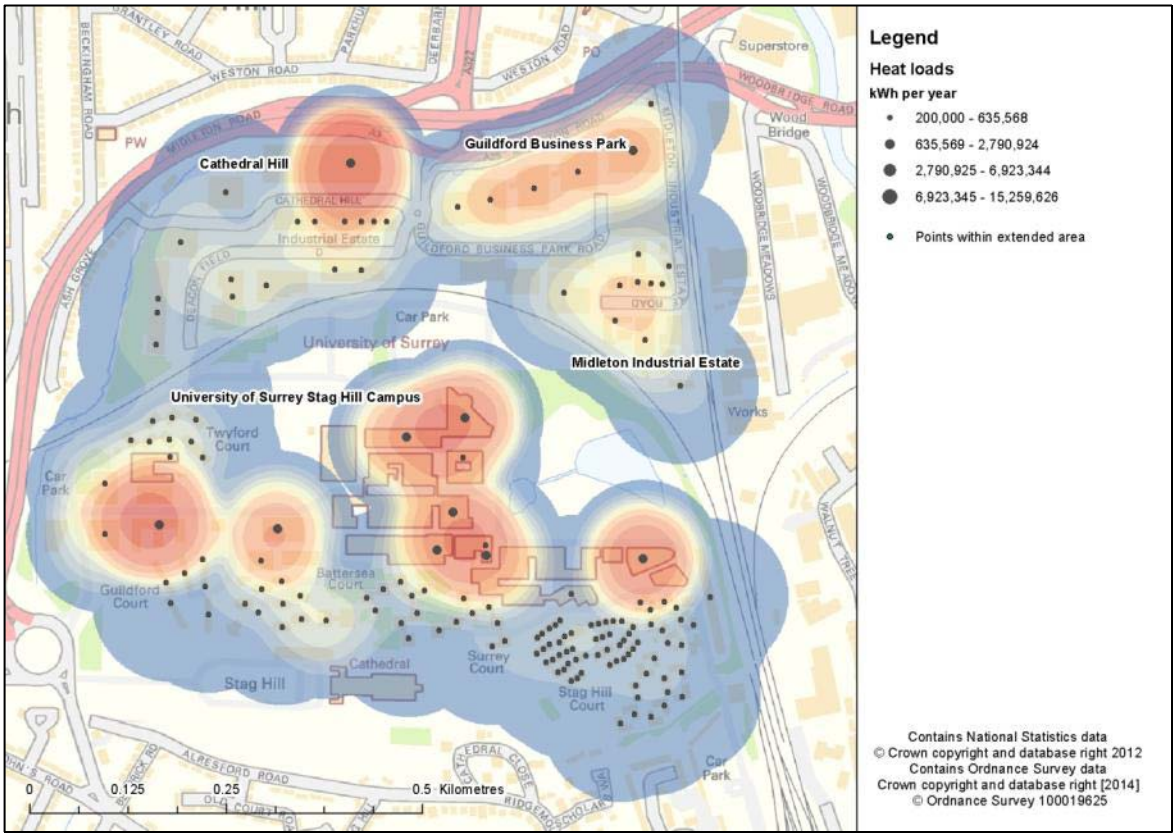


Figure 25: University of Surrey Stag Hill Campus and Guildford Business Park / industrial estates

There could be potential to link the existing district heating system at Stag Hill with a new system in the area north of the campus. However, there is a railway line separating the two areas which could be costly to cross.

There may also be potential to link this area and the central priority area. The space between the two areas contains several proposed development sites from the draft local plan, illustrated in Figure 26 below. If these developments have sufficient heating demand the district heating system could be extended out from the central area to join up with the Stag Hill area.

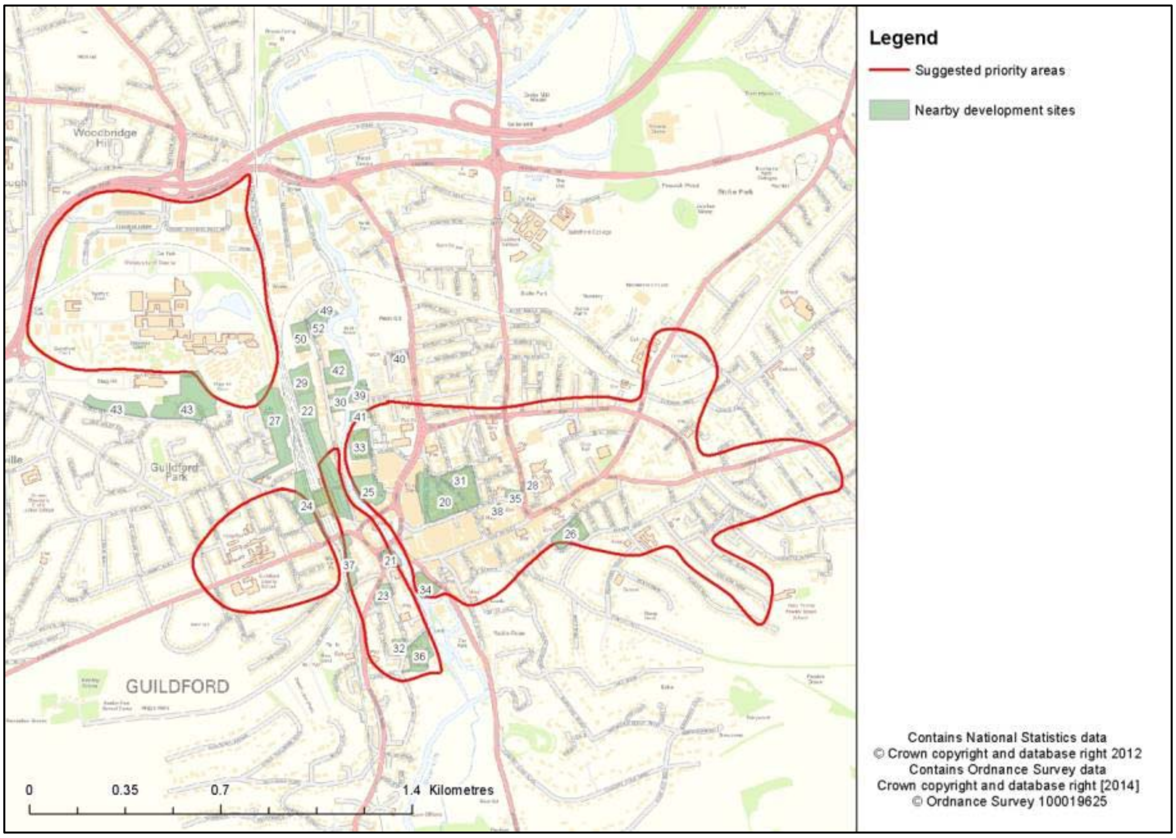


Figure 26: Central priority area and campus / business park priority area with adjoining draft local plan development sites

4.5 Other new development

The previous section has looked at areas of existing high heat demand and potential for district heating, and any proposed new development near to these. In addition there may be new development in areas which are not so close to areas with a high level of existing heat demand, but which could be large enough to support its own district heating system and potentially connect to some existing heat loads.

Information is available about the location of major sites which may be developed, but at this stage the information available does not provide enough detail to model heat demand for new development. Therefore the analysis in this section takes larger draft Local Plan potential development sites where 100 or more new homes could be built[16], on the assumption that these would be the ones with the greatest heat demand. These have been mapped against existing heat demand in Figure 27, which shows the whole of Guildford Borough, Figure 28, which shows Guildford Urban Area, and Figure 29, which shows Ash and Tongham urban area. The proposed site of the Slyfield Area Regeneration Project is shown in Figure 27 and Figure 28; it is the area just north of Guildford City Centre running parallel to the A3 in Figure 28. This currently hosts a sewage treatment works but may be redeveloped to include a significant number of commercial and residential properties.

[16] Separately, SHLAA data was available but not in GIS format so has not been included here. GIS data did not include sites 56, 66, and 82, three of the 28 sites which the draft Local Plan lists as having potential for more than 100 homes.

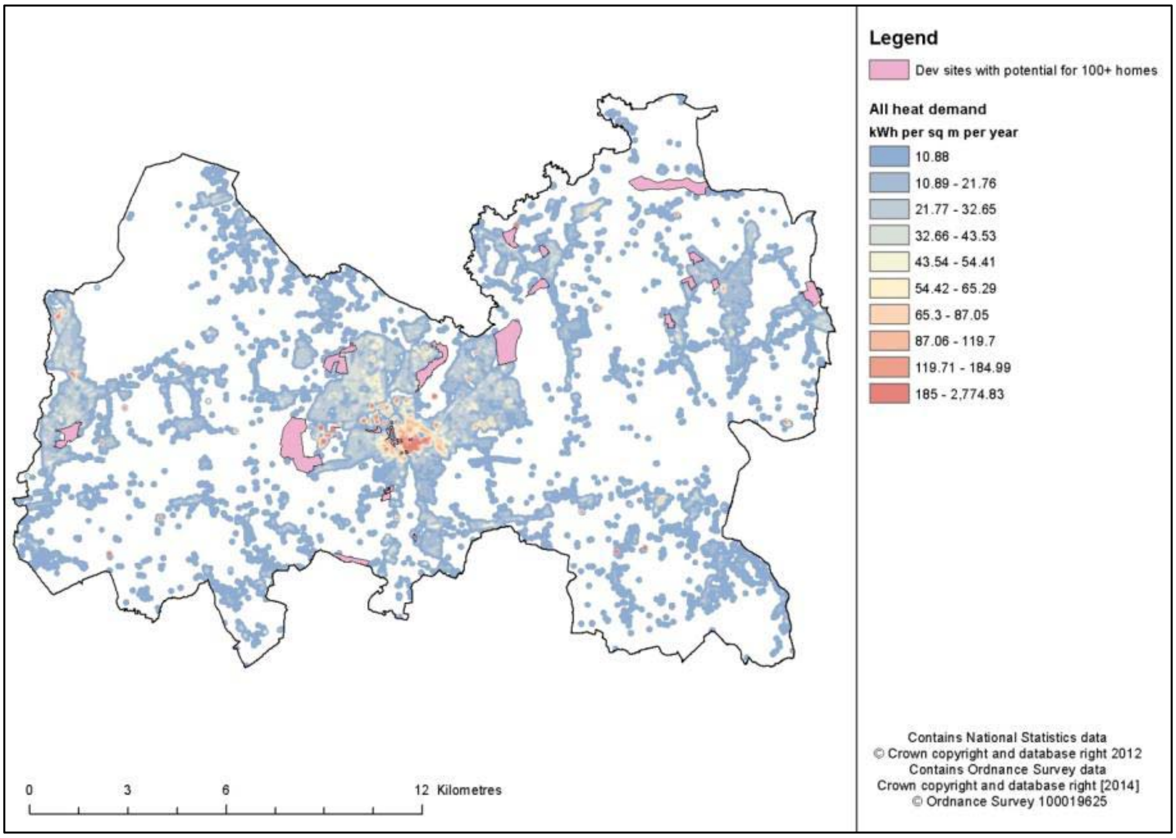


Figure 27: Large development areas with existing heat demand, whole borough

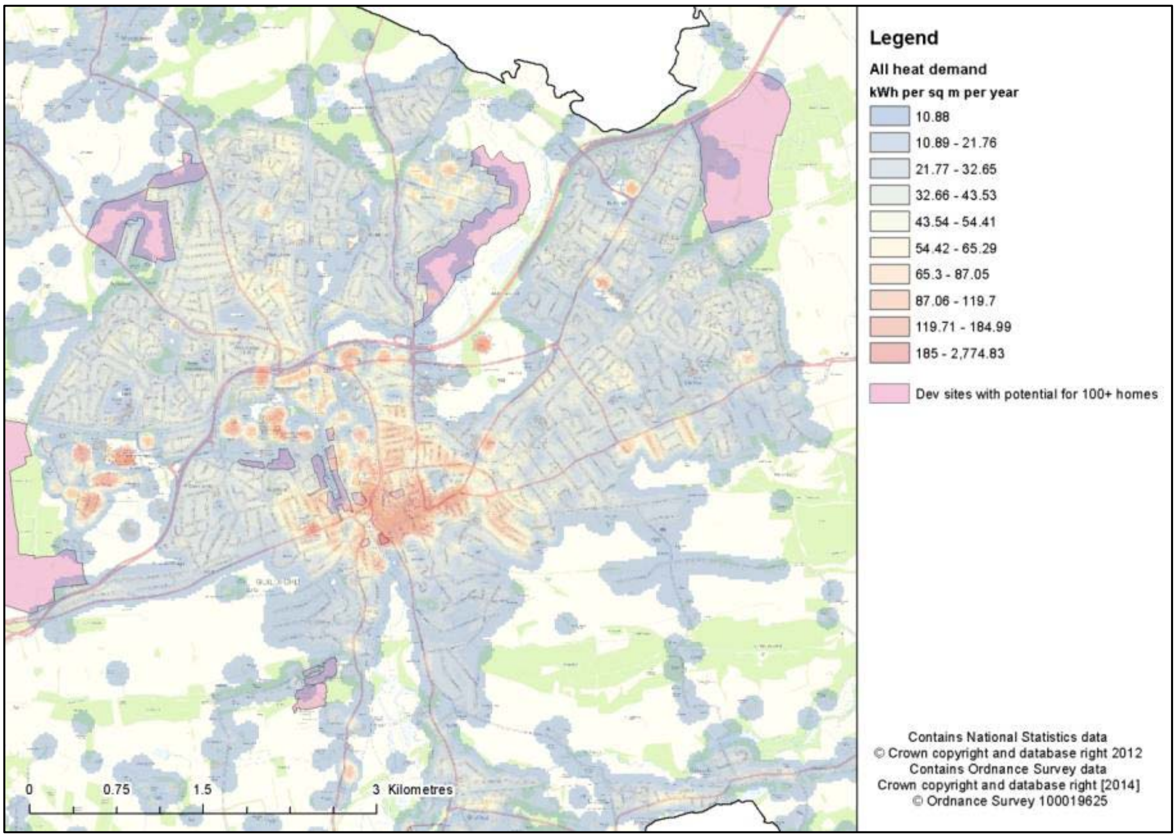


Figure 28: Development areas with existing heat demand, Guildford urban area

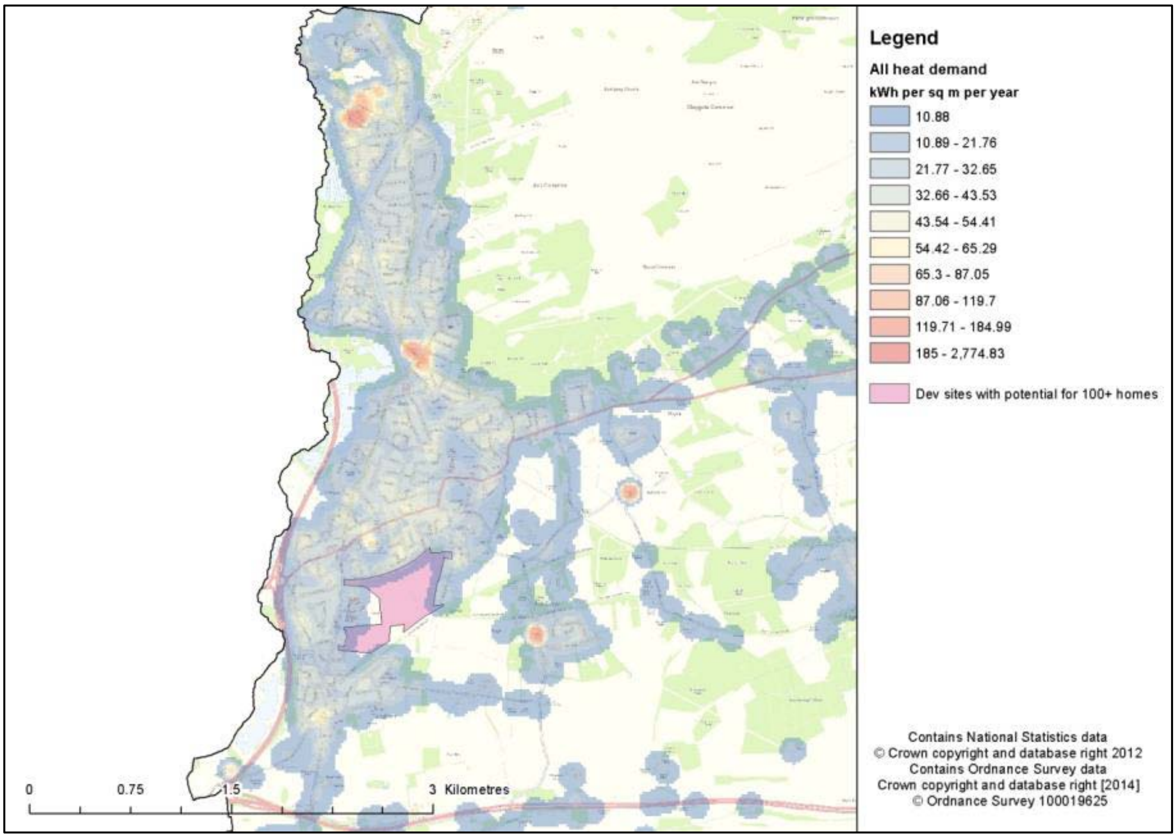


Figure 29: Development areas with existing heat demand, Ash and Tongham urban area

5 Large, stand-alone renewable energy generators

This section presents a high level appraisal of opportunities for larger scale renewable energy installations in Guildford Borough that are not always directly associated with specific buildings, or that can potentially use the River Wey as an energy source. The former includes large scale wind power and ground-mounted solar PV farms, and the latter hydro power and water source heat pumps (WSHP). Technologies involving biomass and waste are out of scope for this particular study.

Where data availability allows, the general approach in assessing these technologies is to first estimate the 'technical' resource in terms of MW, which is broadly limited to considering a fixed set of physical or technical constraints such as wind speeds, ground obstacles or topography. A second analysis then introduces a further set of constraints which are mainly planning related, but are more difficult to define in terms of their impact. Various scenarios for these additional constraints are therefore introduced to provide an indication of the 'deployable' resource, which can then contribute to the evidence base for setting targets or introducing proactive policies to encourage the most appropriate sustainable energy generation technologies.

5.1 Onshore wind power

5.1.1 Overview

Onshore wind power is an established and proven technology with thousands of installations currently deployed across many countries. The UK has the largest wind resource in Europe and onshore turbines currently offer nearly 8GW of capacity, sufficient to provide the electricity needs of over 4.5 million households. The Government's 'UK Renewable Energy Roadmap: 2011' publication proposed to increase this to 13GW of capacity by 2020.

Although there are no rigid categories relating to the scale of wind turbines, individual onshore turbines tend to fall within four size bands: micro, small, medium and large. These typically range from 5 Watt battery charging models up to 2-3 megawatt commercial scale turbines. For the purposes of this study, two scales of wind turbines are assessed – medium and large/commercial scale, typically in the range 700kW-3MW. These have often been deployed individually, for example under community ownership schemes, but they are more often used in wind farm clusters, with larger schemes capable of generating hundreds of megawatts. An appropriately sited large scale turbine (e.g. 2.5MW) will typically generate an amount of electricity equivalent to the annual needs of around 1,500 homes.

Visual impact is by far the issue that most often limits planning consent, especially on or around areas with specific landscape designations. Other environmental concerns include noise and the potential impacts on wildlife, hydrogeology and archaeology; although careful design and siting can normally mitigate these risks. However, consent rates in England and Scotland fell significantly in 2013, and are lower in England than elsewhere. In 2013, just 31% of English planning decisions for onshore wind power projects were given consent, compared to 48% in 2012 and 52% in 2011. This compares to an average of 58% and 72% across the whole of the UK over the same period[17]

In the following analysis, two scales of wind power are considered – large scale turbines ~2.5 MW which are typically deployed in modern commercial wind farms, and medium scale turbines ~800 kW which are of a scale increasingly being seen in community energy projects. Small scale wind is not currently considered but whilst this tends to be less economically viable due to smaller energy outputs and reduced economy of scale, it is likely to be less constrained in relation to proximity to homes, visual impact and other geographical constraints.

[17] UK Renewable Energy Roadmap Update 2013

5.1.2 Large scale wind

In the following analysis, various geographical layers of constraint are applied to the theoretical wind resource to assess their impacts. For the purpose of the analysis, the terms 'level 1' and 'level 2' constraints have been used. Broadly speaking, level 1 represents the technical or physical constraints that are highly likely to prevent wind power development and level 2 the potential constraints specifically linked to designated areas which are less defined and in most cases can only be assessed on a site-by-site basis.

Technical constraints and limitations – level 1 constraints

The estimated potential for large scale wind development was assessed via a GIS based constraints analysis using the level 1 constraints shown in the table below. These indicate areas where: wind speeds are likely to be unviable; turbines could not physically be deployed; or where noise is most likely to impact local residents. The constraints shown are not an exhaustive list of all possible barriers to wind power but instead focus on those most relevant to Guildford Borough.

Turbine size	2.5MW
Hub height	80m above ground level
Minimum wind speed	≥6.5 metres / second at hub height
Minimum distance from dwellings*	600m
Minimum distance from roads and rail	150m
Areas excluded	Areas of broadleaved and coniferous trees Scheduled monuments Historic Parks and Gardens Conservation areas

Table 9: Assumptions and level 1 constraints for large wind

*There is currently no statutory limit or industry-standard measure of the minimum distance a turbine should be located from a dwelling. While Scotland has guidance suggesting 2km and Wales suggests 500m between a wind turbine and housing, England has no separation distance, although noise limits suggest a minimum separation distance of 350 metres for a typical wind turbine.[18] The generous figure of 600m stated above is therefore intended to go some way in minimising visual impacts in addition to potential noise impacts.

