Annex B:

Appendix A: Renewable energy resource and opportunity assessment

Contents

Enhanced energy efficiency standards

Introduction

This chapter sets out the policy context and key issues associated with setting enhanced energy performance standards within the Local Plan.

National minimum standards for energy use and emissions within new developments are set by Part L1A and Part L2A of the Building Regulations, which concern the conservation of fuel and power in new dwellings and new buildings other than dwellings respectively. The current regulations came into operation in 2010 but were re-issued in 2013 and amended in 2016. The regulations apply a cap to a building's emissions through the use of a nominal Target Emissions Rate (TER) measured in $kgCO_2/m^2/year$, which must not be exceeded by the Dwelling Emissions Rate (DER) as calculated according to the Standard Assessment Procedure (SAP) methodology, or the Building Emission Rate (BER) for non-domestic buildings, as calculated using the Simplified Building Energy Model (SBEM).

In October 2019 the Government launched a consultation on the next revision of the Building Regulations and proposed a new 'Future Homes Standard' with the message that "We must ensure that new homes are future-proofed to facilitate the installation of low-carbon heat, avoiding the need to be retrofitted later, and that home builders and supply chains are in a position to build to the Future Homes Standard by 2025". A summary of consultation responses along with the Government's response was published in January 2021.

The consultation response document confirms the Government's intention for homes to be zero-carbon ready by 2025 (a commitment that has been re-stated in the Government's Heat and Building Strategy, published in October this year), with new homes being built to high efficiency standards and without fossil fuel-based heating systems. An interim 2021 uplift is to be introduced, which would require a 31% reduction in carbon from new dwellings, compared to current standards. A package of performance standards is expected to be introduced, which includes:

- a primary energy target,
- CO_2 emission target,
- fabric energy efficiency target,
- minimum standards for fabric and fixed building services.

The document states that a full technical specification for the Future Homes Standard will be consulted on in 2023, with the legislation introduced in 2024 and implemented in 2025. Despite a previous proposal to remove the discretion of local authorities to impose enhanced standards beyond those set by Building Regulations, the Government confirmed that they would not amend the Planning and Energy Act 2008 in the immediate term, but stated an intention to clarify Local Planning Authorities' role in setting energy efficiency requirements for new homes in the future. The situation therefore remains that local authorities have powers to stipulate energy performance standards that exceed the Building Regulations.

A second, separate consultation looking at proposals for a Future Buildings Standard for non-domestic properties, as well as proposals for overheating mitigation, ventilation (Part F) and fabric efficiency of domestic buildings, ran in early 2021, but a summary of responses has not yet been published. The timeframe for policy implementation is expected to align with the Future Homes Standard and also be introduced in 2025 with an interim uplift. The Governments preferred option is for the interim uplift to deliver a 27% reduction in carbon emissions on average per building compared to the existing Part L standard.

Net Zero Emissions in new development

- Where local authorities have followed the process of carbon auditing their plans as set out in the NPPF and PPG, they have generally concluded that it would be very difficult to achieve the required carbon reduction trajectory without new developments being built to a zero-carbon standard, due to the additional emissions growth inherent in new development commitments. This will require ambitious planning policies for new development which also ensure building energy performance is future-proofed.
- A national definition of a net zero carbon building has yet to be agreed, although a framework definition was proposed in April 2019 by the UK Green Building Council (UKGBC) which is based on an “industry consensus on how a net zero carbon building can be achieved today”. At the time of writing, the UKGBC are working to strengthen this definition, for example through supporting energy performance targets and exploring potential routes for a net zero carbon buildings verification scheme. UKGBC is currently pushing for net zero carbon in both construction and operational energy, and ultimately targets ‘whole life’ carbon impacts (including embodied emissions). As part of this work the organisation published detailed guidance on renewable energy procurement and carbon offsetting in March 2021.
- For now, UKGBC is recommending that local authorities make plans for “All new homes (and buildings) to be net zero carbon emissions in operation by 2030 at the latest”, where operational energy is defined as “When the amount of carbon emissions associated with the building’s operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.” Confusingly, and depending on context, an ‘operational’ net zero carbon target can refer either to emissions from regulated energy use only, such as the Government’s 2016 zero carbon homes definition (since abandoned), or to both regulated and unregulated energy use, which is considered ‘true’ zero carbon.
- Any proposed emissions target should now be considered in the context of the Building Regulation proposals and local and national ambitions for net zero

carbon. A widely accepted approach is to implement a baseline energy efficiency or 'fabric' target which then forms part of a hierarchical approach to a net zero carbon standard for new development. This supplements the baseline target with minimum levels of onsite renewable energy generation and carbon offset requirements to achieve net zero carbon.

Local authority-set energy and carbon standards

Hierarchical approach

It is important to consider an overall energy hierarchy when progressing sustainable approaches to energy supply and demand in policy at the local level. This prioritises reducing energy demand before considering the most sustainable ways of supplying energy to meet this lower demand. The London Plan has featured an energy hierarchy since 2004, the basis of which requires developers to first reduce demand, secondly ensure energy is supplied efficiently and finally consider the use of renewable energy generation. The latest version of the London Plan (2021) sets out the hierarchy under part A of Policy SI 2 'Minimising greenhouse gas emissions' as follows:

- **be lean**: use less energy and manage demand during operation
- **be clean**: exploit local energy resources (such as secondary heat) and supply energy efficiently and cleanly
- **be green**: maximise opportunities for renewable energy by producing, storing and using renewable energy on-site
- **be seen**: monitor, verify and report on energy performance.

In the case of net zero carbon targets, financial contributions towards carbon offsetting would be a last resort for emissions that could not be mitigated within the above hierarchy.