Figure 30 below indicates the area of land remaining after the application of level 1 constraints, which calculates to be around 713 ha.

[18] www.parliament.uk/briefing-papers/sn05221.pdf Wind Farms – Distance from housing (July 2012)

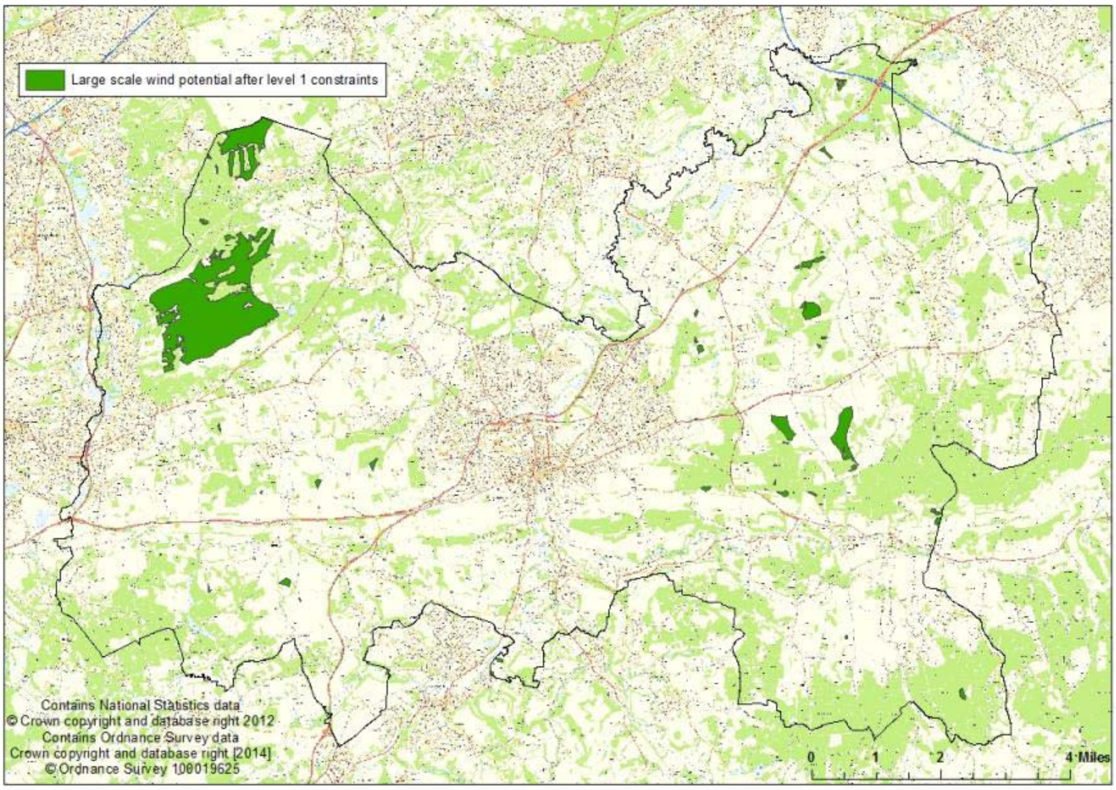


Figure 30: Potential areas for large scale wind in Guildford Borough with level 1 constraints applied

Radar constraints

An additional technical constraint concerns the impact of wind turbines on radar sights and so when locations for wind turbines are chosen the presence of radar coverage needs to be taken into account. The MoD has produced radar 'safeguarding' maps which show areas where wind turbines may interfere with radar. Different areas are affected at different heights above ground level. In these areas, the MoD must be consulted about the location of turbines. However, this does not always mean that turbines cannot be located within the safeguarding areas; this will depend on the specific site being considered.

Figure 31 shows the same unconstrained areas as in Figure 30, but with radar safeguarding areas for 140m above ground level overlaid i.e. turbine rotor tip height. It can be seen that virtually the entire study area is classed as a safeguarding area. However, radar is not considered in the analysis below as this is a generic constraint that needs to be considered on a site-specific basis.

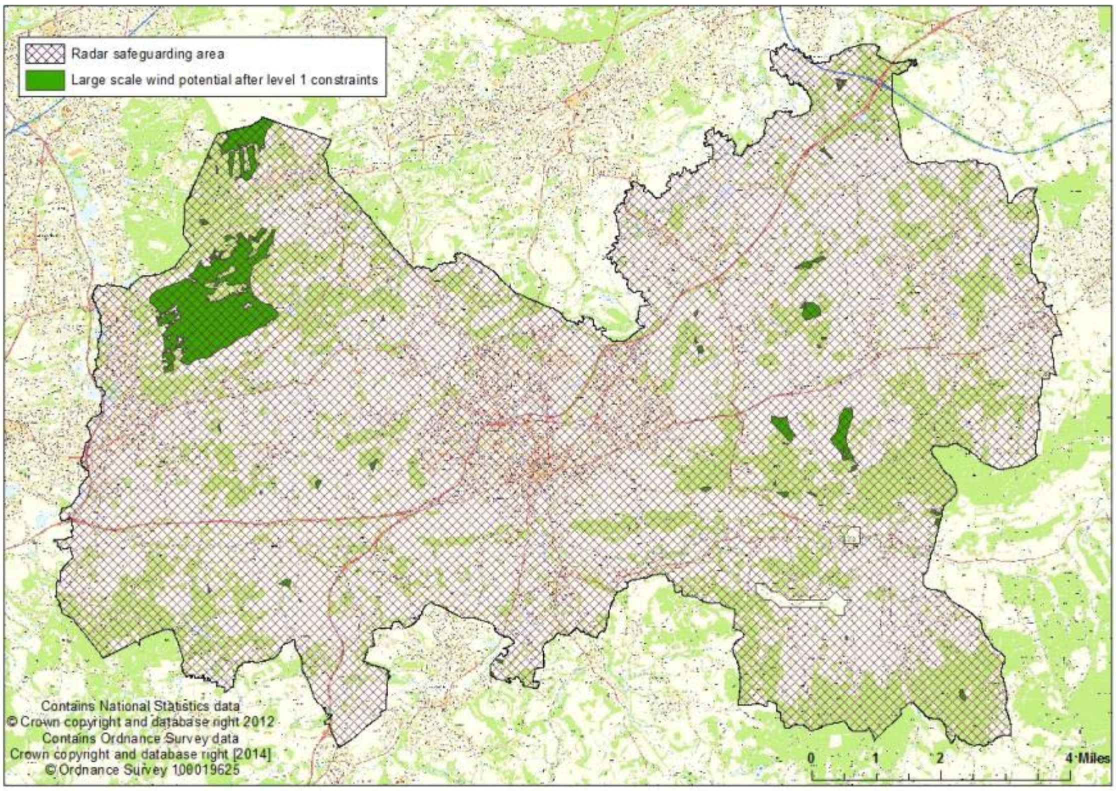


Figure 31: Potential areas for large scale wind in Guildford Borough with level 1 constraints applied, showing areas of radar safeguarding at 140m

Other 'technical' constraints that need to be addressed when considering wind power development are also highly site-specific and are therefore not included in the analysis. These may include (but not be limited to):

- Practical access to sites for abnormal loads, e.g. turbine blades
- Effect of slope and aspect of site topography on wind speeds
- Hydrology & hydrogeology impacts
- Detailed noise impact assessments (the dwelling buffers used above are a crude approximation of acceptable noise limits)
- Line of sight for telecommunications links
- The capacity of the local grid infrastructure to accept new generation capacity
- Landowner agreement
- Potential ecological, ornithological, cultural heritage and archaeological impacts
- Shadow flicker effects on nearby buildings

Landscape and visual impact – level 2 constraints

The constraints discussed in this section refer to landscape designations and landscape sensitivity to wind turbines. In this document, the term 'designated areas' refers to all of the designations listed in Table 10 (referred to below as 'level 2' constraints). While large scale wind turbine development is not formally prohibited within designated areas, it is more likely to be problematic due to potential landscape or environmental impacts. Depending on the site designation, proposed developments will need to be assessed in relation to any harmful impacts they may have on the integrity of the site and/or the objectives of the designation. In the analysis, the impact of each designation is considered individually along with the combined impacts of AONB and SSSI, both of which are national designations which may carry more weight in planning terms than AGLV or green belt. Wind farms would typically have a lifespan of 20-25 years after which the plant can be decommissioned and the land returned to its former state.

Designation	Significance within Guildford Borough
Area of Outstanding Natural Beauty (AONB)	The Surrey Hills AONB falls partly within Guildford. This area will be afforded the highest level of protection due to its national significance and only proposals which can be sensitively incorporated into the area and which complement and enhance the character of the AONB will be considered.
Site of Special Scientific Interest (SSSI)	Sites notified by Natural England as being of national importance for wildlife or geological reasons. There are sixteen SSSI sites in Guildford Borough and these hold a similar weight in planning to an AONB.
Special Protection Area (SPA)	SPAs form part of Natura 2000, a European-wide network of sites of international importance for nature conservation established under the European Community Wild Birds and Habitat directives. Part of the Thames Basin Heaths SPA falls within Guildford Borough and is contained within the SSSI sites described above.
Green belt	Guildford borough contains a large amount of land which is classified as Metropolitan Green Belt (89% of the Borough). This means that it is protected against inappropriate development in accordance with national planning policy to maintain its openness and open character. However, certain types of development are not considered inappropriate in the Green Belt and this is set out in paragraphs 89 – 90 of the National Planning Policy Framework.
Area of Great Landscape Value (AGLV)	An area considered to have a particular scenic value. In Guildford the AGLV covers the same extent as the AONB but includes some additional land. AGLV is a local designation introduced by Surrey County Council and, as such, it does not currently hold the same weight as the AONB, as a national designation, in policy terms. Proposals within the AGLV would need to consider the impact that development may have on the setting of the AONB. There is currently a review of the Surrey Hills AONB boundary underway by Natural England.

Table 10: Description of the key designated areas relevant to Guildford Borough

The analysis shows that all of the remaining areas after level 1 constraints are applied fall into Green Belt. The other land designations and their geographic relationship to these remaining areas are shown separately in Figure 32, Figure 33 and Figure 34 below. Figure 34 also illustrates how the SPA in Guildford Borough is contained within the SSSI. Therefore, for the purpose of simplifying the constraints mapping, the maps and tables that follow only indicate SSSI and do not separately identify SPA unless otherwise stated.

The combined impact of AONB and SSSI is shown in Figure 35, and the combined impact of AONB, SSSI and AGLV in Figure 36. These last two figures indicate that there is very little difference in impact from adding AGLV as a constraint.

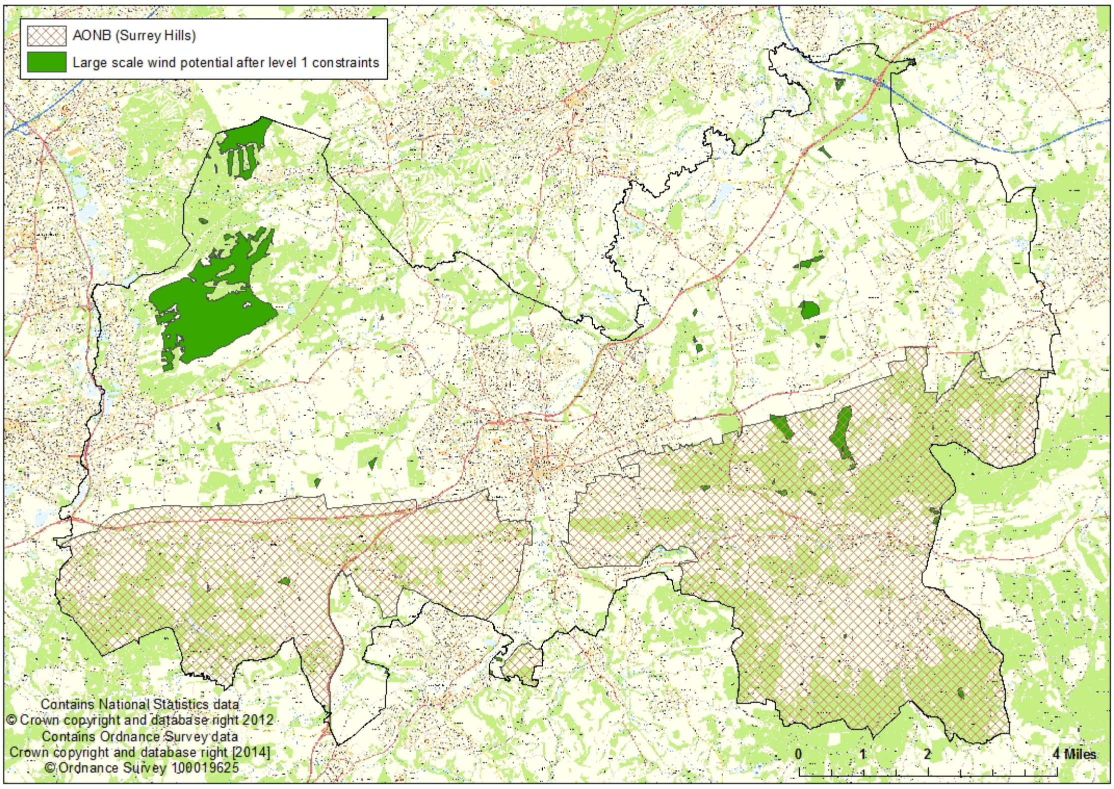


Figure 32: Potential areas for large scale wind in Guildford Borough and relationship to AONB

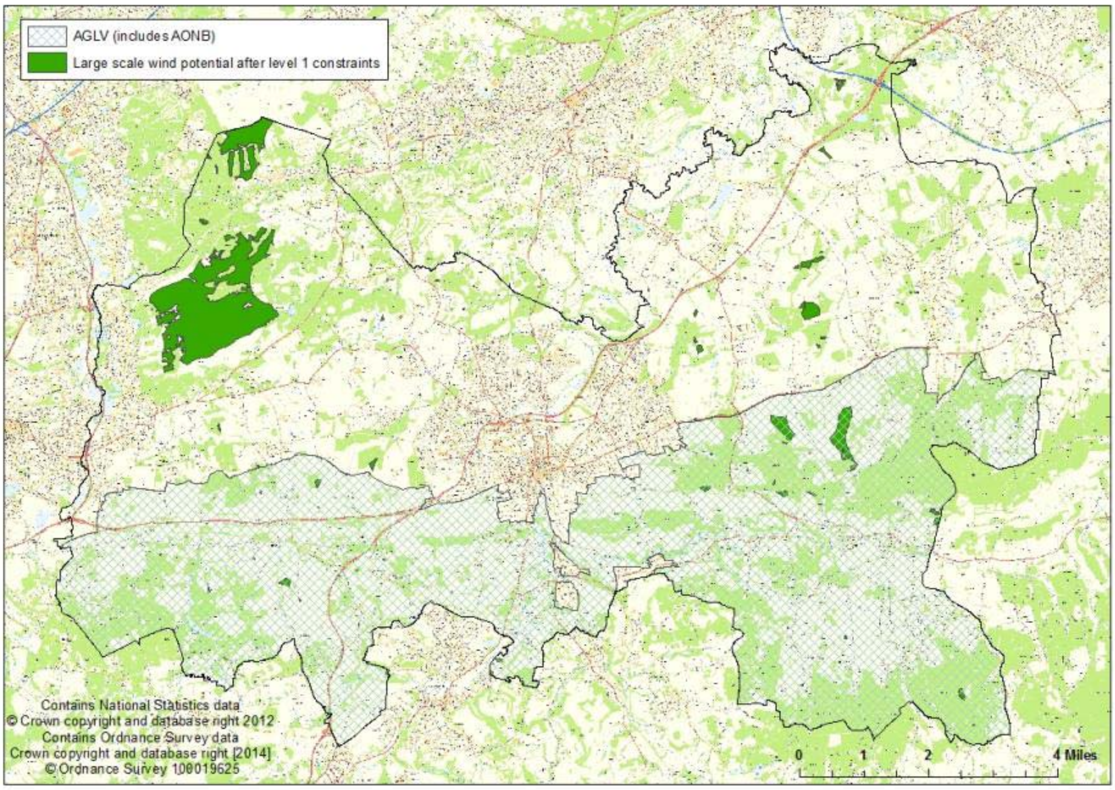


Figure 33: Potential areas for large scale wind in Guildford Borough and relationship to AGLV [note – the AGLV area comprises the AONB plus additional areas]

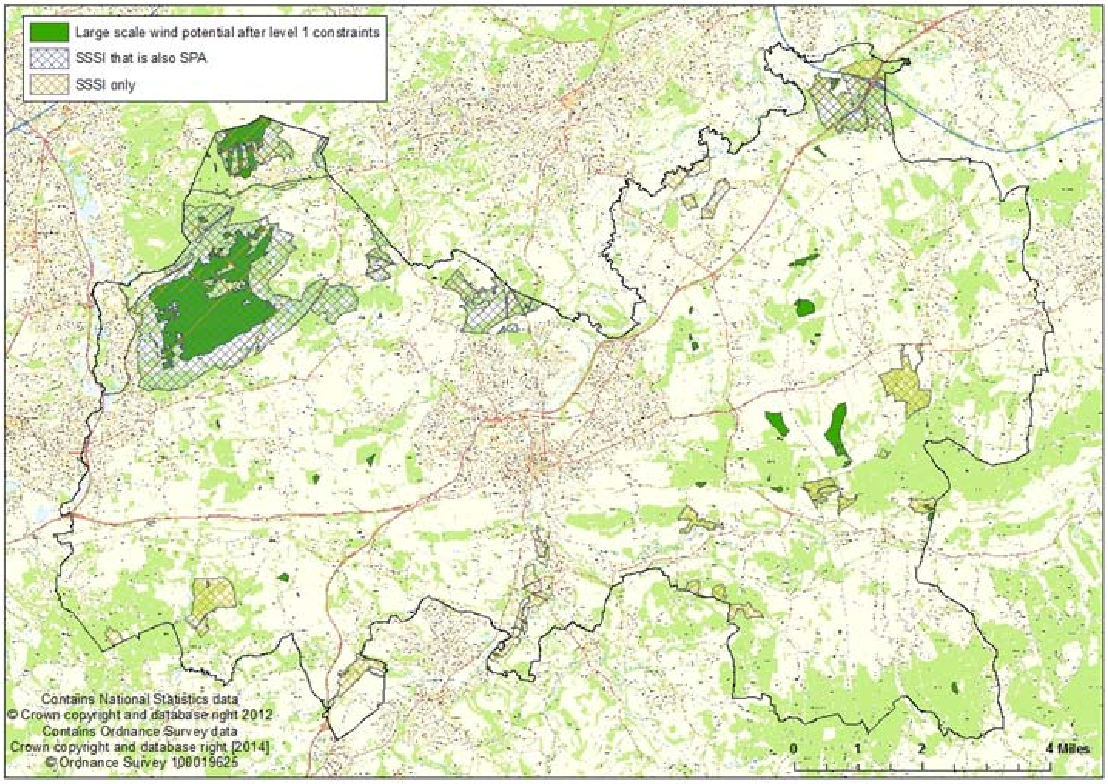


Figure 34: Potential areas for large scale wind in Guildford Borough and relationship to SSSI/SPA

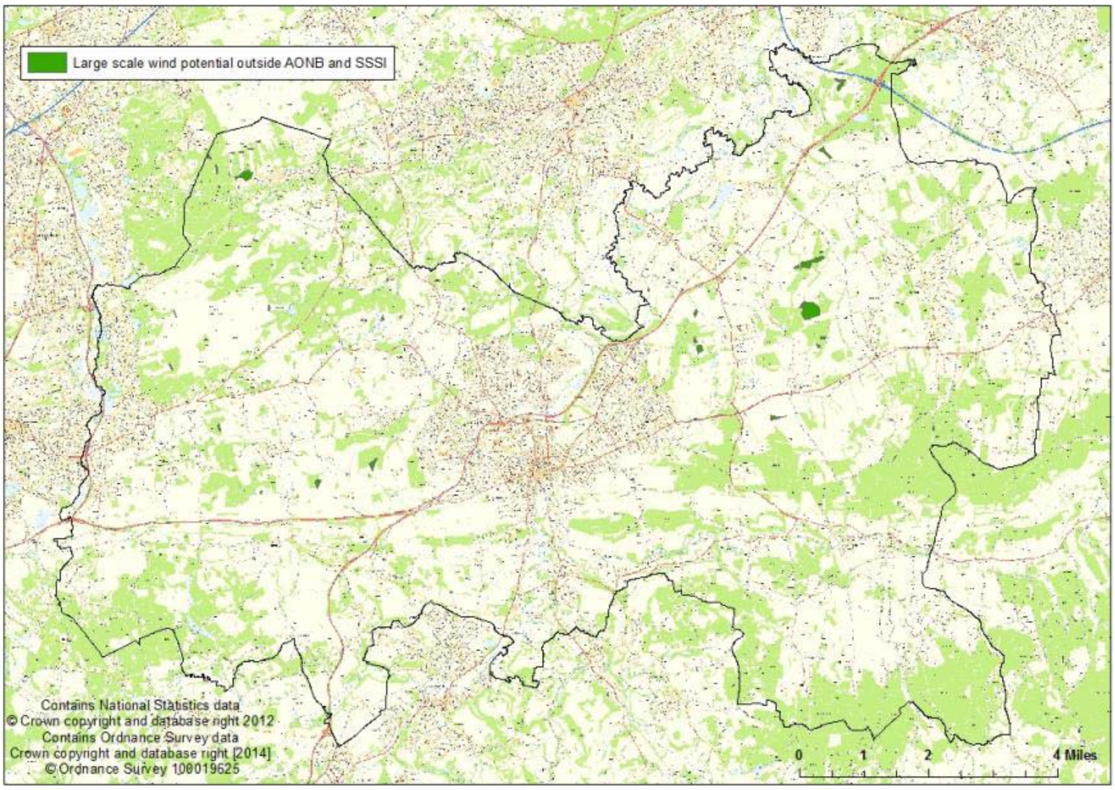


Figure 35: Potential areas for large scale wind in Guildford Borough with level 1 constraints applied and outside the land designations AONB and SSSI

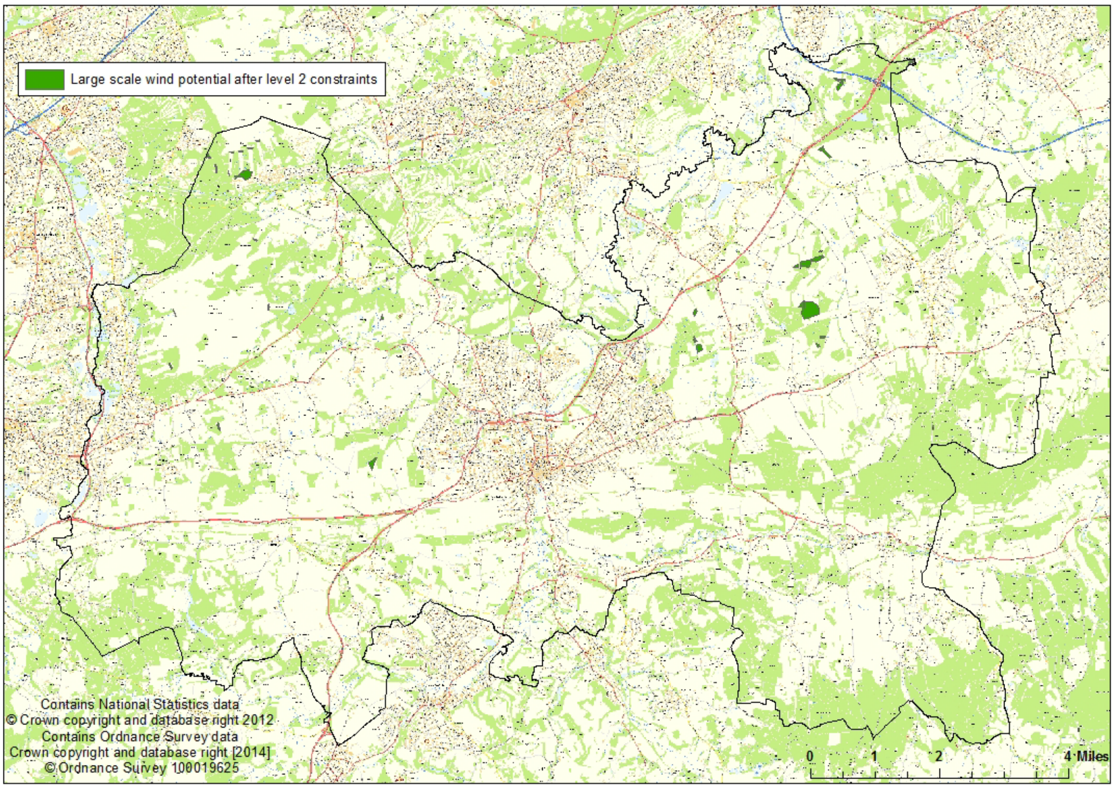


Figure 36: Potential areas for large scale wind in Guildford Borough with level 1 constraints applied and outside the land designations AONB, AGLV and SSSI

A useful way of assessing the visual impact of wind power developments is by considering landscape sensitivity. This term refers to the extent to which the technology has the potential, in the wrong location, to have significant impact on landscape character. In other words, 'sensitivity' in this context is the extent to which the character of the landscape is susceptible to change as a result of proposed wind developments. The cumulative impact of more than one wind development should also be considered.

Guidance produced by the Countryside Agency and Scottish Natural Heritage includes Landscape Character Assessment Guidance[19] and Topic Paper 6, which states that:

'Judging landscape character sensitivity requires professional judgement about the degree to which the landscape in question is robust, in that it is able to accommodate change without adverse impacts on character. This involves making decisions about whether or not significant characteristic elements of the landscape will be liable to loss... and whether important aesthetic aspects of character will be liable to change'

Although a landscape sensitivity assessment is outside the scope of this study, an example study can be viewed[20] as undertaken within the scope of the West Sussex Sustainable Energy Study. The report summarises key attributes of the landscapes across West Sussex, highlights the special qualities of designated areas (which includes the South Downs National Park), provides a sensitivity judgement highlighting those attributes that would be sensitive to specific renewable technologies, and provides guidance on how these technologies can be located to minimise adverse impacts.

[19] Countryside Agency and Scottish Natural Heritage (2002) Landscape Character Assessment: Guidance for England and Scotland CAX 84
[20] Landscape Sensitivity Analysis & Guidance for West Sussex Low Carbon Study
www.arun.gov.uk/assets/Planning/Policy_from_2010/Sustainable_Energy_Study.pdf

Key recommendations from the study, which may be relevant to Guildford Borough, include:

- Results indicate that a strategy to accept character change in some areas may be needed if large/medium scale wind is to contribute to renewable electricity generation in the study area
- When considering the impact of renewable energy generation technologies on landscape character, it is important to recognise that climate change itself will result in changes to our landscapes
- Planning can be used to guide renewable energy proposals so as to spread them apart to avoid cumulative issues, or to cluster them in certain parts of the landscape & keep other areas free of development.

Potential energy yield

Table 11 below quantifies the land area after level 1 constraints are applied and estimates potential capacity and resulting CO_2 savings. It also shows the impact on these figures when each designated area is then independently applied as a constraint, and also the combined impact of AONB and SSSI, and that of AONB, SSSI and AGLV.

	Hectares	Potential installed capacity*(MW)	Energy output (MWh/year)**	Potential CO_2 saving (tonnes/yr)
After level 1 constraints	713.5	105	248,346	111,756
Excluding AGLV	639	92.5	218,781	98,451
Excluding AONB	645	95	224,694	101,112
Excluding SSSI	116	35	82,782	37,252
Excluding Greenbelt	0	0	0	0
Excluding AONB and SSSI	50	27.5	65,043	29,269
Excluding AONB, SSSI and AGLV	46	22.5	53,217	23,948

Table 11: Areas for large scale wind and estimated capacity (small land parcels excluded) after applying level 1 and level 2 constraints as indicated

Explanatory notes:

* Once the constraint layers are applied, the remaining area is made up of parcels of land which vary in size and this column is calculated by looking at each land parcel individually. The remaining land area when all level 1 and 2 constraints are applied (not including potential radar constraints) totals 46 hectares, which reduces to 45.5 ha when parcels less than 0.1 ha (thought to be too small to support a large scale turbine) are excluded. It is then assumed that all parcels ranging from 0.1-20 ha could support one turbine, with a maximum density of 1 turbine per 20 hectares applied to parcels above 20 ha. However, on this basis, after level 2 constraints have been applied none of these larger land parcels would support more than one turbine as they are all below 40 ha. The resulting capacity of 22.5 MW once all level 1 and 2 constraints are applied may therefore be an underestimation. To establish a more accurate estimate, detailed site-specific analysis would be required to look at the shape of each individual site and examine how turbines could be laid out within this in relation to the constraint boundaries.

**Energy yields are calculated from the installed capacity estimates by assuming a capacity factor of 0.27. This is a measure of how much energy a generation plant can produce over the course of a year under ideal conditions (i.e. when it is possible to continually operate at maximum output), compared to how much energy it produces in practice under actual conditions. A factor of 0.27 is a typical value for large scale wind across the UK, but this figure varies year by year depending on wind conditions.

5.1.3 Medium scale wind

Technical constraints and limitations

The same method for large scale wind was used for assessing the potential for medium-scale wind turbines. The first level of constraints applied (level 1) were technical and physical constraints, as detailed in the table below:

Turbine size	800kW
Hub height	50m above ground level
Minimum wind speed	≥6.5 metres / second at hub height
Minimum distance from dwellings	500m
Minimum distance from roads and rail	95m
Areas excluded	Areas of broadleaved and coniferous trees Scheduled monuments Historic Parks and Gardens Conservation areas

Table 12: Assumptions and level 1 constraints for medium scale wind

Figure 37 below illustrates the areas which are not excluded by these 'level 1' constraints. The land indicated has a total area of 710 hectares.

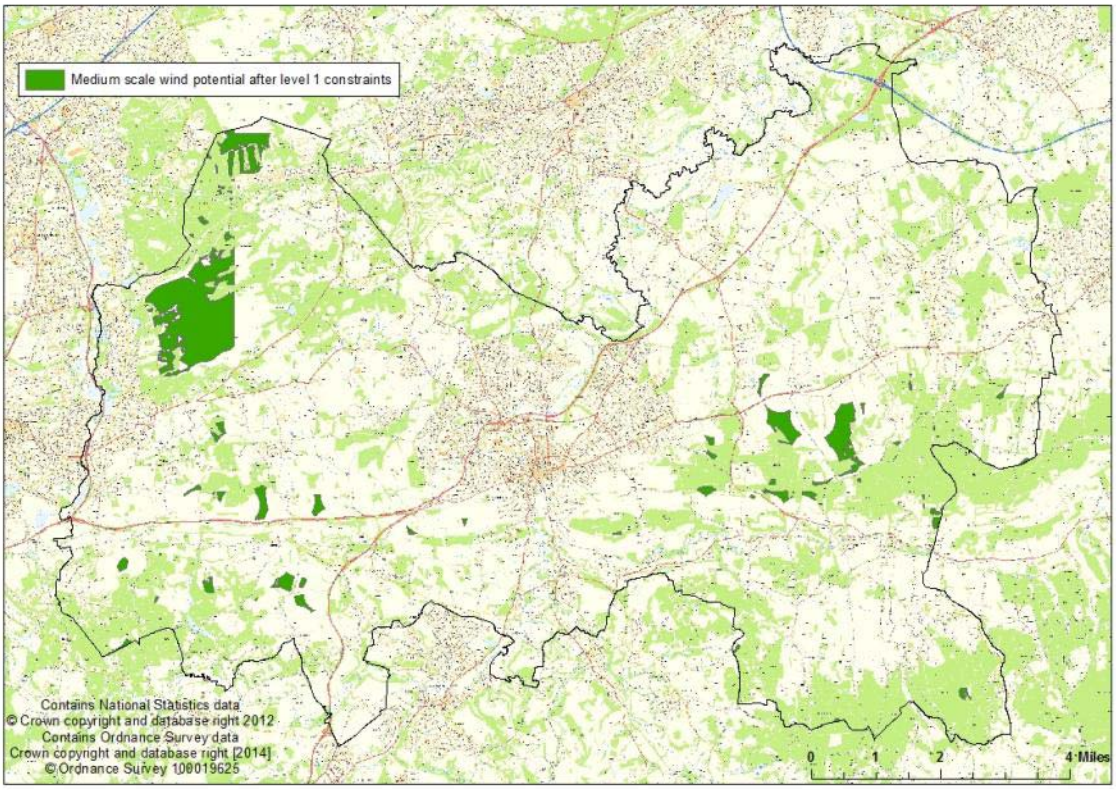


Figure 37: Potential areas for medium scale wind in Guildford Borough with level 1 constraints applied

The radar safeguarding map was again overlaid to show the areas in the Borough where turbines could interfere with the radar. Figure 38 shows the same areas as in Figure 37, but with radar safeguarding areas for 80m above ground level overlaid, to represent the height of the blade tip at this scale. It can be seen that although a smaller proportion of the Borough is affected than at 140m, most of the areas where level 1 constraints have been applied might still be affected by radar at this scale.

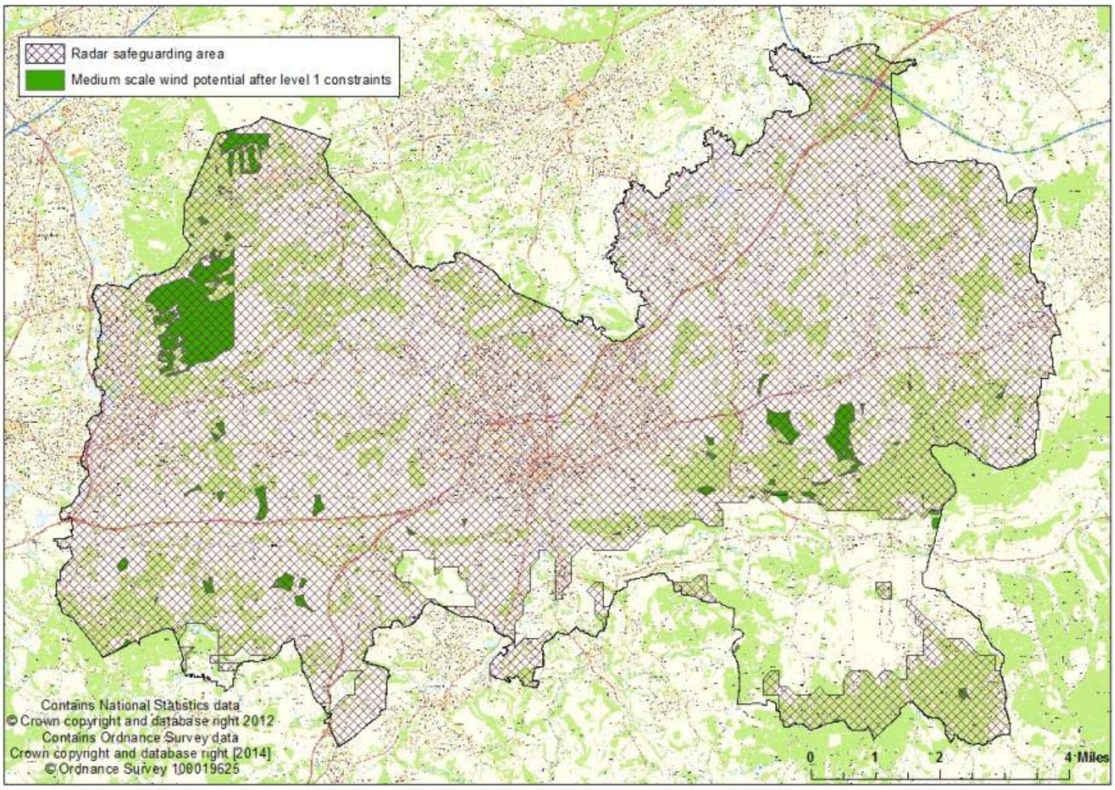
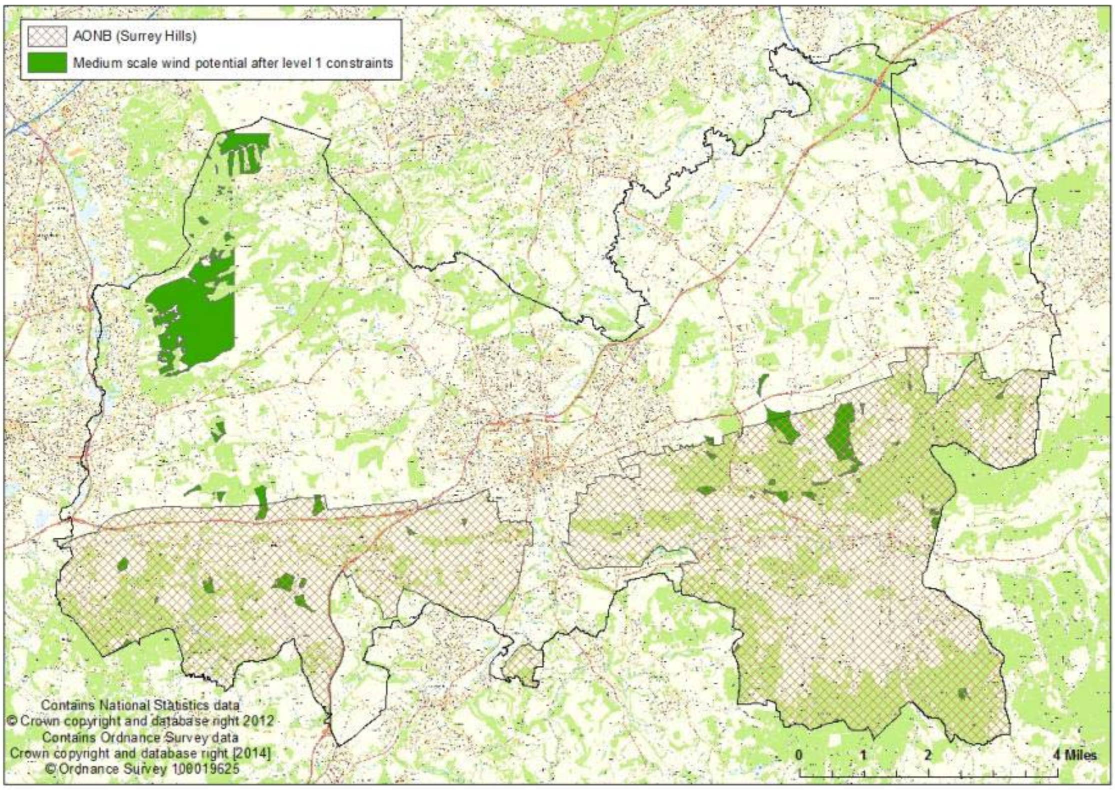


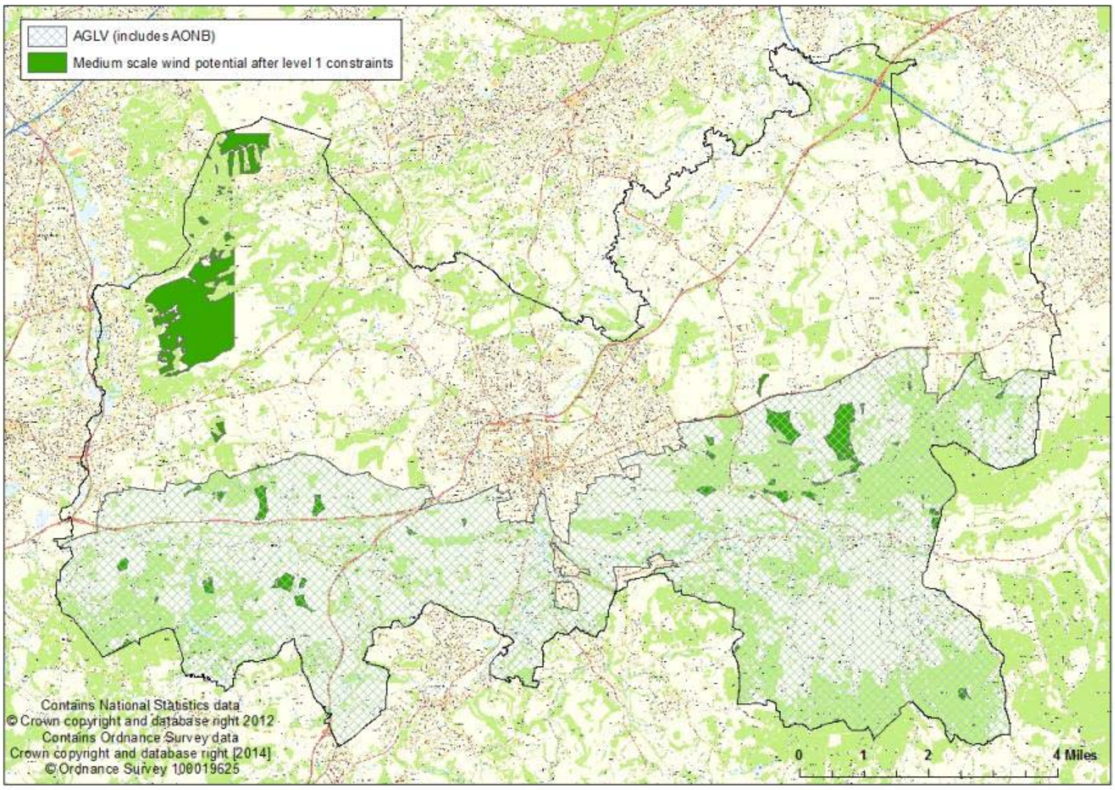
Figure 38: Potential areas for medium scale wind in Guildford Borough with level 1 constraints applied, showing areas of radar safeguarding at 80m

Landscape and visual impact

Analysis was carried out to determine how the area remaining after level 1 constraints were applied is affected by the same land designations (level 2 constraints) considered for large scale wind. The analysis shows that once again all of the remaining areas after level 1 constraints were applied fall into the green belt. The areas remaining outside of the other designations are shown below in Figures 39 to 42, with the combined result shown in Figure 43.