To supplement the energy hierarchy, a similar hierarchical approach to heat supply is also useful to ensure developers consider a range of heat supply options and prioritise the most sustainable solutions where feasible in the wider context of local sustainable energy planning. For example, this should ensure that the potential for establishing or linking up to any local district energy heating/cooling networks is fully explored.

The London Plan sets out its heating hierarchy under part D of Policy SI 3 'Energy infrastructure' as follows:

"Major development proposals within Heat Network Priority Areas should have a communal low-temperature heating system:

1. the heat source for the communal heating system should be selected in accordance with the following heating hierarchy:
    a. connect to local existing or planned heat networks

   b. use zero-emission or local secondary heat sources (in conjunction with heat pump, if required)
   c. use low-emission combined heat and power (CHP) (only where there is a case for CHP to enable the delivery of an area-wide heat network, meet the development's electricity demand and provide demand response to the local electricity network)
   d. use ultra-low NOx gas boilers
2. CHP and ultra-low NOx gas boiler communal or district heating systems should be designed to ensure that they meet the requirements in Part B of Policy SI 1 Improving air quality
3. where a heat network is planned but not yet in existence the development should be designed to allow for the cost-effective connection at a later date".

Carbon reduction standards

Local authority policies and policy proposals to encourage enhanced energy performance are often described in terms of percentage improvements over Part L of the Building Regulations. As noted above, current building regulations require a new building's operational emissions to not exceed an overall Target Emissions Rate (TER) which is assessed by comparison with a notional building of the same form but with a standard services specification. In addition, a Target Fabric Energy Efficiency rate (TFEE) also sets a maximum limit for energy demand based on the fabric energy efficiency of the building. Often, however, this target is flexible in how the reductions are achieved i.e. allowing any mix of enhanced fabric measures or onsite renewable or low carbon energy generation (unless of course a Merton Rule policy is applied in parallel – see paragraph 2.43). As this creates a risk of inappropriate trade-offs and misalignment with the energy hierarchy, it is also useful to specify an additional minimum emissions reduction target which must be achieved specifically through fabric measures.

In this way, the energy hierarchy approach is encouraged to minimise demand as far as possible before energy supply measures are considered. In terms of like-for-like emission reductions, improving building fabric energy efficiency levels beyond Part L 2013 can often be more expensive than onsite low or zero carbon generation options such as solar PV, but will result in the additional benefit of reducing energy demand and costs for the occupant. It will also help to lower peak demands on energy supply infrastructure.

An example of an onsite emissions reduction target within the context of an overall net zero emissions policy can be found in the 2021 London Plan, which sets targets under part C of Policy SI 2 as follows:

"A minimum on-site reduction of at least 35 per cent beyond Building Regulations is required for major development. Residential development should achieve 10 per cent, and non-residential development should achieve 15 per cent through energy efficiency measures. Where it is clearly demonstrated that the zero-carbon target cannot be fully achieved on-site, any shortfall should be provided, in agreement with the Borough, either:

A. through a cash in lieu contribution to the borough's carbon offset fund, or
B. off-site provided that an alternative proposal is identified and delivery is certain".

Very high levels of energy efficiency within new buildings have been achieved from proprietary ultra-low energy housing construction standards that have been deployed at small scale in the UK. These include Passivhaus, which typically achieves 75% reduction in space heating requirements compared to standard UK practice, and Energiesprong, a refurbishment and new build standard achieving net zero operational energy. Currently however these are unlikely to be economically competitive with build solutions based on the net zero carbon hierarchical approach described above.

For new non-residential development BREEAM standards such as 'Excellent' or 'Outstanding' can ensure high all-round environmental standards are achieved but they do not provide a direct measure of emissions reduction compared to building regulations.

Onsite emissions reduction targets applied within the context of energy/heat supply hierarchies therefore provide an effective approach to minimising onsite operational emissions within new development. When implemented as part of an overall net zero emissions policy, the approach can generally be considered reasonable, viable and sufficiently flexible to avoid placing undue burden on developers. Where onsite measures are considered to be unviable with respect to the targets, developers need to provide suitable evidence and agree alternative solutions, such as carbon offsetting, with the planning authority. Such hierarchical policies also usually include set requirements for monitoring and reporting on energy performance for an initial period of operation.

Including a development scale threshold as in the London example assumes that the large majority of potential emission savings are from major developments and that economy of scale makes it more difficult to viably achieve targets on small developments. Although this might simplify the planning process for small scale developments, it could be argued that net zero policies with suitable offsite emission reduction options offer a catch-all solution for all scales of development. However, for the Cotswold District the ratio of minor/major development typical for the area and any consequential benefits of including minor development within such policies should first be evaluated, bearing in mind the overall context of the hierarchical policy being considered and impacts on viability.

Energy Use Intensity targets

An alternative approach to achieving net zero total emissions for new development is described in the London Energy Transformation Initiative's (LETI) Climate Emergency Design Guide.

Total energy use targets are described in terms of 'Energy Use Intensity' (EUI), and are measured in kWh/m2/year. In this context 'total' energy use refers to operational energy use, which includes both regulated and unregulated end uses, but excludes electric vehicle charging. The targets are proposed for three building typologies (residential, office and commercial buildings, but noting that evidence in the residential sector is strongest) and were set by balancing industry capability with energy budgets based on national forecasts for renewable energy generation. The EUI targets are intended to be deployed alongside a target for space heating demand, a ban on the use of fossil fuels on-site, and a requirement for on-site renewable generation at a scale that at least matches the building's demand for energy. Where the latter is deemed not to be possible in a particular case (for example where a tall block of flats has insufficient roof area for the installation of adequate solar PV provision), then Renewable Energy Credits are proposed, where a developer can pay for the equivalent renewable generation capacity elsewhere.