Figures 39: Potential areas for medium scale wind in Guildford Borough and relationship to AONB



Figures 40: Potential areas for medium scale wind in Guildford Borough and relationship to AGLV [note – the AGLV area comprises the AONB plus additional areas]

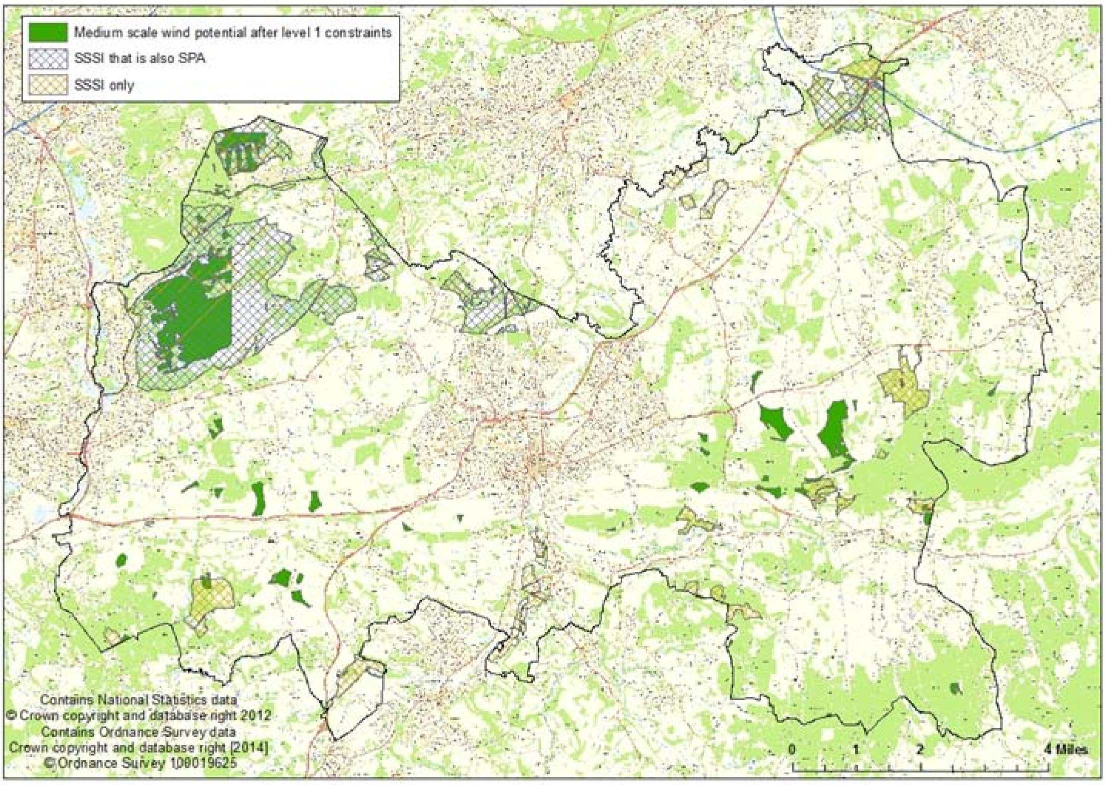


Figure 41: Potential areas for medium scale wind in Guildford Borough and relationship to SSSI/SPA

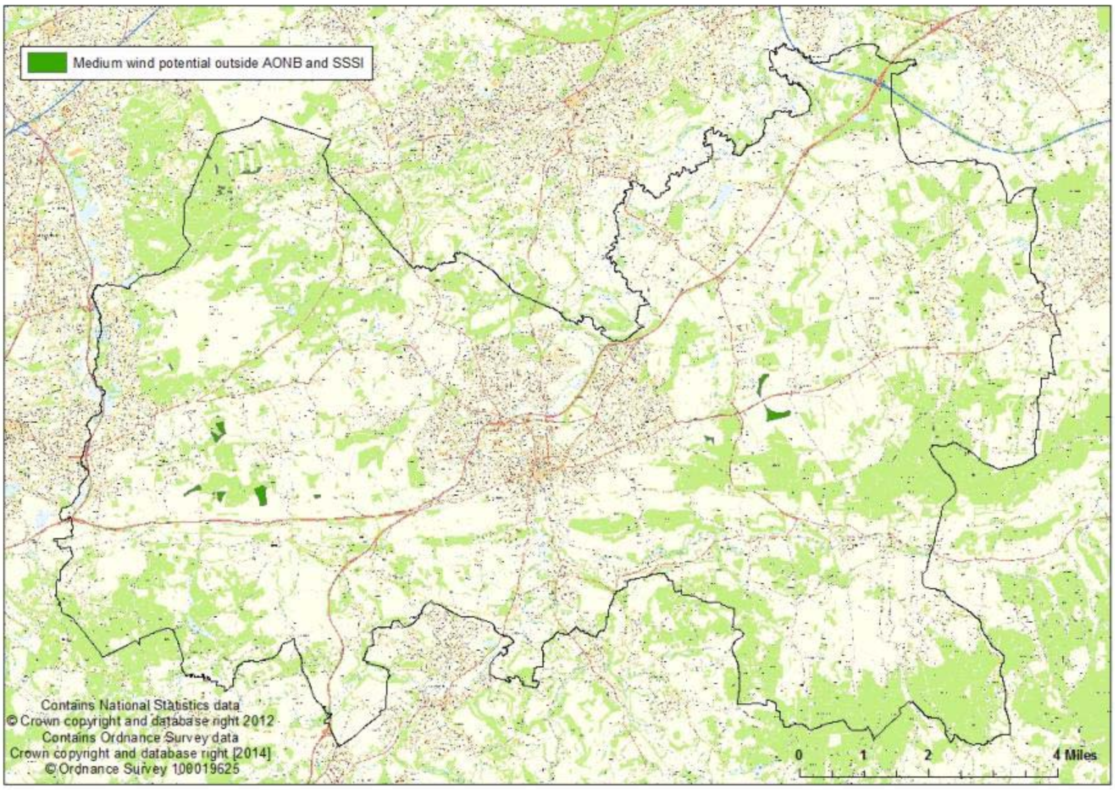


Figure 42: Potential areas for medium scale wind in Guildford Borough with level 1 constraints applied and outside the land designations AONB and SSSI

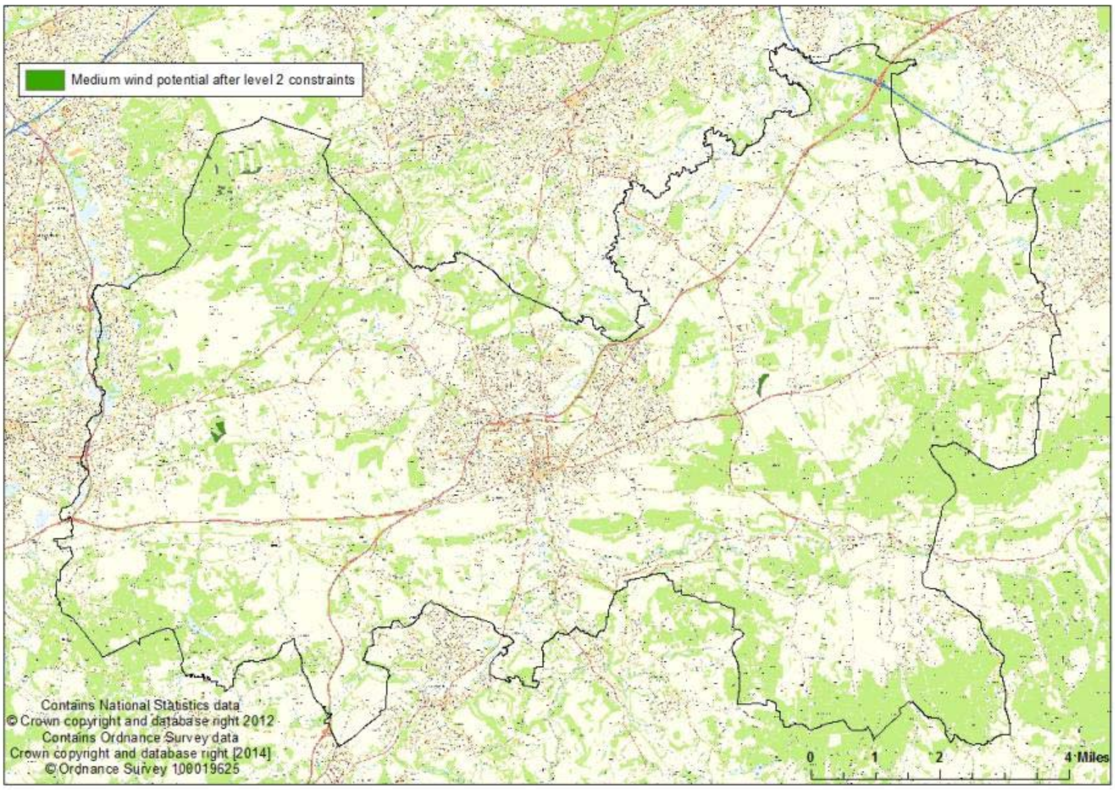


Figure 43: Potential areas for medium scale wind in Guildford Borough with level 1 constraints applied and outside the land designations AONB, AGLV and SSSI

Potential energy yield

Table 13 below again quantifies the land area after level 1 constraints are applied and estimates potential capacity and resulting CO_2 savings. It also shows the impact on these figures when each designated area is then independently applied as a constraint, and also the combined impact of AONB and SSSI, and that of AONB, SSSI and AGLV.

	Hectares	Potential installed capacity*(MW)	Energy output (MWh/year)*	Potential CO_2 saving (tonnes/yr)
After level 1 constraints	710	90.4	213,814	96,216
Excluding AGLV	481	48.8	115,422	51,940
Excluding AONB	507	54.4	128,667	57,900
Excluding SSSI	237	48	113,530	51,088
Excluding Greenbelt	0	0	0	0
Excluding AONB and SSSI	46	15.2	35,951	16,178
Excluding AONB, SSSI and AGLV	19.5	9.6	22,706	10,218

Table 13: Areas for medium scale wind and estimated capacity (small land parcels excluded) after applying level 1 and level 2 constraints as indicated

*Similar assumptions to that for large scale wind (see notes under Table 11) were applied in estimating installed capacity and energy output. However, a maximum density of 1 turbine per 10 hectares was assumed for the modelled 800 kW turbine.

5.2 Solar PV farms

5.2.1 Overview

The type of large scale solar PV referred to here comprises ground-mounted arrays of solar panels often referred to as solar PV 'farms'.

Figure 44: Westmill Solar Farm (a 12 hectare, 5 MW community-owned scheme)

Technical constraints and limitations

Solar PV is a well-understood technology with relatively few technical constraints. Solar PV farms require an open area of land, with limited shading and slope, and which is located within the vicinity of a suitable grid connection point. Solar farms are becoming more common, particularly in the south of the UK where solar irradiation levels are highest – see Figure 45 which shows how solar irradiation levels vary across the UK.

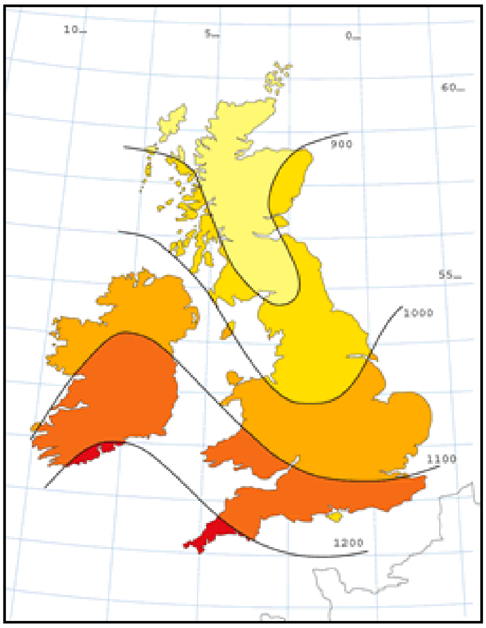


Figure 45: Solar irradiation map showing variation across the UK; banding shows annual totals in kWh/m^2

There is no maximum or minimum size of area needed for a solar farm although commercial viability and other factors have resulted in most UK installations to date being in the range 1-3 MW, where 2-3 hectares of land is typically required for each installed MW. Much larger installations however have more recently appeared such as the 34 MW Wymeswold project on the site of a former airfield in Leicestershire which covers an area of around 60 hectares. A solar PV array would typically involve the erection of multiple rows of PV units mounted on racks which are either fixed or automatically controlled to track the sun. The output of a typical panel would be around 200 watts, so a 1MW solar farm would require 500 racks containing 10 panels in each rack.

Environmental impact
Ground-mounted solar PV installations will need planning permission and any environmental impact will need to be considered when siting an array. Visual impact is usually the most significant factor, but this can often be minimised through careful siting with regard to topography and making use of natural features such as perimeter hedges. Areas with special designations will need particular consideration and for the Guildford area these include nationally designated zones such as Areas of Outstanding Natural Beauty (AONB), Sites of Special Scientific Interest (SSSI) and designated Greenbelt land. Guildford also contains Areas of Great Landscape Value (AGLV) which is a status designated by local authorities rather than national bodies (see Section 5.2.2). Solar farms would typically have a lifespan of at least 25 years after which the plant can be decommissioned and the land returned to its former state.

PV farms should ideally avoid being located on the best agricultural land i.e. Grades 1 or 2, but with suitable safeguards can accommodate grazing animals and may even provide a degree of shelter.

Figure 46: PV array co-located with livestock

5.2.2 Methodology

The basic principle of the solar PV assessment methodology used in this study is to start by looking at the whole study area, and then apply a series of constraints using GIS techniques which indicate where the installation of a ground-mounted solar array would be impossible or highly unlikely. These constraints can be thought of as ‘exclusion zones’; every time a constraint is applied, the area that it covers is erased from the study area, so that the results of the analysis indicate locations where the technology may have more potential.

Identification of exclusion zones for ground-mounted solar farms

The exclusion zones applied in this analysis are as follows:

- Agricultural Land Grades 1 and 2
- Floodplain
- Woodland
- Urban areas and settlements
- Roads, railways and buildings
- Historic parks and gardens

Roads and railways were given an assumed width of 10m. Buildings were given an assumed size of 100m^2, which brings some inaccuracy in the data due to the size of buildings in reality varying significantly. In addition a separation zone of 20m was applied to residential buildings and 5m to non-residential buildings. These separation zones are treated as absolute constraints for this analysis, although in practice there are no official distances from buildings as such stated in planning law.

Further constraints

The above set of 'exclusion zone' constraints can be thought of as being fixed and will narrow down the 'search' area for locations having the most potential for solar PV farms. Other geographical factors that may constrain the deployment of the technology can then be considered. The degree to which these may act as constrains is however site specific, meaning that certain generic assumptions need to be made when mapping their impact and that care is needed when interpreting the results. The further constraints considered here are proximity to a grid connection point, designated areas and competing land use demands.

- **Proximity to grid connection** – when siting a solar array, the distance to the nearest electrical substation must be taken into consideration. Connecting the array to the grid can be a significant additional cost and cable runs should therefore be kept to a minimum. There is no widely accepted industry standard for a 'maximum viable distance' as this depends on a number of site-specific factors such as size of array and the land type through which the cable would be routed. The available capacity of the substation is also a critical factor and even if one is very close to the proposed PV farm, it may not be suitable for connection without a significant upgrade, which can be costly. Solar PV farms would typically be connected to either an 11kV or 33kV substation depending on a number of factors including the connection voltage, location and MW capacity of the farm[21].

  With regard to the potential for large solar PV farms GIS analysis was carried out to determine the location of 33kV substations in Guildford Borough, using data from UK Power Networks and SSE, the two Distribution Network Operators that cover the Borough. Land within a 3km radius[22] from each substation was identified on the assumption that these areas will have more potential for economically viable grid connections. 11kV substations are much more common and widespread hence smaller PV farm installations will be less constrained in terms of substation proximity criteria.

- **Designated areas** – whilst land designations per se may not always restrict the development of solar PV farms, they need to be taken into account when siting an array. The same land designations as described in the wind power assessment (see Table 10) are used again here. Each area has been mapped to examine its potential impact in relation to the locations previously identified following application of the exclusion zones.

  Note – all of the Thames Basin Heaths Special Protection Area (SPA) that lies within Guildford Borough is also designated as SSSI (as shown in Figure 34). Therefore, for the purpose of simplifying the constraints mapping, the maps and tables that follow only indicate SSSI and do not separately identify SPA.

- **Competing land use demands** – the gross area remaining outside the exclusion zones is very large and it is highly unlikely that the majority of this will be considered for solar PV farms given competing land uses such as crops and other development. The analysis therefore assumes an alternative scenario where only 10% of this area is included in the resource assessment for solar PV farms. Whilst this figure is somewhat subjective, it is considered to be a reasonable assumption for the purpose of this study. Note that this constraint is not applied geographically; it is only applied to the total land area figure as a comparison.

[21] As an approximate guide, 33 kV substations would typically accommodate 3-phase generators in the range 4-20 MW in rural locations or 7-20 MW in urban locations [source: Long Term Development Statement for Western Power Distribution (East Midlands) PLC's Electricity Distribution System, Nov 2012].

[22] This distance may vary but has been chosen as an indicative value based on discussions with installers.

5.2.3 Findings

Figure 47 shows the extent of the area outside the exclusion zones potentially suitable for solar PV farms across the Borough and a subset of this indicating the areas that are within 3km of a 33kV substation (i.e. that might be suitable for larger scale PV farms). It is also worth considering that there may be substations in neighbouring Local Authority areas which have capacity and are closer to sites near the Borough boundary than substations within the Borough.

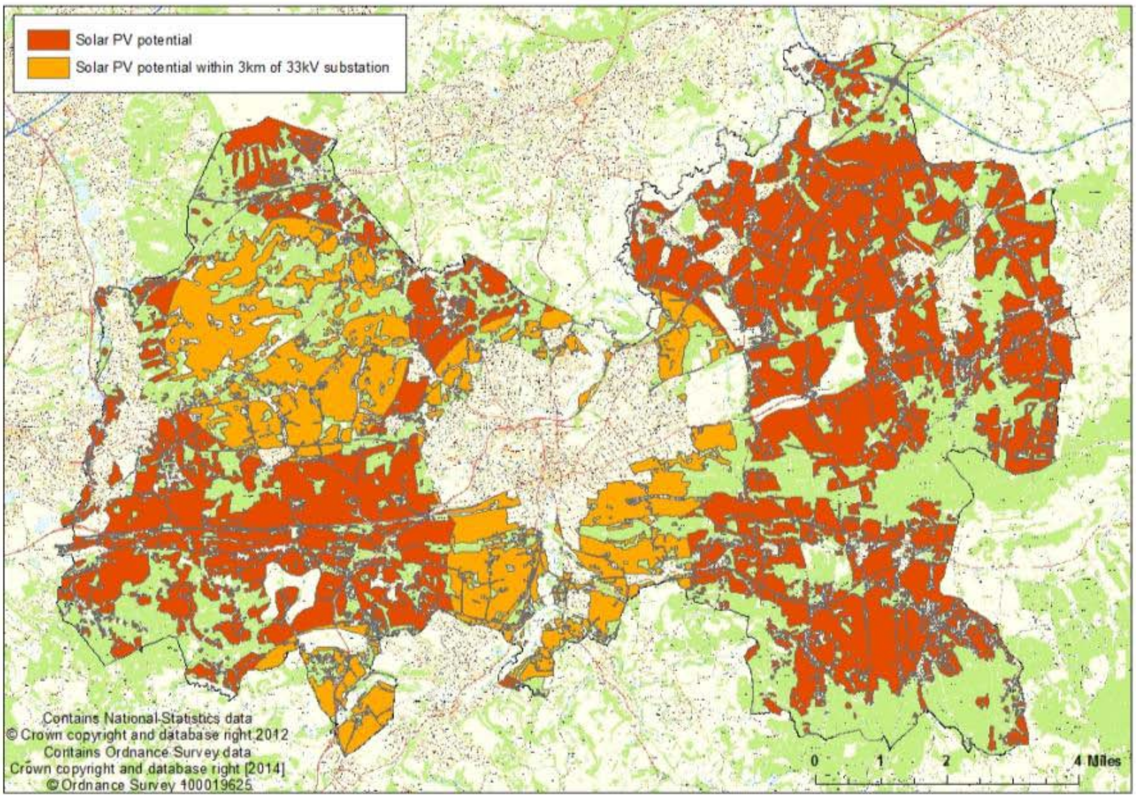


Figure 47: Potential areas for solar PV farms in Guildford Borough outside of exclusion zones

Figures 48 to 51 then show a series of maps which indicate the land areas that could be suitable for solar PV farms when considering areas both outside the exclusion zones and outside each specified designation in turn.

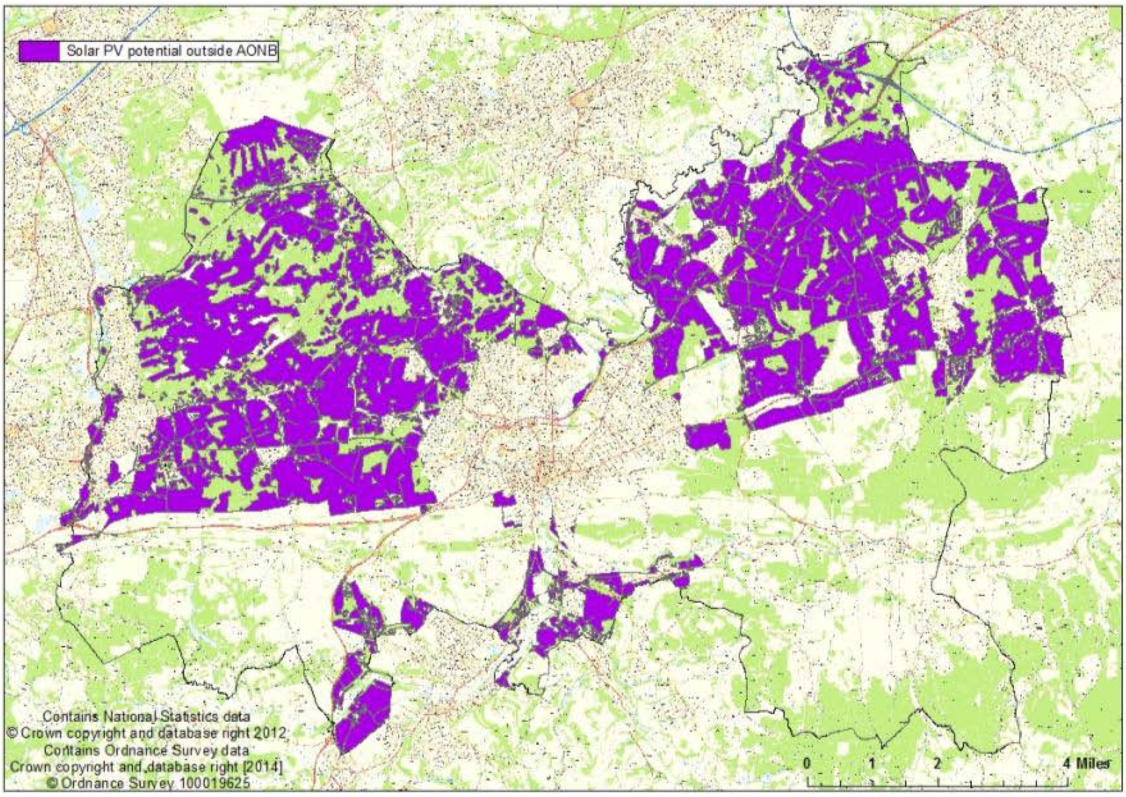


Figure 48: Potential areas for solar PV farms in Guildford Borough outside of exclusion zones and AONB

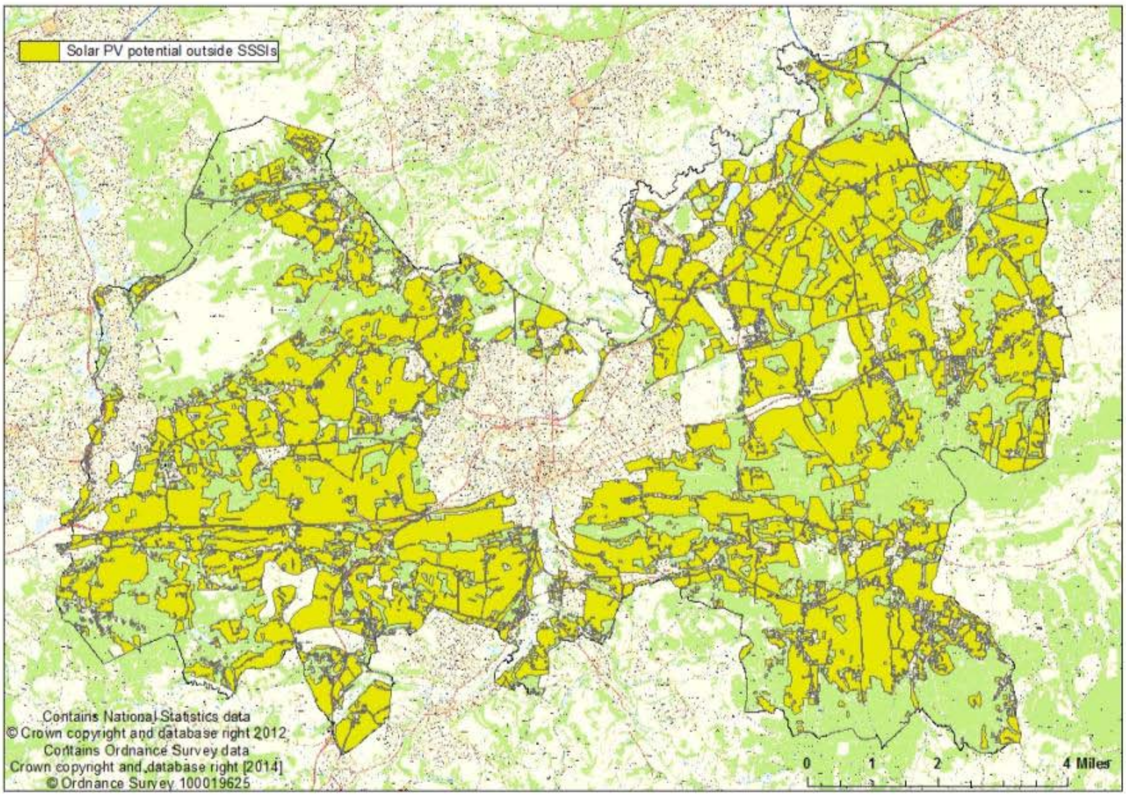


Figure 49: Potential areas for solar PV farms in Guildford Borough outside of exclusion zones and SSSI

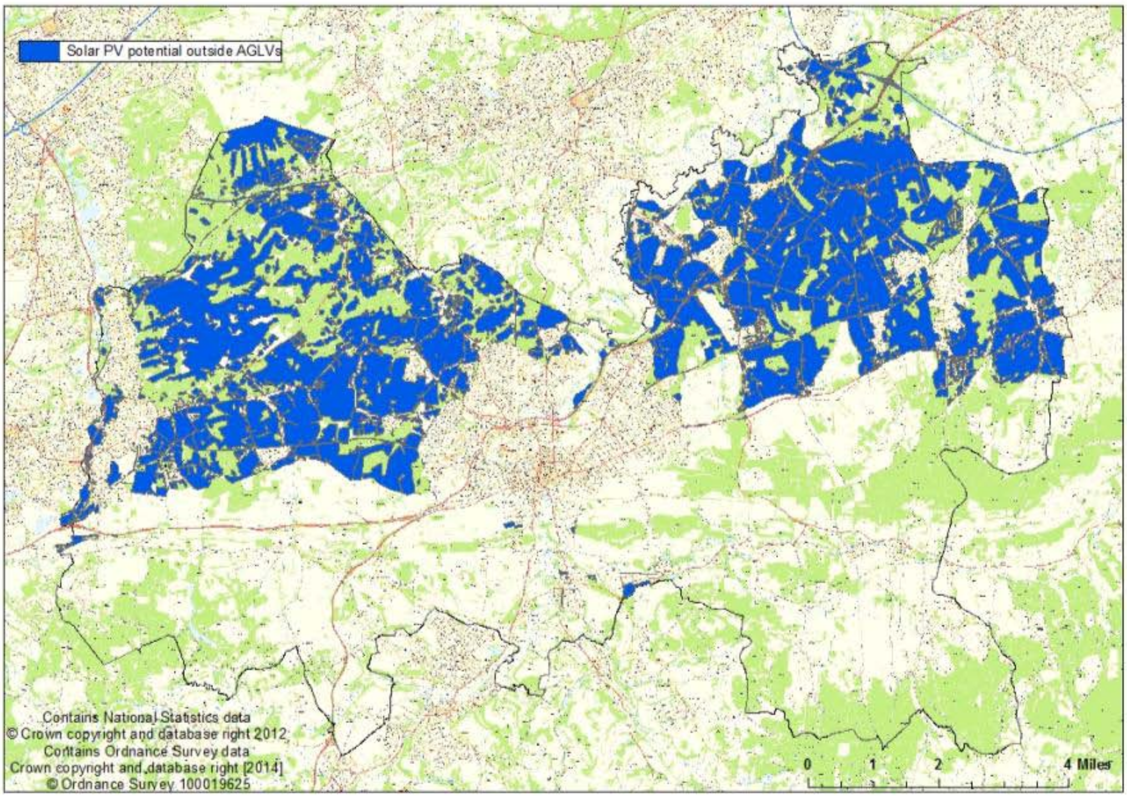


Figure 50: Potential areas for solar PV farms in Guildford Borough outside of exclusion zones and AGLV [note – the AGLV area comprises the AONB plus additional areas]

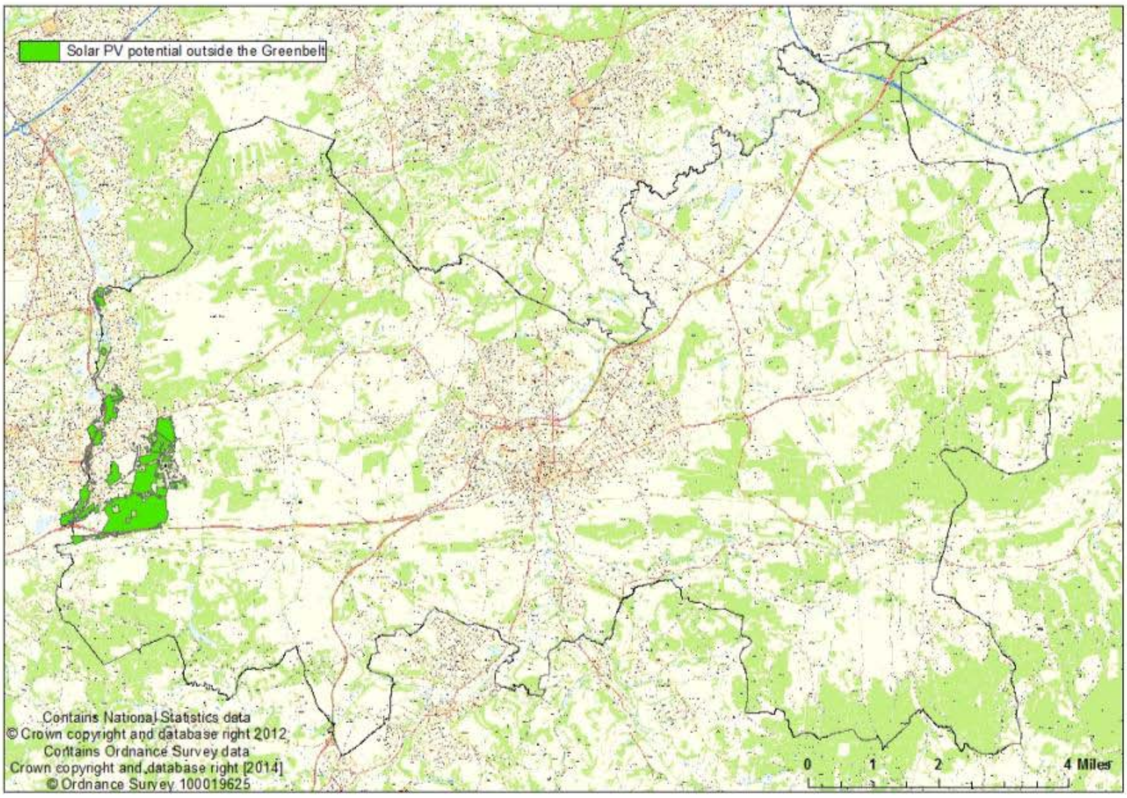


Figure 51: Potential areas for solar PV farms in Guildford Borough outside of exclusion zones and Greenbelt

Figure 52 and Figure 53 then show the combined impacts of AONBs and SSSIs, and the combined impacts of all designations respectively.

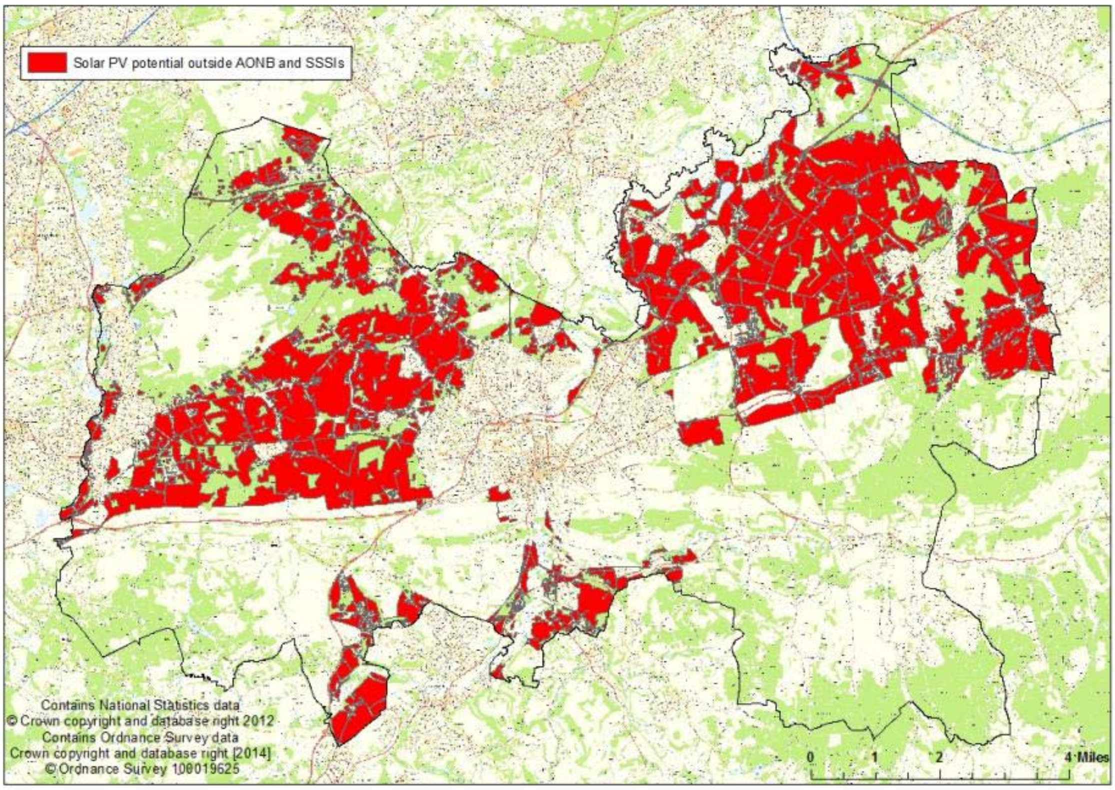


Figure 52: Potential for solar PV farms in Guildford Borough outside exclusion zones, AONB and SSSI

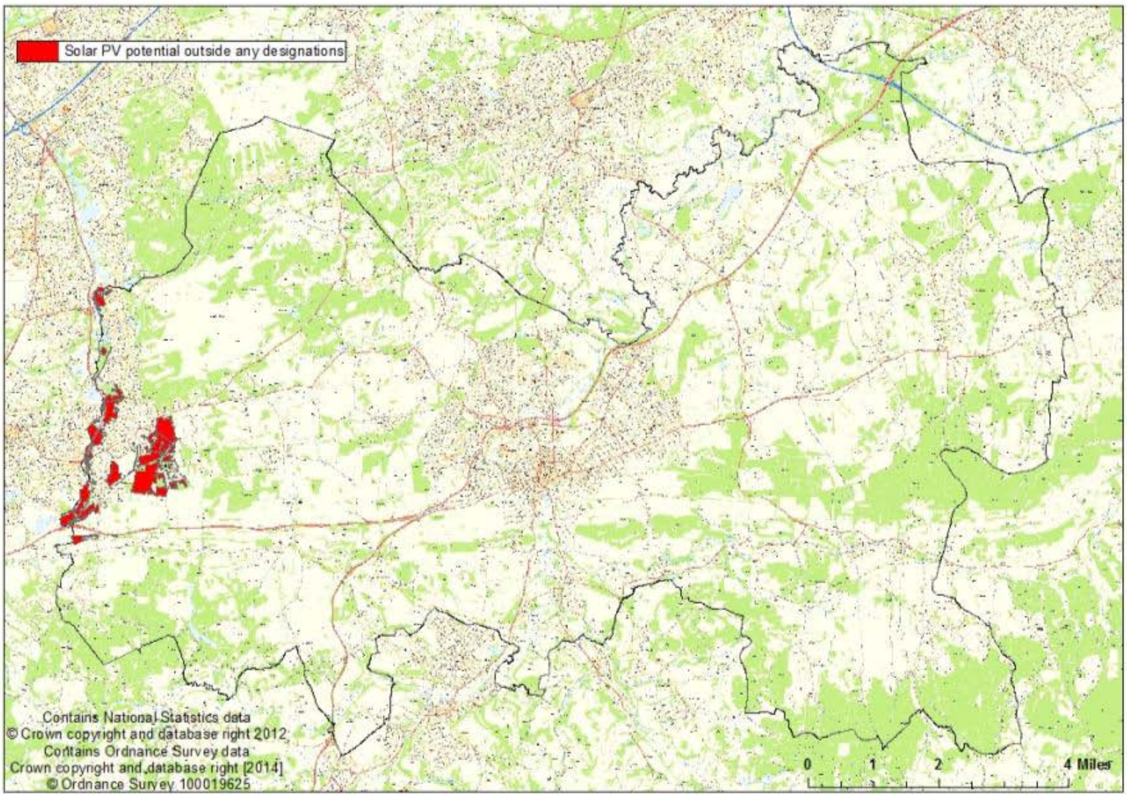


Figure 53: Potential for solar PV farms in Guildford Borough outside exclusion zones, AONB, SSSI, AGLV and green belt

Table 14 shows the impact on the total area of land that would potentially be suitable for solar PV farms after the various constraints criteria are applied, starting with the total area outside the exclusion zones. The table also shows the subsequent PV farm capacities in MW, assuming that a 1 MW array requires three hectares of land, along with estimated annual energy yields and CO_2 savings.

Assumption criteria (not cumulative)	Area of land available outside of exclusion zones (ha)		Potential capacity for PV (MW)	Annual generation potential (MWh)	Potential CO_2 savings[23] (ktonnes/yr)
Total area outside of 'exclusion zones'	13,073	see Figure 47	4,358	3,817,608	1,718
Within 3 km of 33kV substation	8,430		2,810	2,461,560	1,108
Excluding AONB	7,905	See Figures 48-53	2,635	2,308,260	1,039
Excluding SSSI	12,062		4,020	3,521,520	1,585
Excluding AGLV	6,727		2,242	1,963,992	884
Excluding Green belt	320		106	92,856	42
Excluding AONB and SSSI	6,953		2,318	2,030,568	914
Excluding all land designations	202		67	58,692	26

Table 14: Potential for solar PV farms in Guildford Borough at varying levels of potential constraints

Table 15 then shows the same set of data, but assuming that only 10% of the respective areas are considered due to competing land use.

Assumption criteria (not cumulative) with 10% 'competing land use' factor applied	Area of land available outside of exclusion zones (ha)	Potential capacity for PV (MW)	Annual generation potential (MWh)	Potential CO_2 savings (ktonnes/yr)
10% of total area outside of 'exclusion zones'	1,307	436	381,761	172
Within 3 km of 33kV substation	843	281	246,156	111
Excluding AONB	791	264	230,826	104
Excluding SSSI	1,206	402	352,152	158
Excluding AGLV	673	224	196,399	88
Excluding Green belt	32	11	9,286	4
Excluding AONB and SSSI	695	232	203,057	91
Excluding all land designations	20	7	5,869	3

Table 15: Potential for solar PV farms in Guildford Borough at varying levels of potential constraints

[23] CO_2 factor of 0.45 $kgCO_2/kWh$ used [Defra/DECC 2012]

5.3 Hydropower

5.3.1 Overview

Hydropower is the use of water flowing from a higher to a lower level to drive a turbine connected to an electrical generator, with the energy generated proportional to the volume of water and vertical drop or head. Although it is a well developed form of renewable energy, environmental constraints on large multi-MW scale plant means that most potential exists for mainly small or micro-scale schemes. Small scale hydropower plants in the UK generally refer to sites ranging up to a few hundred kilowatts where electricity is fed directly to the National Grid. Plants at the micro-scale (typically below 100kW) may include schemes providing power to a single home.

'Low head run of river' schemes are typically sites in lowland areas, often installed on historic mill sites using the existing channel system and weir or dam. 'High head run of river' schemes are typically found on steeper ground in upland areas and the diverted water is typically carried to the turbine via an enclosed penstock (pipeline).

Figure 54: The Town Mill in Guildford showing the single storey Toll House and (right) the 35kW hydro turbine during installation

Technical constraints and limitations

Hydropower is a well-established and proven technology and there are few technological constraints to its use other than ensuring that heads and flow rates are adequate throughout the year, that there is adequate site access, that the site can accommodate the necessary equipment and that the electricity generated can be transmitted to its end use. For the same reasons, energy yields can be accurately predicted and economic viability established relatively easily.

Environmental impact

Small-scale hydro schemes will typically include dams, weirs, leats, turbine houses and power lines, which will have a visual impact on the locality, but which can usually be minimised by careful siting and design. Other important considerations include hydrology and the river ecology. Hydro plants may have an impact on upstream water flows and waterfalls, and fish populations can be vulnerable to changes in water flows and from the risk of physical harm from the plant equipment. Measures such as 'fish passes' are often incorporated to mitigate these impacts. Minimising risks to eels, which are common throughout the River Wey[24], is particularly important; the European eel is classed as 'Critically Endangered' by the IUCN Red List of Threatened Species and is therefore a protected species.

[24] www.weyriver.co.uk/theriver/wildlife_5_fish.htm

Any potential impacts of hydro installations on the status indicators of a water body as set out in the Water Framework Directive will need due consideration. Requirements will normally include abstraction licences, discharge permits and flood defence consent from Environment Agency. The cumulative impacts of hydro or other water abstraction activities along a river will need to be assessed for their impact on the protected rights of other river users. Additionally, permissions are normally issued with time limits on the abstraction period – unless these are reasonably long the developer may have concerns over the long term viability of the plant if there is a risk of these not being renewed in the future.