Setting targets based on energy consumption rather than carbon emissions avoids the need to consider the effect of grid decarbonisation on assumed carbon factors and means that compliance can be measured post-completion relatively easily.

Table 1: LETI EUI targets for new development typologies

Rooftop Solar PV	Proposed EUI target (kWh/m2/year)	Proposed space heating target (kWh/m2/year)
Residential	35	15
Commercial offices	55	15
Schools	65	15

Cornwall Council has taken a similar approach for residential development in their recent Climate Emergency Development Plan Document (DPD), which was submitted for independent examination in November 2021. Under policy SEC1, development proposals would be required to achieve Net Zero Carbon and to submit an Energy Statement that demonstrates how the EUI targets will be achieved. These are however slightly higher than those recommended by LETI at 40kWh/m2/year total demand, 35kWh/m2/year space heating demand, and a requirement to provide on-site renewable generation to match total demand (with a preference for solar PV). Where this is shown to be either not technically feasible or economically viable, the policy would require developers to maximise renewable energy generation as far as is possible, and/or connect to a district heat network. As a last resort the residual could be offset by a contribution to Cornwall Council's Offset Fund, as far as economic viability allows. The policy proposals suggest that major non-domestic developments (floorspace over 1,000m2) should be required to achieve a BREEAM 'Excellent' rating.

Embodied carbon

Recognition of the need to address 'whole life' carbon impacts, which incorporate both operational and embodied emissions, has grown in the last couple of years and has become an area of particular focus for organisations such as the RIBA, LETI, CIBSE and the UKGBC. In LETI's Embodied Carbon Primer the authors note that industry still has some way to go before net zero embodied emissions can be widely achieved (in terms of the knowledge and skills development needed) and that a phased approach where targets become more restrictive over time might be most appropriate. LETI suggest that a best practice approach for policymakers might be to adopt a policy hierarchy that advocates circular economy principles (i.e. where re-use and refurbishment are preferred to demolition and new construction), mandates embodied carbon reduction strategies based on a consistent and recognised methodology for embodied and whole life carbon analysis, adopts embodied carbon targets, and phases in the requirement for Environmental Product Declarations (EPDs) for at least all building parts forming the substructure, frame and upper floors. LETI neither specifically endorse or reject carbon offsetting as a means to account for embodied emissions, but note that this approach can be controversial.

Carbon offsetting

Carbon offsetting schemes are designed to allow developers to make financial contributions to offset emissions that cannot be mitigated onsite. This system has already been in use for several years in London, where the developer pays a specified amount per tonne of carbon to be offset. Similar approaches are also being taken by an increasing number of local authorities elsewhere including the West of England Combined Authorities and the Greater Manchester Combined Authorities. However, the resources to implement such schemes may make this option more difficult to adopt in smaller individual local authorities.

In the absence of developments which truly do not generate carbon emissions through their operation and occupation, carbon offset regimes can therefore provide funds to create new carbon saving projects and bring forward the rate at which carbon emission reductions are achieved. In general, however, carbon offsetting is often viewed as a controversial area of carbon management both because of the risk that it distracts from the pressing need to reduce emissions at source by seeking to compensate for carbon that has already been emitted, and because the claimed savings can be difficult to monitor and verify. It is important therefore that policies are designed in such a manner as to ensure that all viable onsite methods of reducing carbon emissions are exhausted first. They should also be seen as temporary measures until regulatory regimes, development economics and the development industry deliver true carbon neutral or carbon positive developments on-site through use of sustainable materials, very high energy efficiency standards and integrated renewables. Care should also be taken to ensure that the emission reductions funded by carbon offset schemes are genuinely additional to what would have happened otherwise.

Where carbon offset regimes are in operation, the local authority takes on the responsibility for delivering carbon emission savings or reductions to offset for the residual carbon emissions from developments. Defined administration structures are needed to stimulate new markets and carbon saving activities to ensure that the system is keeping up with the pace of emissions it is intending to mitigate for. There is the potential to share back office processes with neighbourhood authorities to reduce costs.

Although, in the case of carbon offsetting linked to zero carbon planning policies, carbon offset payments are usually calculated on the basis of abating carbon emissions for only 30 years' worth of building occupancy, there is an assumption that during this period the decarbonisation of grid electricity and heat will be achieved through future technological and/or policy developments and therefore will account for emissions over the remaining life of the building. A carbon price to value offsets at £95 per tonne of CO_2 has been recommended for London boroughs in GLA guidance and in a report for the West of England Authorities.

Other considerations

Emission factors used by the 2013 Building Regulations (which is based on the 2012 version of SAP) are now considerably out of date and do not reflect the current level of electricity grid decarbonisation achieved in the UK. To address this issue, a draft SAP10 methodology was published in 2018, followed by a version 10.1 in October 2019 and 10.2 in August 2021. Version 10.2 is expected to replace the 2012 version as part of the next update of the Building Regulations and would reduce the carbon emissions factor from 0.519 to 0.136 gCO_2/kWh. This reduction will have a considerable impact on the contribution of renewable power generation technologies to emission reduction targets, as well as to any carbon offsetting calculations.

Future proofing measures could be encouraged in anticipation of the Future Homes Standard and the increasing need to achieve net zero carbon onsite or through connection to zero carbon local energy networks. These might include use of low temperature heat distribution systems compatible with heat pumps or making provisions for future connection to district heating networks.

In moving towards net zero emission buildings, fabric energy efficiency will continue to increase, bringing with it an increased risk of overheating. Appropriate mitigation measures should therefore be highlighted in sustainable design policy.