5.3.2 Methodology

The technical potential for a hydropower installation is normally based on the Flow Duration Curve for a particular river stretch. This shows how the flow is distributed over a year, with the x-axis showing the percentage of time in a year that the flow exceeds the value given on the y-axis. Therefore a flatter curve indicates less annual variability in the flow of the river and better characteristics for a hydro project as it will generate a more even amount of power year round. A comparison of Flow Duration Curves for the River Wey in Guildford, the River Ouse in Bedford and the River Mole at Castle Mill in Surrey is given in Figure 55. Hydropower schemes are operational near the gauging stations where this data was obtained on the River Ouse (74 kW) and the River Mole (55 kW), but it can be seen that the Ouse demonstrates a more favourable profile i.e. indicating slightly higher flow rates for a higher percentage of the time.

Additional flow data for the River Wey is available from the Centre for Ecology & Hydrology website[25].

[25] www.ceh.ac.uk/data/nrfa/data/meanflow.html?39141

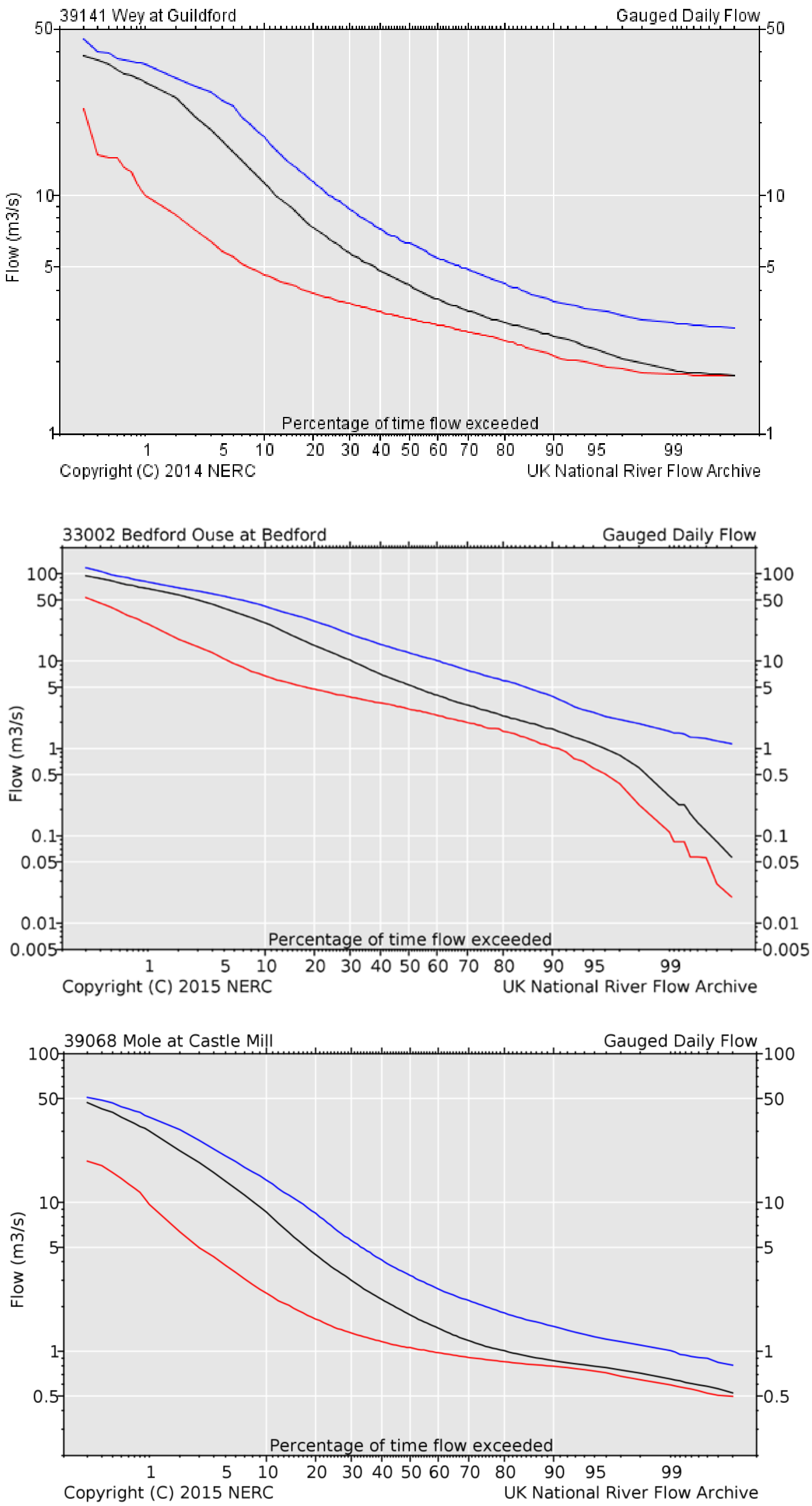


Figure 55: Comparison of Flow Duration Curves for the River Wey at Guildford, the River Ouse at Bedford and the River Mole in Surrey [Colour key: black = annual, blue = Dec-Mar, red = Jun-Sep]

A study by the Environment Agency published in 2010[26] aimed to assess and map opportunities for small-scale hydropower on rivers in England and Wales and to assess the basic environmental sensitivity associated with exploiting them. Environmental sensitivity was assessed based on three factors:

- Prevalence of diadromous species – fish which migrate between freshwater and saltwater
- Prevalence of other migratory or mobile species
- Whether the site is based in a Special Area of Conservation (SAC)

Using this data it is possible to estimate the potential resource along the River Wey within Guildford Borough and plot sites of interest on a map.

5.3.3 Findings

Table 16 shows the number of sites where hydro could be developed within Guildford Borough and the total kW capacity that this would amount to if all identified sites were to be developed.

Scale (kW)	Number of sites	Total kW
0-10	34	46.9
10-20	2	33.3
20-50	3	105.3
50-100	11	853.1
100-500	6	746
500-1,500	0	0
Total	**56**	**1,784.6**

Table 16: Sites with potential for a hydro scheme in Guildford Borough

The best sites for development of a hydro scheme are those with a high power output and low environmental impact. A further analysis of the 17 sites at the 50-500 kW scale was therefore carried out and is shown in Table 17 in order of size. It should be noted that Site 4 is the location of the current 35 kW hydro scheme at the Town Mill adjacent to Yvonne Arnaud Theatre.

Number	Name of site	Feature present at site	Potential power output at each site (kW)	Sensitivity
1	Bowers Weir	Weir	157	High
2	Papercourt Weir	Weir	130	High
3	Papercourt Lock	Lock	127	High
4	Millbrook Weir (Toll House)	Weir	118	High
5	Millmead Weir	Weir	111	High
6	Bowers Lock	Lock	103	High
7	Millmead Lock	Lock	94.6	High
8	Stoke Lock	Lock	93.8	High
9	Stoke Mill	Mill	92.9	High
10	Newark Lock	Lock	91.6	High
11	Newark Weir	Weir	79.3	High
12	Broadmead Weir	Weir	77.2	High
13	Stoke Mill House	Mill	76.2	High
14	Walsham Lock	Weir	70.6	High
15	[2nd Weir near Bowers Lock]	Weir	63.6	High
16	St Catherine's Lock	Lock	57.5	High
17	Unstead Lock	Lock	55.8	High

Table 17: The size and sensitivity of potential 50-500 kW hydro sites in Guildford Borough

All sites at this scale are in the high sensitivity band, meaning that developing a hydro scheme here would carry risks of having a high environmental impact. Further site investigations would be needed to identify the

[26] www.climate-em.org.uk/images/uploads/GEHO0310BRZH-E-E_technical_report.pdf

nature of the impacts and the extent that these could be mitigated. Figure 56 shows the location of the sites numbered 1-17.

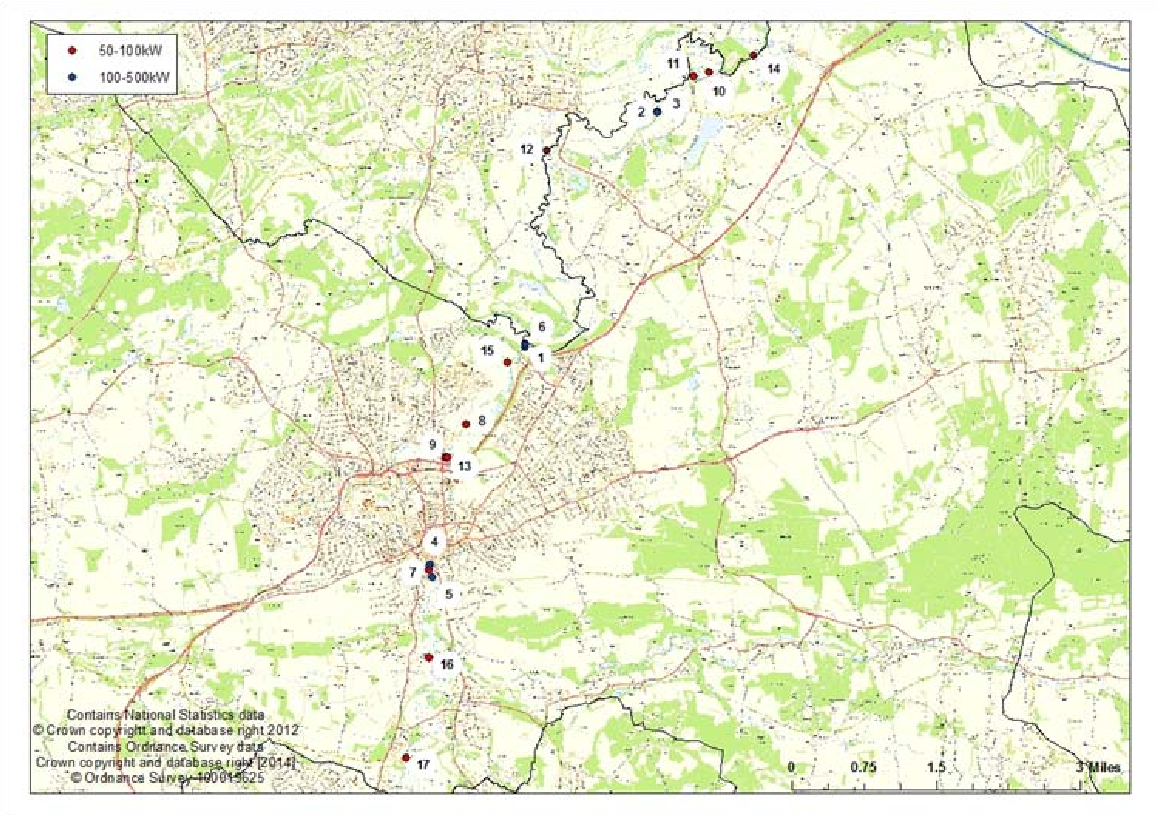


Figure 56: Locations of potential hydro sites in Guildford Borough

Looking in more depth at the three locations having the largest potential hydro capacities (sites 1-3) it was determined that these locations are:

- Site 1 – weir adjacent to Bowers Lock and the site of Bowers Mill
- Sites 2 and 3 – the lock and weir at Papercourt Lock

5.4 Water source heat pumps

5.4.1 Overview

Water source heat pumps (WSHPs) are a relatively unknown technology in the UK but have the potential to contribute significantly to national renewable heat targets and associated emissions reductions. They function in a similar way to Ground or Air Source Heat Pumps in that they extract energy from the environment and deliver it in the form of heat or cooling to buildings. This is achieved using standard refrigeration technology that can make the process more efficient and incur fewer emissions when compared with conventional heating technologies. Larger rivers or lakes can provide a good source of heat as temperatures under the surface are relatively stable at 7-12 DegC all year round.

As the name implies, WSHPs extract energy from bodies of water such as ground aquifers, rivers or lakes by using electricity to drive a heat transfer process. There are two main ways of doing this – by using a closed system, where a heat transfer fluid is circulated through a pipe which loops through the water body (i.e. the pipe acts as an intermediate stage of transferring heat between the water and the heat pump); or an open system, where the water is routed directly to the heat pump and then returned to its source. WSHP units and heat exchangers are reasonably compact compared to other low carbon heating technologies such as biomass boilers and so less space is needed in the plant room.

Technical constraints and limitations

An open system is generally more efficient but can introduce technical challenges from the risk of corrosion and fouling from abstracting water direct from the source. Closed loop systems require some form of pipework located in the water body and so the design of this should avoid impacting other users of the river or lake. WSHPs can be of particular benefit when serving heat/cooling networks, but to maximise efficiency circulation temperatures should be kept as low as possible. This will generally require low temperature heat distribution systems in buildings such as underfloor heating.

Environmental impact

Open systems will have similar environmental impacts to hydropower systems and so will fall under the same regulations and requirements where water is abstracted (see Section 0 on hydropower), but closed types may also have an effect. Any impacts of a WSHP on the status indicators of a water body as set out in the Water Framework Directive will need due consideration. Impacts on fish and wildlife are particularly important and with WSHPs any localised changes in the temperature of the water body will need to be minimised. Generally, cooler discharges are preferred and variations in the mixing zone should be limited to 2-3 DegC, so where water is abstracted it is often best to co-locate intake and outlets to help achieve this.

5.4.2 Methodology

In mid-2014 DECC released a 'high level water source heat map' of England[27] which was designed for local authorities, community groups and private developers to highlight the opportunities for deploying innovative heat pump technology at larger scale i.e. for heat networks. The methodology involved using the National Heat Map to identify sites of high heat demand which are adjacent to rivers with sufficiently high flow rates. This identified 40 urban rivers with the highest potential for WSHP deployment for heating and cooling purposes, and estimated maximum annual heat production per urban river stretch in GWh per year. However, none of these are located in the Guildford local authority area. A more detailed water source heat map is being prepared for release in 2015.

5.4.3 Findings

In the right locations, WSHPs have the potential to provide efficient low carbon heating or cooling at scale. In particular they could contribute to heat/cooling networks in urban areas, possibly in the longer term alongside other low carbon energy sources which together create a balanced energy loop serving different types and uses of buildings. Future decarbonisation of the electricity grid will increasingly benefit heat pump technologies as their overall emissions reduce. They remain however relatively unknown to most developers and the public at large and their benefits are likely to be better realised and disseminated when more have been installed and demonstrated. Two examples installations at different scale in the UK include Kingston Heights by the Thames[28], which incorporates a 2.3 MW WSHP for space and water heating of a mixed development, and Crescent Apartments by the River Trent[29], where two 25 kW WSHPs provide space and water heating to an indoor swimming pool.

The methodology employed by DECC for the water source heat map focuses on matching large urban heat loads with high flow rate rivers and, most likely due to the absence of the latter, the Guildford area was not identified in the study. Average daily flow rates for the River Wey[25] range from around 1.5-10 m^3/s with a mean flow of 5.982m^3/s. Using this flow rate and assuming an acceptable drop in river temperature of 2 degC,

[27] www.gov.uk/government/publications/water-source-heat-map
[28] www.heatpumps.org.uk/PdfFiles/HeatPumpNewsNo.15.pdf
[29] www.heatpumps.org.uk/CaseExSpecial6.html

the theoretical potential for heat generation is substantial at around 50 MW. Only a proportion of this would be used in practice however and a viable WSHP installation would be dependent on finding suitable adjacent heat loads (see Section 0). Nevertheless such a resource may justify more detailed survey work on the Wey and other water bodies in Guildford Borough to establish viability and the impact of scale for this technology.

6 Building-integrated renewable energy systems

6.1 Introduction

By 'building-integrated' we generally mean small or micro scale technologies which are incorporated into individual buildings to supply some or all of their energy demands. The technologies considered in this section include roof-mounted solar photovoltaics (PV) and solar water heating systems, biomass (woodfuel) boilers and air or ground source heat pumps. Micro-scale wind power is not included due to its limited potential within the built environment, where low average wind speeds generally make this technology unviable when compared to other generation technologies.

An assessment of the potential for building-integrated renewable energy technologies on buildings can be undertaken in a number of different ways and is dependent on numerous factors such as:

- technology type and scale
- building type, size, location and use
- future policy incentives, building regulations and national/local refurbishment programmes
- development of technologies and their environmental and economic performance

Methodologies used in estimating technology uptake vary considerably and will usually depend on whether the development is existing or forthcoming, the scale of study i.e. national, regional etc and the level of data available.

6.2 Key issues – existing development

The approach taken in assessing existing buildings within Guildford Borough is based on the total number of domestic and non-domestic buildings along with various technology-specific assumptions and the relative split between buildings with and without access to the mains gas network. The analysis draws on typical heat and electricity loads for dwellings and non-domestic buildings throughout Guildford Borough by using DECC sub-regional energy consumption statistics.[30] This basic approach serves to illustrate the 'technical' potential of each technology independently, and whilst some assumptions are inevitably subjective, the resulting outputs together with the discussion on the relevance of new development are intended to form an evidence base which prompts further debate on what stakeholders may aspire to and what may be achievable in practice. Additional views on 'deployable' capacities are also provided using data from studies which generically consider the future uptake of specific technologies across the UK on both existing and future development.

6.3 Key issues – future development

Over the next 15 years the demand for energy within Guildford Borough is expected to change. New development is likely to lead to a commensurate increase in the demand for heat and power; however it also provides an important opportunity for the integration of low carbon and renewable technologies into the existing energy system. At the same time we can anticipate an increased demand for electricity to replace gas and oil in driving low carbon heating and transport systems, with DECC projecting a significant uptake of heat pumps and electric vehicles which will use power from a progressively decarbonising grid. Understanding the extent to which these technologies might be deployed in the future can help local authorities to identify key opportunities and constraints in order that they might address them appropriately.

The potential for building-integrated technologies within future development will largely depend on how developers respond to building regulations and the relative capital costs of technologies in terms of £/tonne CO_2 avoided. Likely technology mixes are therefore very difficult to predict without detailed knowledge of the development size and energy demand profile; they are best considered on a site-specific basis when more is

[30] www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2010

known about building types and floor areas. There is also a strategic view to be taken of the likelihood that new or existing development may be served by district energy networks (see Section X), which would tend to replace building-integrated heat technologies.

Guildford Borough Council is currently in the process of updating their Local Plan. This document will set out planning policy within the local authority area and will set the strategy for how the area will develop over time. The content of the Plan will be shaped by the findings of the evidence base; those that are particularly relevant in this case include the draft West Surrey Strategic Housing Market Assessment (SHMA)[31], the Strategic Housing Land Availability Assessment (SHLAA)[32], the Employment Land Assessment[33] and the Retail and Leisure Study[34]. The Council expect the completed Local Plan to be in place by 2016. At this point in time however, the level of detail relating to the size and precise nature of proposed developments is insufficient to allow the future technical capacity for building-integrated technologies to be effectively modelled. The aim of this section therefore is to set out and discuss the key issues that may influence the changing demand for energy and the rollout of renewable technologies.

6.3.1 Housing

The SHMA is designed to provide the Council with a better understanding of housing needs within the area, and it provides guidance on the number, type and size (in terms of the number of bedrooms) of new dwellings required both in the market sector and for affordable housing. The SHLAA identifies land that may have development potential over the next 15 years and assesses when it might be developed. The following table sets out the number of dwellings required within each size category.

	1 bed	2 bed	3 bed	4+ bed
Market housing	**10%**	**30%**	**40%**	**20%**
Affordable housing	**40%**	**30%**	**25%**	**5%**

Table 18: The demand for housing across the West Surrey housing market area (this includes Guildford, Waverley and Woking borough councils), as set out in the draft West Surrey SHMA

Whilst the most recent data from the English Housing Survey[35] indicates that the Guildford area has quite a high proportion of larger dwellings at present compared to the national average, the text of the SHMA notes that there is now a real need for small (1-2 bed) and medium-sized (3 bed) dwellings.

This is also likely to have an impact on the types of renewable generation technologies that may be suitable. For example, communal or district heating schemes may become more economically viable where dwelling density is higher, whereas individual biomass boilers would be far less likely to be appropriate in high-rise flats, where the storage and delivery of fuel might be problematic. Similarly, blocks of flats are statistically more likely to have flat roof space in comparison to other dwelling types, which can make them better-suited to solar panel installations due to the lower risk of pitch and/or orientation issues. Air source heat pumps are likely to be technically feasible in the majority of modern dwellings (although it is important that clear instructions are provided to the tenants as to how best to use them), but ground source heat pumps may be more difficult and expensive to install in urban areas (such as Guildford town centre) where vertical, rather than horizontal ground loops may be necessary.

[31] www.guildford.gov.uk/shma
[32] www.guildford.gov.uk/shlaa
[33] www.guildford.gov.uk/ela
[34] www.guildford.gov.uk/retailstudy
[35] www.gov.uk/government/statistics/english-housing-survey-2012-to-2013-household-report

The main role of the SHLAA report is to identify land where housing development may be feasible over the timescale covered by the Local Plan (i.e. up until the year 2031). A draft target of 262 houses per year is included within the report, but in reality the figure may need to vary from this level considerably from year to year. It is important to note here that both the SHLAA report and the SHMA are purely technical in nature, and that further work still needs to be done to determine the viability of development on each parcel of land listed. Again, this level of uncertainty makes it difficult to usefully estimate the location and scale of future energy demand.

6.3.2 Building Regulations

The future demand for energy will also be affected by the efficiency of any newly-constructed dwellings, which will be primarily determined by the tightening of Building Regulations Part L1A in 2016 and beyond. The current government has confirmed a commitment to ensure that all new dwellings are built to a 'zero carbon' standard by 2016 (note that this relates only to regulated emissions, and not to unregulated emissions[36]), and discussions as to how this may be measured, monitored and regulated are ongoing. At the time of writing, it seems likely that the government intend to broadly follow the recommendations of the Zero Carbon Hub[37], and require each property to achieve minimum fabric standards (i.e. in line with the Fabric Energy Efficiency Standard, which is already included within the Code for Sustainable Homes criteria), along with a mandatory 'carbon compliance' standard, to provide a limit to the total carbon emissions acceptable per square metre.

Where it is not possible, or is uneconomic, to reduce demand or provide a renewable supply of energy on-site in order to reduce emissions from the carbon compliance level to meet the zero carbon standard, developers may choose to offset the remainder through 'allowable solutions'. The government consulted on the concept of allowable solutions earlier this year and released a summary of the responses in July[38], however as yet little information is known as to how this will be taken forward into formal legislation. The report did indicate that it would be likely that such a scheme would be nationally, rather than locally, managed. It is expected that non-domestic buildings will be required to meet the zero-carbon standard from 2019 onwards, although at present there is no real information available as to whether the requirements will be similar to those expected for dwellings.

Figure 57 provides an overview of how the individual instruments are expected to fit together towards the achievement of the zero carbon standard.

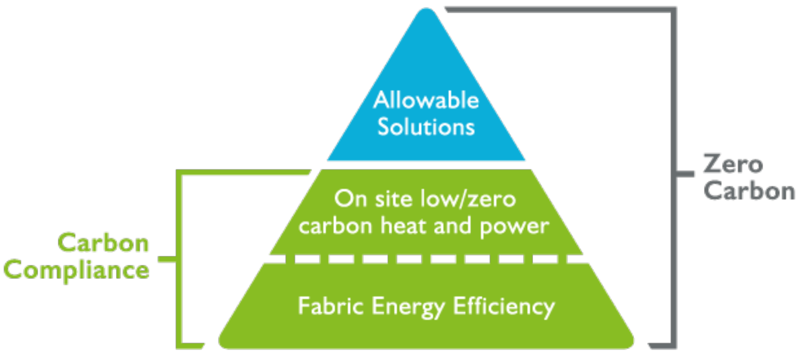


Figure 57: Zero carbon hierarchy of proposed instruments

[36] Regulated emissions are those resulting from space and water heating, fixed lighting and ventilation; unregulated emissions are those from all other sources including appliances.
[37] www.zerocarbonhub.org/zero-carbon-policy/allowable-solutions
[38] www.gov.uk/government/uploads/system/uploads/attachment_data/file/327842/140626_Government_Response_to_Consultation_-_Next_Steps_to_Zero_Carbon_H__FINAL.pdf

6.3.3 Non-domestic development

Calculating an estimate for the demand for heat and power from non-domestic buildings in the future is again difficult in this case due to the lack of detailed information available at this point in time. The Draft Local Plan for the Guildford Borough contains a list of sites that have been identified as possibly appropriate for new development throughout the period up until 2031, and it is possible to obtain the footprint area (in m^2) of each of these sites from the associated GIS files. Very broad usage categories have been assigned to each parcel of land, the majority of which are defined in line with the classification system set out in the Town and Country Planning (Use Classes) Order 1987 (as amended). However, although a specific number of dwellings have been estimated for each of these sites, no predicted floor areas are provided and no split of any kind has been estimated between the non-domestic usage classes.

Estimating an 'average' dwelling size or footprint area is particularly difficult given that the proposed breakdown of housing types/sizes differs from the breakdown of existing dwellings in Guildford and nationally (i.e. it is expected that a greater proportion of dwellings will be flats rather than houses, therefore it is logical to assume that the 'average' floor area will be comparatively small, and similarly the garden footprint area is also likely to be lower than the national average). This means that it is not straightforward to separate the domestic footprint area from the non-domestic footprint area in this way. In addition, the standard non-domestic usage categories are misaligned with the available energy and cost benchmarking categories to the extent that attempting to create aggregate benchmarks renders them effectively meaningless.

Amongst other factors, the usage type, size, and precise location of a non-domestic building will determine the type of renewable technology that might be appropriate in each case. This is particularly true where the building is being considered as an anchor load for a district heating system. For example, a building such as a leisure centre or a hotel is far more likely to provide a consistent, stable and predictable demand for heat than a large but poorly-heated industrial warehouse. As with blocks of flats, non-domestic buildings are often built with flat roofs, which can mean that they may be more likely to be suitable for solar PV and/or solar thermal panels. Biomass boilers may be appropriate where there is sufficient demand for heat and space for fuel storage and delivery on-site, and where the fuel can be locally and sustainably sourced.

6.3.4 The cost of installing future renewable and low carbon heat technologies

The cost of installing different renewable technologies will have a large impact on the way in which developers choose to meet their energy and carbon reduction targets. A consortium led by the Sweett Group was commissioned by the Department for Energy and Climate Change (DECC) in 2013 to undertake a study to look at the costs and performances of a range of technology types for both renewable heating and cooling now and into the future[39]. The project looked primarily at capital rather than operational costs, and involved the collection and analysis of empirical, disaggregated data from industry practitioners throughout the supply chain (i.e. manufacturers, suppliers and installers). The table below provides a summary of the cost data collected in terms of pounds per kilowatt for each of the technologies reviewed within the report.

[39] **'Research on the costs and performance of heating and cooling technologies' DECC/Sweett, Feb 2013**

Technology	Capacity (kW)					
	0 - 5	5 - 10	10 - 20	20 - 50	50 - 100	>100
Air to air heat pump	-	£1,138	£584	£1,415	-	-
Air to water heat pump	£1,380	£1,187	£556	£1,963	£1,240	£513
Biomass	-	-	£945	£568	£383	£208
Ground source heat pump	-	£2,403	£1,980	£1,652	£1,172	£1,719
Solar thermal	£2,060	£1,199	£1,025	-	-	-

Table 19: Summary of cost per kW for different technologies investigated

It is highly likely that the costs and performance of each of these technologies will change over time as their markets expand. Both economies of scale and industry learning and innovation are expected to result in reductions in the cost per unit of performance output, but the extent of these changes is likely to depend on a number of factors. For example, market dynamics in relatively immature markets can lead to short term price fluctuations, the projected growth in the market for a particular technology can provide an increase in the number of opportunities for economies of scale and learning, and external factors such as exchange rates, overseas competition and energy prices can also have an impact. Additionally, the report assumes that the costs of each technology will be subject to a 'learning rate', whereby the amount of cost reduction is proportional to the increase in market size.

The following chart is taken from the Sweett report, and provides an indication of how future costs may reduce from their current level over time assuming a 'medium' learning rate. The figure indicates that the biggest proportional reduction in cost is likely to be seen within the biomass CHP and solar thermal technology categories, with biomass boilers (without CHP) and heat pumps seeing less of an improvement. The report also provides examples of the impact of 'high' and 'low' learning rates.

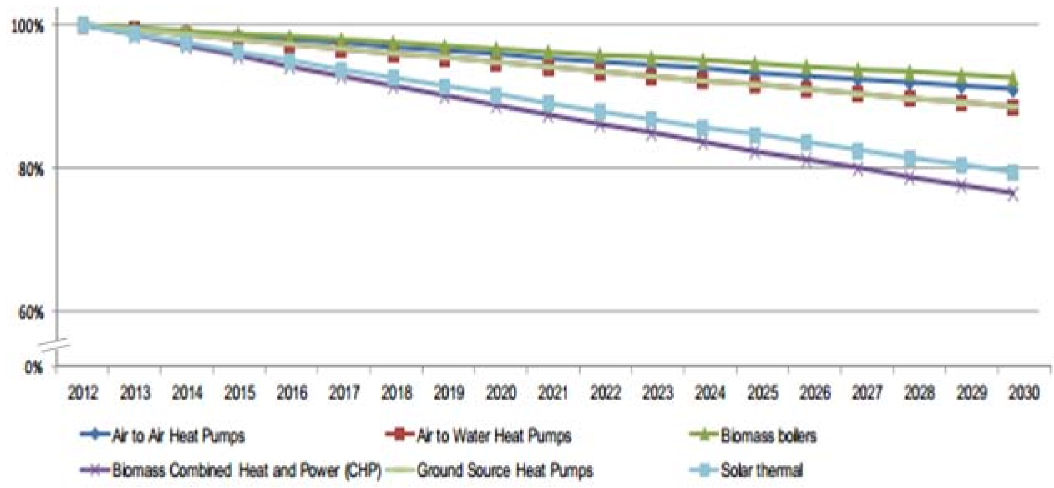


Figure 58: Projection of estimated cost reduction to 2030 assuming 'medium' learning rates (taken from 'Research on the costs and performance of heating and cooling technologies' DECC/Sweett, Feb 2013)

6.4 Roof-mounted solar PV and solar water heating

6.4.1 Overview

Both solar PV and solar water heating are well-established technologies in the UK with uptake being significantly boosted since the recent introduction of the Feed-in Tariff and Renewable Heat Incentive schemes. Guildford Borough for example saw over 3.9 MW of solar PV capacity installed between April 2010 (launch of the Feed-in Tariff) and September 2014, with 3.3 MW of this deployed on dwellings.[7]

The ideal application for roof-mounted solar generation systems is on unshaded south facing roofs angled at 37 degrees to the horizontal; taken as an average for the UK this represents the optimum orientation for solar energy capture. In general, however roofs with minimal shading which face south west through to south east with a pitch of 20-60 degrees will have the best chance of being viable. Figure 59 illustrates the proportional drop in energy capture at sub-optimal configurations.

TILT degrees			West							South						East			
											-	-	-	-	-	-	-	-	-
	90	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80	90
0	87	88	90	91	92	92	93	93	93	93	93	93	92	92	91	90	89	87	86
10	84	87	90	92	94	95	95	96	96	97	97	96	95	94	93	91	89	87	84
20	82	85	90	93	94	96	97	98	99	99	98	97	96	95	93	91	88	84	81
30	78	83	87	91	93	96	97	98	99	100	98	97	96	95	93	89	85	81	78
40	75	79	84	87	92	94	95	96	96	96	96	95	94	92	90	86	82	77	72
50	70	74	79	83	87	90	91	93	94	94	94	93	91	88	83	80	76	73	70
60	65	69	73	77	80	83	86	87	87	87	88	87	85	82	78	74	71	67	63
70	59	63	66	70	72	75	78	79	79	79	79	79	78	75	72	68	64	61	56
80	50	56	60	64	66	68	69	70	71	72	72	71	70	67	66	60	57	54	50
90	41	49	54	58	59	60	61	61	63	65	65	63	62	59	60	52	50	47	44

Figure 59: Efficiency map for solar PV systems as a function of tilt and orientation (courtesy of Solar Trade Association)

Flats and non-domestic properties often have flat roofs and so orientation is not critical, although systems will then need tilted frames to house the solar array. These need to be suitably spaced in rows to avoid self-shading issues. For pitched roofs, solar PV generally needs around 8m^2 of roofspace per kW for high efficiency panels (e.g. monocyrstalline silicon) and grid-connected systems are able to export power if there is insufficient load in the property at any one time. The size of solar water heating systems however is more limited by the hot water demand of the property they are serving, with domestic systems typically requiring 1.5m^2 of roofspace per resident. Properties also need to have sufficient space to accommodate a hot water tank.

Standard installations of solar panels are considered to be 'permitted development' and therefore do not normally require planning consent. However, installations on listed buildings or on buildings in designated areas are restricted in certain situations and may require planning consent.

6.4.2 Technical potential for existing development

The theoretical potential for solar technologies is very large considering the number of roofs that could support them. For the purposes of this study a high level assessment has been undertaken which considers types and numbers of buildings across Guildford Borough and typical system sizes. For solar water heating, take-up in buildings located in off-gas areas is assumed to be higher due to the increased benefits of displacing higher cost heating fuels such as electricity and oil. Numbers of 'off-gas' buildings were estimated by identifying numbers of buildings lacking a gas meter, which is assumed to be a reasonable proxy. The proportion of roofs which may be most suitable within each building category and the subsequent potential for each technology was then estimated by applying the following assumptions:

Solar PV assumptions	Solar water heating assumptions
• 25% of dwellings • 40% of small/medium commercial premises • 80% of industrial/large commercial premises • 10% Capacity Factor • Emissions factor for mains electricity assumed to be 0.45kgCO_2/kWh	• 25% of off-gas dwellings • 10% of on-gas dwellings • 10% of off-gas non-domestic premises • 5% of on-gas non-domestic premises • 13% Capacity Factor • Assumed that domestic off-gas properties would displace mains electricity (emissions factor 0.45kgCO_2/kWh) and non-domestic properties would displace oil (emissions factor 0.25 kgCO_2/kWh)

Table 20: Assumptions for the technical potential of solar technologies

The assumed capacities of the combined systems were then calculated to get a total installed capacity. The results were then compared to the methodology employed by Bristol City Council for a solar mapping project undertaken in 2012[40]. This involved detailed GIS modelling of the city's roofscape along with corroboration of the results with a large sample group of buildings on which bespoke installer surveys were carried out.

Table 21 and Table 22 show the potential installed capacities, energy yields and savings for solar PV and solar water heating across Guildford Borough according to the assumptions set out above. As a rough cross-check, application of the statistical findings of the Bristol solar PV study results in an upper and lower capacity of 49.6 MW and 24.8 MW respectively for solar PV.

Assessment of Solar PV					
Building category	Total no. of buildings	Typical system size per property (kW)	Total potential capacity (MW)	Electricity output (MWh/year)	Potential CO_2 savings (tonnes/yr)
Domestic - flats	8,601	0.5	1.08	942	424
Domestic - small terraced	3,266	1	0.82	715	322
Domestic – other housing	42,133	2	21.07	18,454	8,304
Small/medium commercial	4,729	5	9.46	8,285	3,728
Industrial/large commercial	263	10	2.10	1,843	829
		Totals	**34.5**	**30,240**	**13,608**

Table 21: Solar PV potential in Guildford Borough

Assessment of solar water heating						
Building category	Total no. of buildings	Approx. no. of off-gas buildings	Typical system size per property (kW)	Total potential capacity (MW)	Heat output (MWh/year)	Potential CO_2 savings (tonnes/yr)
Domestic (excl. flats)	48,336	7,684	2	12.0	13,546	3,400
Non-domestic	4,643	531	5	1.29	1,464	278
			Totals	**9.20**	**10,410**	**2,842**

Table 22: Solar Water Heating potential in Guildford Borough

[40] www.bristol.gov.uk/page/environment/solar-energy : see 'Bristol Sunshine: An Analysis of Rooftop Solar Mapping'. The formulas stated on P17 were used as an approximate comparison.

6.4.3 Scenarios for deployment

Solar PV and solar water heating are both proven and effective technologies which can be roof-integrated i.e. designed to form part of the roof itself and therefore can offset some of the cost of conventional roofing materials. Additionally, solar PV may be particularly attractive to developers in helping to meet emissions standards through offsetting mains electricity which currently carries a high carbon content compared to other fuels. With substantial price reductions since 2010 and a large range of PV materials to choose from, including semi-transparent panels, tiles and shingles, solar PV is now a mainstream technology which is expected to reach grid parity (generate power at or below the cost of mains power) in the short to medium term and is therefore very likely to feature in the large majority of new developments.

To estimate future uptake of solar PV, a recent study for the Energy Networks Association on behalf of the Smart Grids Forum[41] was reviewed. The study developed a comprehensive model to evaluate investment options in tackling the future challenges on the electricity grid of switching to a low carbon economy. Part of this work required modelling the uptake of low carbon technologies under low, medium and high scenarios. Annual growth rates used in the study for solar PV were applied to an assumed 2014 baseline capacity in Guildford Borough, taken to be 3.9 MW as discussed in Section 6.4.1[42]. The resulting projection of installed capacity up to 2021 is shown in Figure 60 for each scenario.

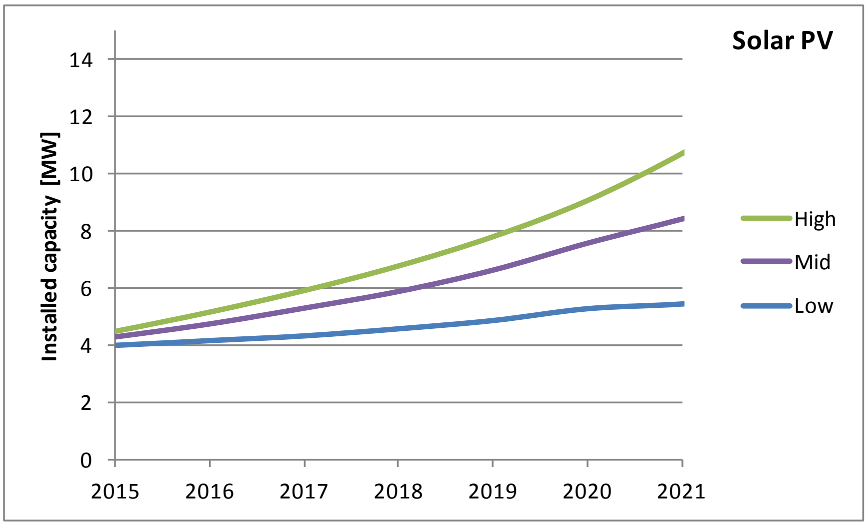


Figure 60: Estimated projection of installed capacity for solar PV across Guildford Borough (using growth rates from Smart Grid Forum study 2012)

To estimate future uptake of solar water heating, a different data source was reviewed – the Domestic RHI Impact Assessment study[43]. This takes a similar approach to the Smart Grid Forum study and models three uptake scenarios for renewable heat technologies. The equivalent impact assessment for the non-domestic RHI however does not include comparable uptake scenarios and so is not considered. Modelled UK uptake rates up to 2021 for domestic solar water heating in terms of number of installations per year were applied pro rata to Guildford Borough on household numbers.

Figure 61 indicates the resulting number of installations under each scenario.

[41] DECC/Ofgem Smart Grid Forum (2012): Assessing the impact of low carbon technologies on Great Britain's power distribution networks
[42] This figure is likely to be an underestimation as it does not include solar PV installed prior to the introduction of the Feed-in Tariff
[43] www.gov.uk/government/uploads/system/uploads/attachment_data/file/211978/Domestic_RHI_Impact_Assessment.pdf

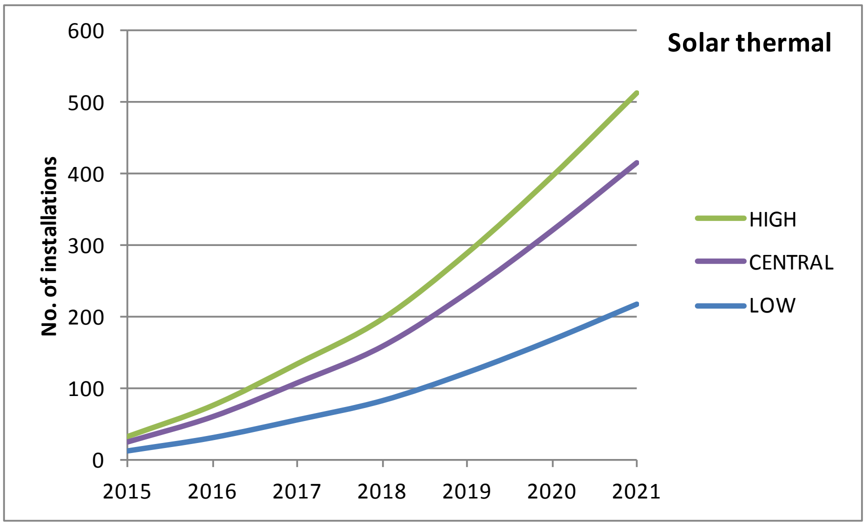


Figure 61: Estimated projection of domestic installed capacity for solar water heating across Guildford Borough (using growth rates from Domestic RHI Impact Assessment 2013). Figures do not include any pre-RHI installations.

6.5 Biomass (woodfuel) boilers

6.5.1 Overview

As with other renewable heating technologies, the use of sustainable woodfuel has recently been boosted by the introduction of the Renewable Heat Incentive scheme which has served to stimulate demand and as a consequence has enabled local woodfuel supply chains to better service local markets. When locally produced and consumed, woodfuel can be a sustainable low carbon energy source that has additional economic benefits for the community.

Woodfuel is produced from a number of sources including woodlands, arboricultural activities, recycled wood waste and woody energy crops e.g. short rotation coppice. A critical factor however is quality, as woodfuel 'feedstocks' generally need to be processed into usable forms of woodfuel such as logs, woodchip or pellets which have specific properties concerning moisture content, size and composition. Woodfuel quality specifications need to be matched to the requirements of the boiler in which the woodfuel will be burnt.

Woodfuel boiler technology is now fully scalable and can range from household pellet stoves up to large scale biomass power plants or combined heat and power units serving district heating networks. Boilers are generally larger than conventional gas or oil boilers and require additional space for woodfuel storage along with adequate access for its delivery. Hot water storage (buffer) tanks are often specified with woodfuel boilers to help optimise boiler operation. A boiler flue is also needed which will need to comply with building regulations. Restrictions on the type of fuels used may be in force where the plant is located in Smoke Control Areas or Air Quality Management Areas (AQMAs). Guildford Borough does not currently contain any AQMAs but has defined Smoke Control Areas on a street-by-street basis[44] and so the risks of smoke nuisance should be assessed.