Solar PV/thermal (roof-mounted)

Description of technology

Both solar PV and solar water heating are well-established technologies in the UK, with uptake having been significantly boosted through the Feed-in Tariff (FiT) and the Renewable Heat Incentive (RHI) schemes. The breadth of uses for solar PV technology is vast and spans many diverse applications such as solar phone chargers, roof or ground-mounted power stations and solar streetlamps. There is also a new design for a solar PV integrated motorway noise barrier that is being considered for use by Highways England, and a trial of track-side solar panels being used to power trains by Imperial College. Solar car park canopies also offer potential, as demonstrated by the 88.5kW system installed at the Ken Martin Leisure Centre by Nottingham City Council.

Another application currently being developed in the UK is 'floatovoltaics' (floating PV arrays). These often involve situating panels on rafts of floats, anchored to the sides of a reservoir or lake. UK examples include the 6.3 MW floating solar PV array which has been developed on one of Thames Water's reservoirs, Queen Elizabeth II Reservoir, near Heathrow airport. This consists of 23,000 panels and covered around one tenth of the reservoirs surface. Other examples include Godley Reservoir near Manchester. This has a capacity of 3MW and consists of 12,000 panels. United Utilities are also developing a Lancaster reservoir. These arrays generally take up a small area of the reservoir and can have a positive environmental impact by covering portions of water bodies and therefore reducing evaporation during summer months. Another positive for those looking at opportunities for floating solar farms in the UK is that the example project (QEII) did not require planning permission, unlike for solar panels installed on land. It is worth mentioning that the examples used above are reservoirs which may reduce issues with multiple land use. In more natural spaces, however, there may be a risk that the lower light levels underneath the panels could affect the local ecosystem, in particular those organisms at the very bottom of the food chain (e.g. algae). This would need to be considered in more detail should there be any proposals for a floating array at sites such as the Cotswold Water Park which, despite being a man-made lake system, has been designated as a Site of Special Scientific Interest (SSSI).

Rooftop deployment is generally limited to roofs with minimal shading and which face south-west through to south-east with a pitch of 20-60 degrees. Systems can be roof-integrated, i.e. designed to form an integral part of the roof itself and therefore can offset some of the cost of conventional roofing materials using a range of PV materials including semi-transparent panels, tiles and shingles. 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, with each frame suitably spaced in rows to avoid self-shading. For pitched roofs, solar PV generally needs around 7.5m^2 of roof space per kW for high efficiency panels (e.g. monocrystalline silicon) and grid-connected systems are able to export power if there is insufficient load in the property at any one time. The rooftop size of solar water heating systems however is limited by the hot water demand of the property they are serving, with domestic systems typically requiring 1.5m^2 of flat panel per resident. Properties also need to have sufficient space to accommodate a hot water storage 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 (e.g. on the site of a scheduled monument or in a conservation area) are restricted in certain situations and may require planning consent. The Cotswolds Conservation Board, who are responsible for coordinating the conservation and enhancement of the Cotswolds Area of Outstanding Natural Beauty (AONB), are generally supportive of roof-mounted solar arrays so long as they do not detract from the character and appearance of the building or area (including in relation to non-designated heritage assets). Their position statement on renewable energy notes that in particular “there are many large farm buildings where panels could be placed with little or no negative impact on the landscape of the AONB”[1].

Existing development within Cotswold

Cotswold District saw 19MW of solar PV capacity installed between April 2010 (launch of the Feed-in Tariff) and March 2019 (when it closed), with a third of this deployed on domestic dwellings. Accredited domestic installations of solar water heating systems under the Renewable Heat Incentive (RHI) scheme from April 2014 to July 2020 totalled 30, which equates to approximately 0.09MW assuming an average system capacity of 2.9kW. Figures are not available for non-domestic installations.

Assumptions used to calculate technical potential

CSE’s solar PV model estimates the potential energy output from the installation of PV panels on the buildings within a given region of the UK. There is an associated cost-benefit model which calculates the financial viability in terms of Net Present Value (NPV) and Internal Rate of Return (IRR) of all the potential PV installations. Together, the two models aim to evaluate each section of roofing of each building in the region for both the technical and financial viability of a solar PV installation.

The model uses LiDAR data for the region. This tells us the height above sea-level of each metre-by-metre square section of the region (if the resolution of the LiDAR for

[1] https://www.cotswoldsaonb.org.uk/wp-content/uploads/2017/08/renewable-energy-ps-2014-final-apr2014.pdf

that region is 1m, which most areas of the UK now have). It also uses Ordnance Survey building footprint polygons for the region to be modelled. The process/method used is as follows:

1. Model horizons: using the LiDAR data, the model builds a horizon profile for each point of LiDAR data that falls within the footprint of a building. This is the horizon height in degrees from horizontal in a ring around the building, as if an observer was standing on the roof of the building and reporting how much sky could be seen in each direction.
2. Detect roof planes: For each building, the model detects the various roof planes that make up the roof of the building using a modified version of the RANSAC algorithm. For example, it would detect one roof plane in a flat-roofed building, two in a building with gables, and our in a building with a hip roof. The higher-resolution the LiDAR is, the more accurate this process is. This tells us the size and compass orientation of each potential PV panel site.
3. Exclude unsuitable roof sections: Roof sections are excluded from the model for a range of reasons:
    - They are too North-facing;
    - They are angled too steeply;
    - They are too overshadowed to the South, South-East or South-West (using the horizon data calculated earlier);
    - The roof section is too small for a useful installation.
4. Calculate PV energy output: Using a tool called PV-GIS[2], the PV energy output of an installation with a given location, size, compass orientation, and horizon model is calculated. This includes modelling losses due to temperature, reflection, solar spectrum, and cabling/inverters.
5. Perform cost-benefit analysis: The NPV and IRR are calculated for each potential PV installation of each building (see Appendix D for detailed assessment assumptions). For example, if a building has three potential PV sites on its roof called P1, P2 and P3, in descending order of energy output per square metre, the NPV and IRR are calculated for the following installations: [P1], [P1 P2], and [P1 P2 P3]. This is so the worst site (P3) is only considered if it would be worth installing both P1 and P2.

The limitations of this model are that it cannot detect where buildings might be unsuitable for PV installation due to roof weakness, type of building, or listed status. Also, if there is no LiDAR coverage for the region, modelling will not be possible. The quality of the outputs will be reduced if there is only low-resolution (greater than 1m

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[2] 'Grid-connected PV systems' model from PVGIS, via the PVcalc API. It uses the PVGIS-SARAH database, which is the recommended one for Europe, excluding Scandinavia (https://ec.europa.eu/jrc/en/PVGIS/docs/usermanual#fig:default_db)

by 1m resolution) LiDAR coverage. Within the Cotswold District the LiDAR coverage is 39.4%. This is relatively low, however most urban areas have good coverage.

The resulting outputs include a GeoPackage showing the suitable roof planes (with the ability to categorise them e.g. by tenure, residence type, NPV, IRR). This data can also be presented in a spreadsheet with one row per roof plane. Each roof plane (row) is given a peak power (MW), usable area (m^2), total yield (kWh/year), yield per roof area (kWh/m^2/year), installation cost (£), NPV and IRR.

Results

Technical potential

The potential installed capacities, energy yields and savings for solar PV across Cotswold are presented below according to the assumptions set out in Error! Reference source not found.. Potential capacity for solar thermal results have not been included as part of this analysis, however roofs with high potential in solar PV will also have high potential in solar thermal technology.

Table 2 shows the results from the solar PV analysis split by residence or building type. The average capacity is highest for non-domestic buildings (this is also shown in Figure 3 with non-domestic being higher than other tenures). However, Figure 1 shows that the total estimated technical capacity and energy yield is slightly lower than flats which is due to there being 5,750 flats and only 3,434 non-domestic buildings. These buildings are likely to have higher yields and capacity due to having a larger roof area than bungalows and terraces. Flat blocks may also receive less shading due to being higher-rise. Some of these buildings will already have solar panels and this is not accounted for.

Table 2: Assessment of roof-top solar PV by Building Type

Building type	Total Number of buildings	Total estimated technical capacity (MWp)	Average estimated capacity per roof/ building (kW)	Potential energy yield – electricity output (MWh/ year)	Potential CO_2 savings (tonnes/ year)
Terrace / end terrace	9,082	27.57	3.04	23,284.53	3,166.70
Semi-detached	12,864	40.56	3.15	34,211.37	4,652.75
Detached	14,733	66.72	4.53	56,795.02	7,724.12
Flat	5,750	98.51	17.13	86,050.64	11,702.89
Bungalow	1,761	7.90	4.49	6,702.22	911.50
Non-domestic	3,434	90.37	26.32	78,605.59	10,690.36
Total	**47,624**	**331.63**	**58.65**	**285,649.36**	**38,848.31**

Figure 1: Roof-mounted Solar PV Potential and Potential CO_2 savings across Residence Type