The number of existing woodfuel boilers in Guildford is not known, but RHI statistics[45] indicate that there were a total of 49 domestic RHI accreditations and up to 5 non-domestic accreditations in the Borough between Nov 2011 and Oct 2014. For context, the average proportion of national RHI accreditations was around 23% for biomass systems during 2014.

[44] http://www.guildford.gov.uk/article/1734/Smoke-control-area
[45] https://www.gov.uk/government/statistics/rhi-and-rhpp-deployment-data-october-2014

6.5.2 Technical potential for existing development

The assumptions used below are based on total numbers of domestic and non-domestic buildings in the Borough and that uptake of biomass heating is likely to be much greater in areas that are off the mains gas grid.

Biomass (woodfuel) boiler assumptions

- 75% of off-gas dwellings
- 5% of on-gas dwellings
- 75% of off-gas non-domestic premises
- 5% of on-gas premises
- Domestic boiler capacity factor assumed to be 23%
- Seasonal efficiency of woodfuel boiler assumed to be 90%
- Non-domestic boiler capacity factor assumed to be 18%
- Emissions factor for mains electricity assumed to be 0.45kgCO_2/kWh
- Emissions factor for woodfuel assumed to be 0.025kgCO_2/kWh
- Assumed that 76% of suitable domestic off-gas properties would displace mains electricity (emissions factor 0.45kgCO_2/kWh) and 24% of suitable domestic off-gas properties would displace oil (emissions factor 0.25 kgCO_2/kWh) as their main heating fuel.
- Assumed that all suitable non-domestic off-gas premises would displace oil (emissions factor 0.25 kgCO_2/kWh)
- Assumed that all suitable on-gas buildings would displace mains gas (emissions factor 0.2055 kgCO_2/kWh)

Table 23: Assumptions for the technical potential of biomass (woodfuel) boilers

Table 24 shows the potential installed capacities, energy yields and savings for woodfuel boilers across Guildford Borough according to the assumptions set out above.

Building category	Total no. of buildings	Approx. no. of off-gas buildings	Typical system size per property (kW)	Total potential capacity (MW)	Heat output (MWh/year)	Potential CO_2 savings (tonnes/yr)	Approx. woodfuel requirement (tonnes/yr)
Domestic	57,493	9,140	18	167	128,131	41,448	27,379
Non-domestic	4,643	531	100	60	160,576	25,708	34,311
			Totals	**227**	**288,708**	**67,156**	**61,690**

Table 24: Biomass (woodfuel) boiler potential in Guildford Borough

6.5.3 Scenarios for deployment

To estimate future uptake of biomass boilers the Domestic RHI Impact Assessment study was again considered. Modelled UK uptake rates up to 2021 for domestic biomass boilers in terms of number of installations per year were applied pro rata to Guildford Borough on household numbers.
Figure 62 indicates the resulting number of installations under each scenario.

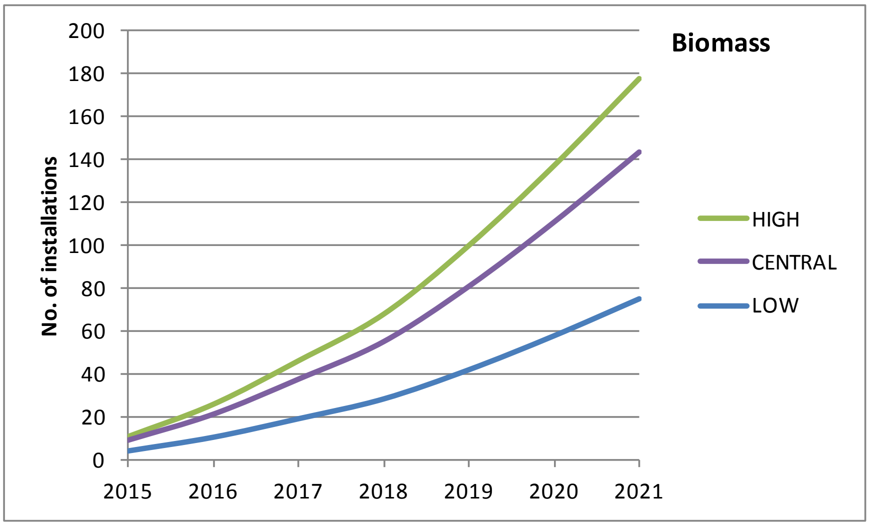


Figure 62: Estimated projection of domestic installed capacity for biomass boilers across Guildford Borough (using growth rates from Domestic RHI Impact Assessment 2013). Figures do not include any pre-RHI installations.

6.6 Ground and air source heat pumps

6.6.1 Overview

Ground and air source heat pumps operate by using electricity to drive a standard refrigeration process to heat or cool buildings. Overall efficiency is sufficiently high in well-designed systems to make the technology a viable low carbon alternative to conventional heating or cooling systems. In the long term, they are expected to become significantly more widespread as their environmental performance increases in line with the gradual decarbonisation of UK grid electricity.

Space requirements for heat pumps vary according to type; ground source heat pumps require space for bore holes or a larger area for trenching refrigerant pipes, whereas air source heat pumps are physically similar to standard air conditioning units. This can mean that ground source systems are more constrained for use in retrofit projects in built up areas where space is limited. The ground conditions and presence of groundwater can also impact their performance and design in a given location.

Heat pumps work best when coupled with low temperature heat distribution systems and therefore require properties to be well insulated in order for them to operate efficiently. They are often well-suited to new developments with high thermal insulation standards, but upgrades may need to be carried out on retrofit projects before heat pumps are considered a viable option.

Both ground and air source heat pumps are considered to be permitted development and therefore most installations can take place without the need for a planning application. Air source heat pumps however are subject to additional restrictions due to issues of visibility and potential noise disturbance.

6.6.2 Potential for existing development

As with the other renewable heat technologies considered above, an assessment of heat pump deployment potential assumes the majority of up-take to be in off-gas areas of the Borough. Technically the large majority of buildings could have either a ground or air source heat pump and so the theoretical resource is very large. For simplicity, both types of heat pump are considered together i.e. where space requirements limit the deployment of ground source heat pumps it is assumed that air source heat pumps would be an alternative option.

Heat pump assumptions
• 75% of off-gas dwellings • 5% of on-gas dwellings • 95% of domestic heating load met • 75% of off-gas non-domestic premises • 5% of on-gas premises • 50% of non-domestic heating load met • Heat pump Co-efficient of Performance 2.5

Table 25: Assumptions for technical potential of heat pumps

Table 26 shows the potential installed capacities, heat output and savings for heat pumps across Guildford Borough according to the assumptions set out above.

Building category	Total no. of buildings	Approx. no. of off-gas buildings	Typical system size per property (kW)	Total potential capacity (MW)	Heat output (MWh/year)	Potential CO_2 savings (tonnes/yr)
Domestic	57,493	9,140	9	63	91,729	14,167
Non-domestic	4,643	531	100	60	80,288	4,404
			Totals	**123**	**172,017**	**18,571**

Table 26: Heat pump potential in Guildford Borough

6.6.3 Scenarios for deployment

To estimate the future uptake of heat pumps the Domestic RHI Impact Assessment study was again considered. Modelled UK uptake rates up to 2021 for both air source and ground source domestic heat pumps in terms of number of installations per year were applied pro rata to Guildford Borough on household numbers. Figure 63 and Figure 64 indicate the resulting number of installations under each scenario.

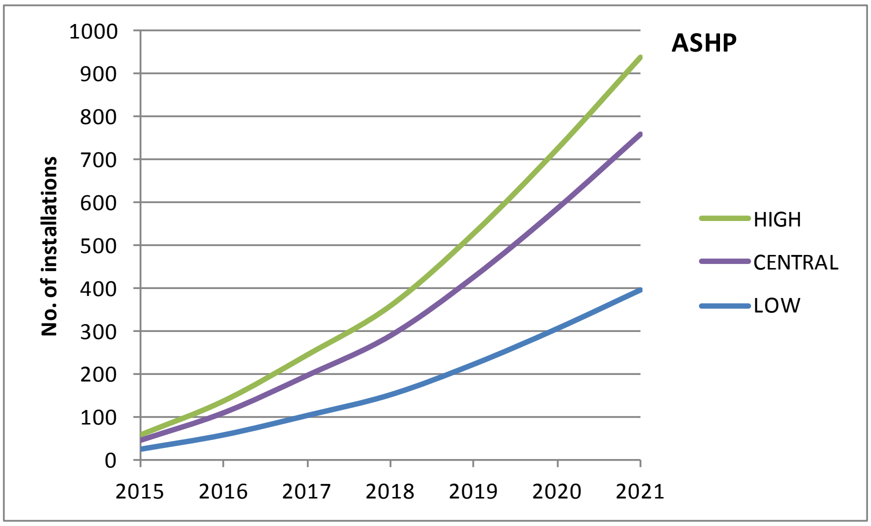


Figure 63: Estimated projection of domestic installed capacity for air source heat pumps across Guildford Borough (using growth rates from Domestic RHI Impact Assessment 2013). Figures do not include any pre-RHI installations.

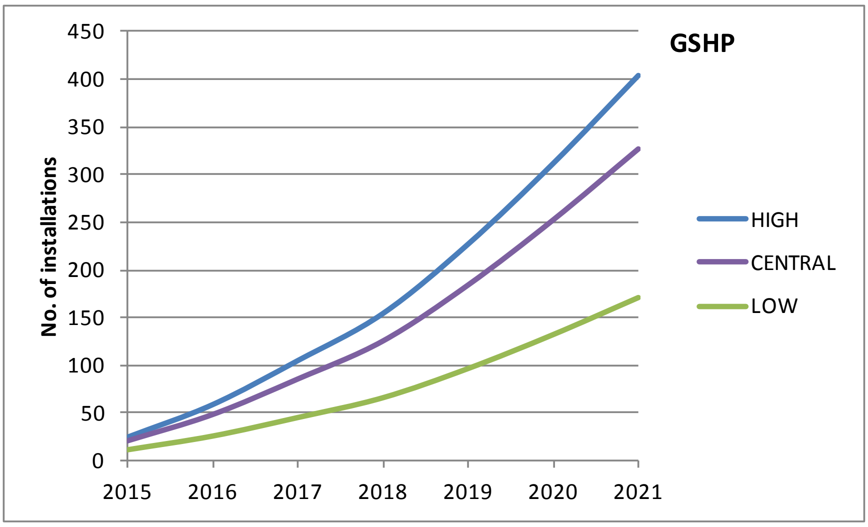


Figure 64: Estimated projection of domestic installed capacity for ground source heat pumps across Guildford Borough (using growth rates from Domestic RHI Impact Assessment 2013). Figures do not include any pre-RHI installations.

7 Summary and conclusions

7.1 Heat mapping

Analysis of the National Heat Map has identified areas with the highest spatial heat densities and point loads across Guildford Borough including both residential and non-residential buildings. Further 'overlay' modelling has identified specific locations which may have increased potential for district heating by applying a set of criteria which considers co-location of areas with the highest heat densities, large residential heat loads and anchor loads (anchor loads are likely to have relatively high and stable heat demands and/or be in sectors more likely to participate in heat distribution projects). The analysis identified eight locations that met the overlay criteria and which were then considered in more detail. Of these, three areas were thought worthy of more detailed study:

- Central Guildford
- Royal Surrey County Hospital and surrounding area
- University of Surrey's Stag Hill Campus and adjacent industrial estates

These areas could be considered as heat 'priority areas' which are likely to have the most potential for viable district heating networks. Potential future development sites, as identified in the draft Local Plan 2014, have also been overlaid to assess their proximity to existing heat loads, as new developments may sometimes act as a trigger for district heating projects which can then be designed to also serve adjacent buildings. Although a lack of data on heat load profiles for the new development sites has limited the extent to which these future heat loads can be assessed, the mapping identifies areas where significant existing and future heat loads are co-located.

This high level analysis provides a starting point for identifying areas with the greatest potential for district heating systems and can be used by planners and other stakeholders early on in the sustainable energy masterplanning process to assess strategically important developments sites. It can help to trigger timely and more in-depth feasibility studies once more detailed data becomes available for clusters of existing or future buildings previously identified within heat priority areas.

7.2 Large stand alone renewable energy generators

Onshore wind power and solar PV farms

The analysis shows that whilst opportunities for medium and large scale wind are somewhat limited within Guildford Borough, there are small areas in which wind development at this scale has potential. The technical resource for large scale wind is estimated to be 105 MW, equivalent to 42 large scale turbines which have the potential to annually generate electricity equal to 39% of the Borough's 2012 electricity consumption. The gross technical resource for Solar PV farms is potentially much larger as site specific requirements are less restrictive but this has been reduced by 90% due to the likelihood of competing land use e.g. crops. The resulting resource is estimated to be 436 MW which could potentially equate to 60% of the Borough's 2012 electricity consumption.

However, both these 'technical' resource figures reduce significantly if designated areas such as AONB, SPA, SSSI, AGLV and Greenbelt are introduced as planning constraints. For example, if all designations are treated as exclusion areas for these technologies, the net resource reduces to zero and 7 MW for large/medium scale wind and solar PV farms respectively – see Figure 65 below.

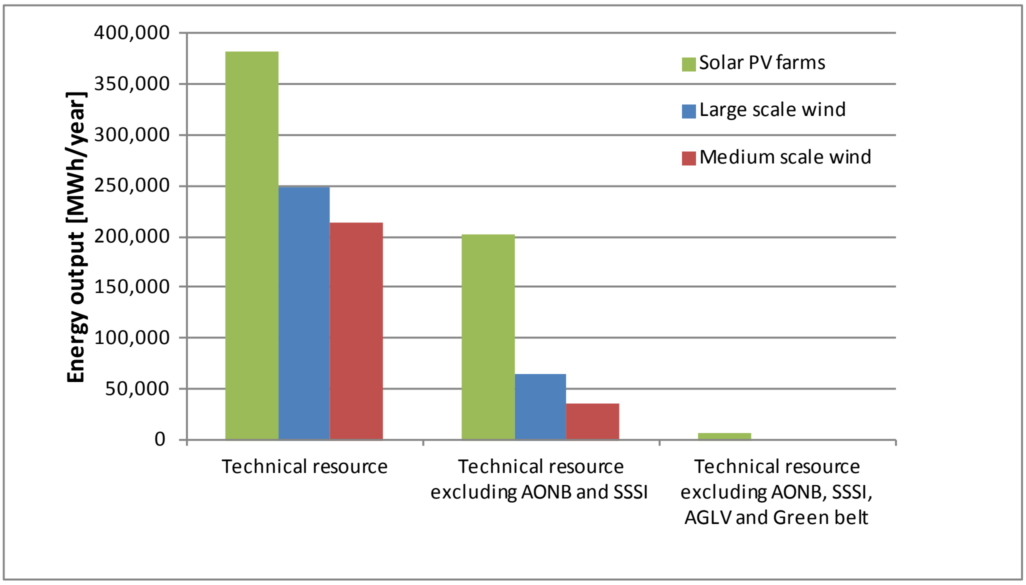


Figure 65: Estimated technical resource for wind and solar PV farms in Guildford Borough with various levels of potential constraints

It is important to note that wind power or solar PV farms are not automatically excluded from these designated areas by the planning system, but that certain designations may carry more weight than others meaning that the impact of the technologies will differ across the areas. The land designations considered each have their own set of criteria on what makes an area worthy of designation and justification is set out when each specific area is assessed by the designating body. Proposals within each location should be considered on a case-by-case basis and should be site-specific. The analysis therefore simply aims to identify areas where planning constraints are least likely to impact deployment of these technologies.

The results suggest that deploying larger scale wind power either now or in the future is likely to impact on landscape character and openness. Should Guildford wish to consider deploying such infrastructure, the significance of this impact, which would in part be dependent upon the designations in place at the chosen location, would need to be weighed against the benefits of long term local sustainable energy generation. Although the analysis also indicates that solar PV farms may offer more potential in terms of energy generation, deployment of a more significant amount of this technology may require similar concessions. It should be noted however that any change in land use from the deployment of either wind or solar PV is not permanent. Indeed, the installation of wind and solar PV systems for a period of 25 years, with easy restoration to the original land use state, might be seen by some authorities as a way of preserving the existing land use for future generations in the mid to long term.

Hydro power and water source heat pumps

In addition to the existing 35 kW scheme at the Town Mill adjacent to Yvonne Arnaud Theatre, the River Wey's course through Guildford Borough offers a number of opportunities for hydro generation as demonstrated by a 2010 Environment Agency report on opportunities for small scale hydro power on rivers in England and Wales. A total of 56 sites were identified having a combined capacity of 1.8 MW, with 17 of these estimated to be in the 50-500 kW range. The locations having the largest potential hydro generation capacities were found to be at Bowers Lock and Papercourt Lock.

Less is known about the potential for water source heat pumps. In the right locations, they have been shown to have the potential to provide efficient low carbon heating or cooling at scale as long as the buildings to be served are in close vicinity; as demonstrated by the Kingston Heights installation by the Thames, which incorporates a 2.3 MW water source heat pump for space and water heating of a mixed development. Future decarbonisation of the electricity grid will increasingly benefit heat pump technologies as their overall emissions reduce. Although no potential sites were identified within Guildford in the 2014 DECC water source heat map, this focused on matching large urban heat loads with high flow rivers, a combination which Guildford would appear to lack. However, the technical potential for heat generation on a river the size of the Wey is substantial at around 50 MW and may justify more detailed survey work to establish viability and the impact of scale for this technology.

7.3 Building-integrated renewable energy systems

This section has attempted to estimate the potential for building-integrated renewable energy technologies across Guildford Borough. A technical assessment has first evaluated the potential by making broad assumptions on the proportions of buildings that may be more likely to adopt the technologies; this has been done independently for each technology and has not considered an overall technology mix. The results are intended to form an evidence base of the gross potential on which further assumptions can be made on scenarios for deployment. The modelling of the deployment of renewables within potential future development has been limited by a lack of detail on types, sizes and mixes of new development sites. Low and zero carbon energy opportunities at major sites, including the new strategic employment sites referred to in Guildford's draft Local Plan should be considered at the masterplanning stage once more detail is known on characteristics such as floor area of each development type and site layout.

An estimation of deployable potential for Guildford has been made using proportional data taken from other national studies on likely uptake rates for each technology. The data however comes from different sources, is in different formats and its application here is therefore currently limited to the domestic sector. It does however generally consider installations on both existing and new development. Figure 66 summarises the technical potential developed in the analysis and a scenario for deployment using 'mid-scenario' uptake rates for the domestic sector.

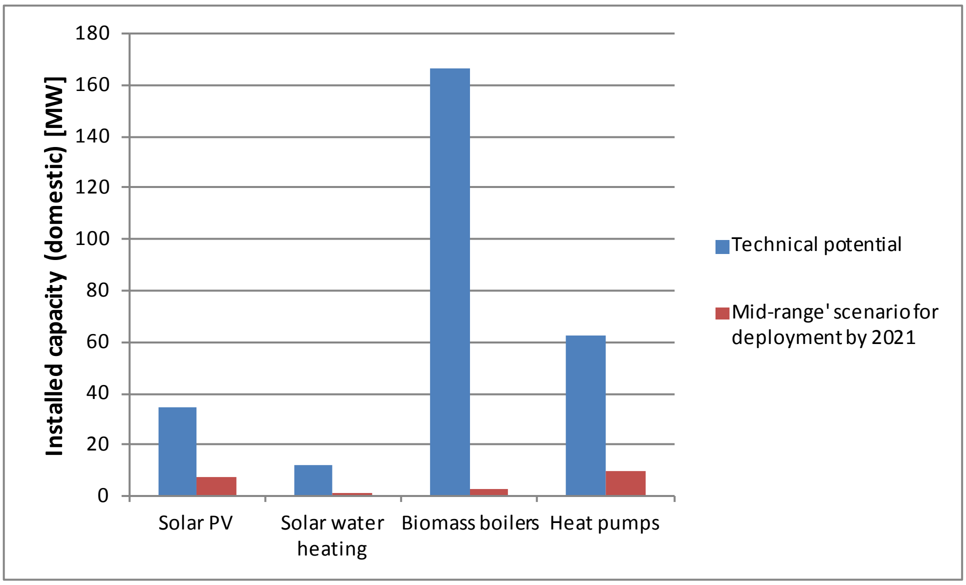


Figure 66: Comparison of technical resource and 2021 deployable potential for domestic installed capacity within Guildford Borough

Clearly the technical potential as expected is considerably higher than the deployable potential for each technology. Theoretically the full potential for solar and heat pump technologies is only constrained by the number of buildings where they can physically be installed and deliver adequate performance; the technical potential assessed in the analysis therefore makes an attempt to allow for some broad constraints without the need for detailed modelling. Biomass boilers however will be constrained by the availability of woodfuel which should ideally be locally obtained, and potentially by Guildford's Smoke Control Areas which only permit authorised fuels or exempt appliances. The scenarios for deployment shown should be considered as estimates only as a high number of uncertainties are apparent both in the source modelling and in the application of uptake rates to Guildford's building stock. However the modelling does illustrate the types of building-integrated technologies that Guildford can seek to encourage and strategically plan for as part of its overall approach towards achieving a low carbon, more sustainable and more secure range of local energy supplies.