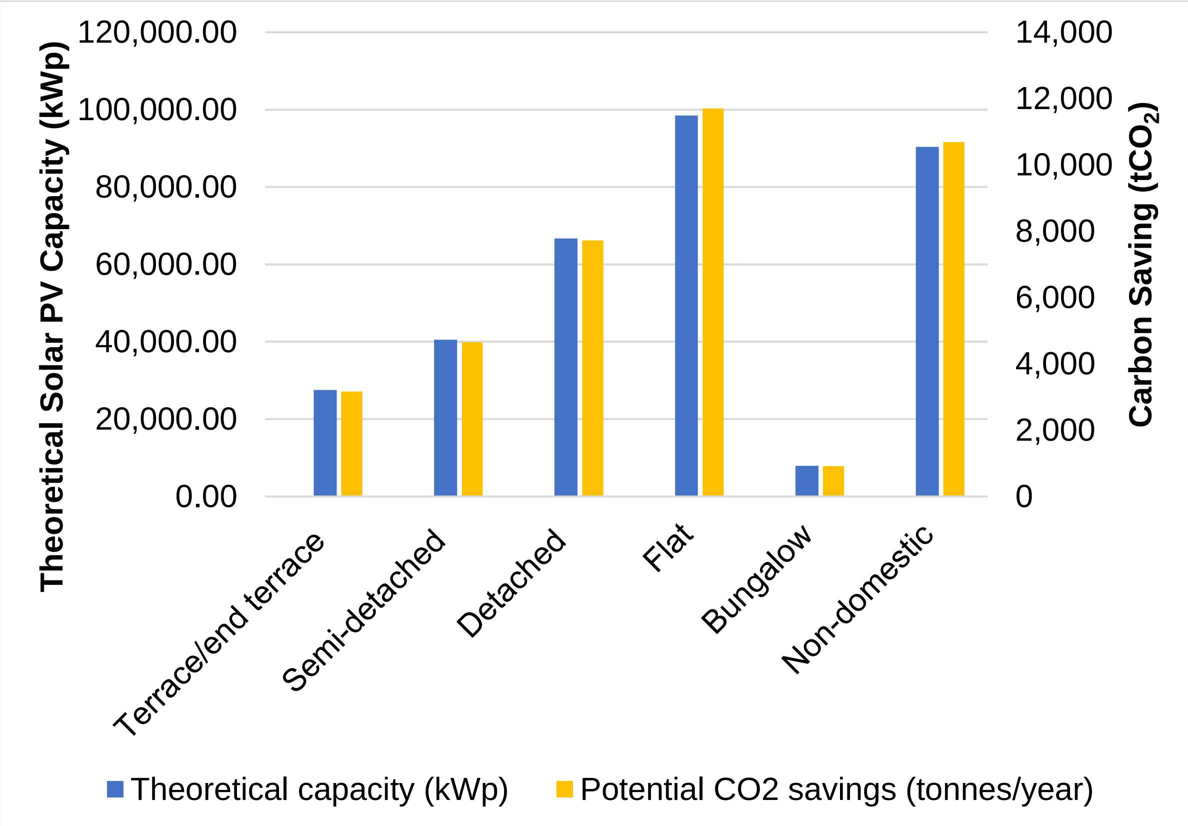
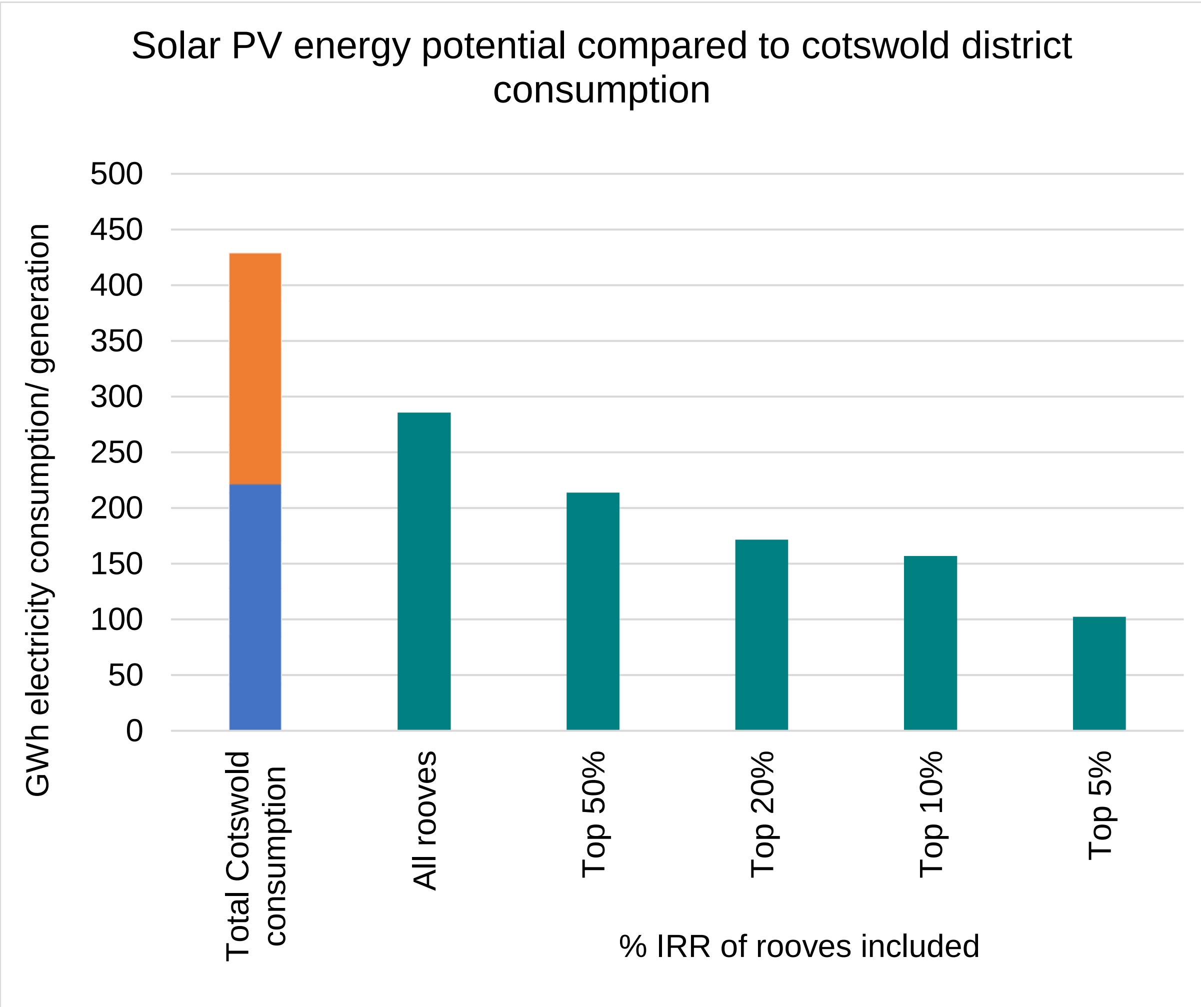


Figure 2 shows the solar PV generation potential from all roofs that were selected in the analysis to only the top 5% of IRR. It shows that even if all roofs selected in the analysis had solar PV this wouldn't cover both the domestic and non-domestic electricity demand across the district. However, it would cover either domestic or non-domestic.

Figure 2: Cotswold District electricity consumption compared to estimated solar PV generation potential

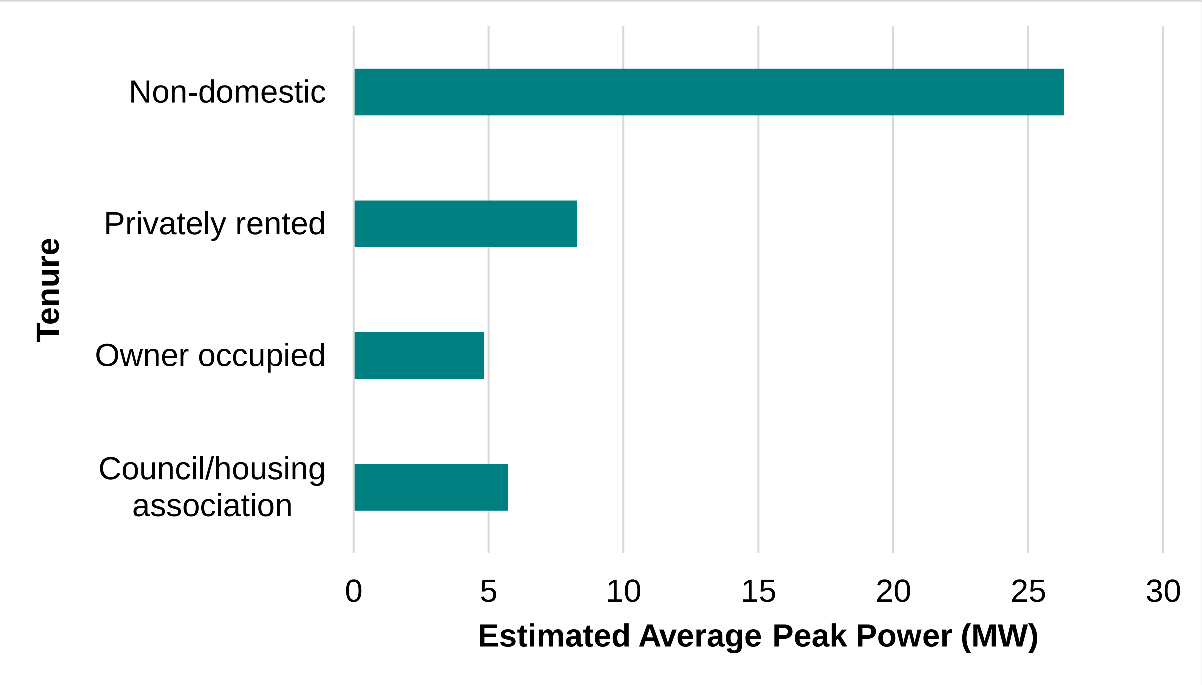


The solar PV analysis can also be split by tenure. Out of the domestic properties, the private rented homes have the highest average capacity per building (kW) (as shown in Table 3 and Figure 3). This could be due to blocks of flats more commonly being private rented. However, as there are more owner occupied homes, this has the highest potential yield of electricity.

Table 3: Assessment of roof-top solar PV by tenure

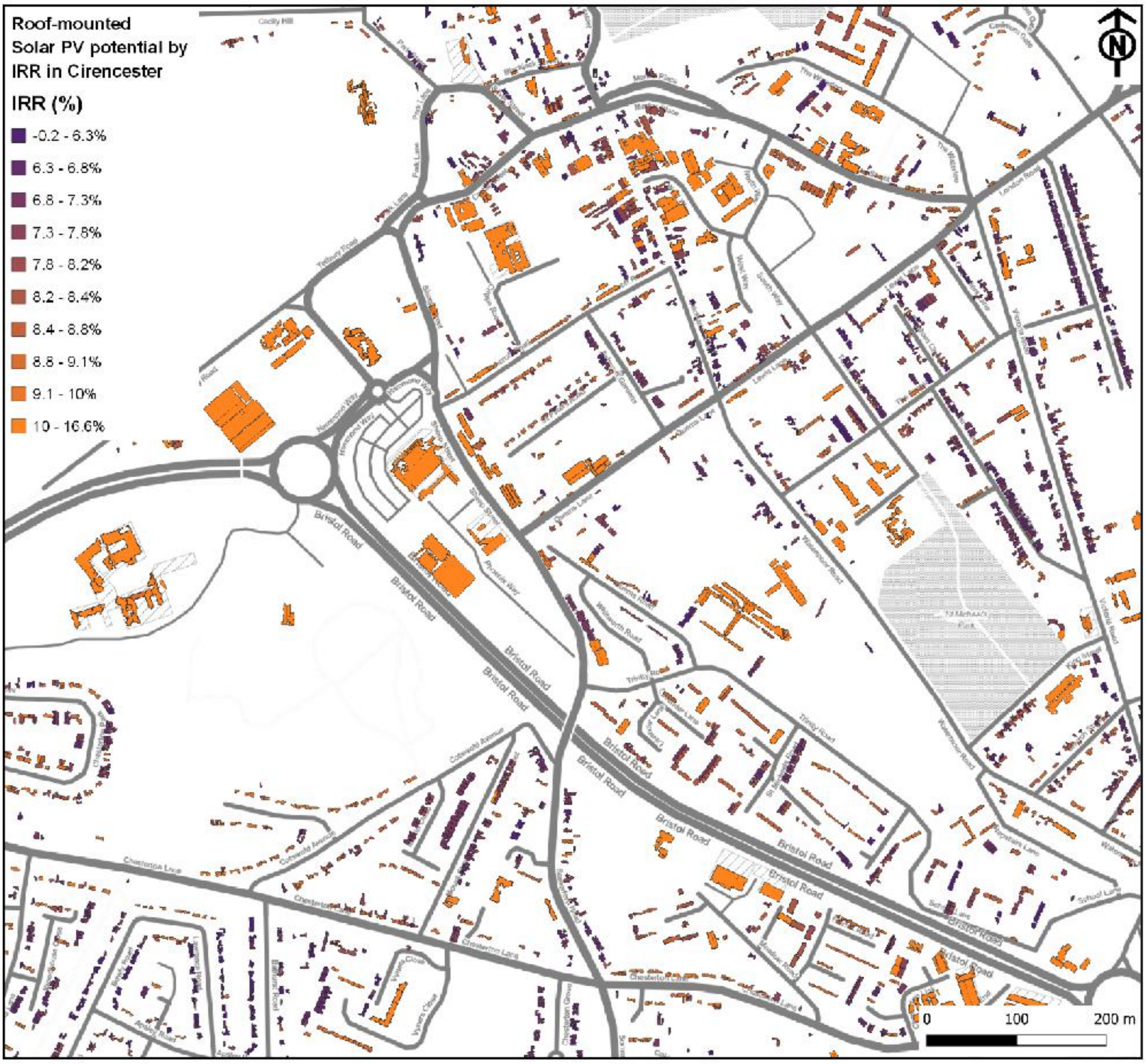
Tenure	Total Number of buildings	Total estimated technical capacity (MWp)	Average estimated capacity per roof/ building (kW)	Potential energy yield – electricity output (MWh/year)	Potential CO_2 savings (tonnes/year)
Council/ housing association	7,061	40.44	5.73	34,489.06	4,691
Owner occupied	30,950	149.70	4.84	127,956.87	17,402
Privately rented	6,179	51.12	8.27	44,597.84	6,065
Non-domestic	3,434	90.37	26.32	78,605.59	10,690
Total	**47,624**	**332**	**45**	**285,649**	**38,848**

Figure 3: Estimated average peak power (capacity) across tenure



The analysis can be viewed spatially on maps with each roof either showing financial indicators such as NPV or IRR or the electricity yield or peak of the roof. Figure 4 shows the % IRR of roofs in a select area of Cirencester. Maps of other areas can be created upon request.

Figure 4: Solar PV potential by IRR (%) in Cirencester



Issues affecting deployment

Rooftop solar PV is a mature and relatively easy-to-install renewable energy technology which can be used to help meet tightening building emissions standards by displacing higher-carbon mains electricity, and for these reasons it is often a popular option with developers. However, the steady decarbonisation of mains grid electricity means that the 'value' of these carbon savings will also continue to drop, although financial benefits will remain for those receiving free electricity from onsite PV systems.

In addition, the cost of solar PV has fallen dramatically over the last decade[3] and this trend is likely to continue with the expectation that UK grid parity (generation of power at or below the cost of mains power) will eventually be achieved for rooftop systems without the need of subsidies. Costs can also be minimised through collective buying schemes such as Solar Together. Technological advances in energy storage systems and smart power management controls, along with increasing demand from heat pumps and electric vehicles and the introduction of time-of-use tariffs to optimise benefits are also likely to act as on-going incentives for solar PV in the wake of the Feed-in Tariff scheme closure. Additionally, the Government introduced the Smart Export Guarantee scheme in January 2020, which places an obligation on licensed electricity suppliers to offer a tariff and make payment to small-scale (>5MW) low carbon generators for electricity exported to the grid. However, this only applies to exported power rather than total generation and so is generally less beneficial than incentives previously offered under the Feed-in Tariff. It also may not provide long-term financial security to owners as the suppliers can offer any rate that is not zero. In October 2019 the Government also increased VAT payable on solar PV battery systems from 5% to 20%, although the reduced rate of 5% still applies for the domestic installation of solar panels (both solar PV and solar water heating).

Solar PV will therefore continue to play a vital role in the large majority of new developments and will make a significant contribution to total installed capacity across the UK. Future uptake on existing buildings however is difficult to predict and will be more limited until subsidy-free financial viability improves.

Solar water heating is much less common, with preference generally given to solar PV during the more lucrative Feed-in Tariff period, although installations on buildings located in off-gas areas can be financially advantageous due to the increased benefits of displacing higher cost heating fuels relative to mains gas, such as electricity and oil. Installations on non-domestic buildings are more limited as viability depends on hot water demand and competition with point-of-use hot water heating. Relative to heat pumps, the technology is likely to play a much lesser role in the decarbonisation of heat, particularly if grid electricity continues to decarbonise as predicted.

[3] https://www.gov.uk/government/statistics/solar-pv-cost-data

Solar PV (ground-mounted)

Description of technology

In addition to PV modules integrated on built development, there are a large number of ground-mounted solar PV arrays or solar farms within in the UK. These consist of groups of panels (generally arranged in linear rows) mounted on a frame. Due to ground clearance and spacing between rows (and between rows and field boundary features) solar arrays do not cover a whole field and allow vegetation to continue to grow between and even underneath the panels.

Ground-mounted solar project sizes vary greatly across the UK although, as with wind, developers in a post-subsidy environment are increasingly focusing on large-scale development, with the largest currently consented scheme in England (Cleve Hill in Kent) being over 350 MW[4]. There is no one established standard for land take per MW of installed capacity, although land requirements for solar are comparatively high compared with wind. For the present assessment, an approximate requirement of 2 hectares per MW has been applied based on existing and past guidance and recent development experience.

As of 2020, the UK had 13,462 MW of installed solar PV capacity, with this providing 13,158 GWh of electricity during the year (4.2% of total energy demand)[5] (the lower energy generation relative to wind despite the similar installed capacity is due to the lower capacity factors of solar PV generation[6]). These figures include all forms of solar PV – although according to the most recent available data, ground-mounted

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[4] Cleve Hill Solar Park (2020) Cleve Hill Solar Park granted development consent – 28/05/2020. Available at: www.clevehillsolar.com/.

[5] Department for Business, Energy & Industrial Strategy (June 2021) Energy Trends: UK renewables: Table 6.1 - Renewable electricity capacity and generation (ET 6.1 - quarterly). Available at: www.gov.uk/government/statistics/energy-trends-section-6-renewables.

[6] 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 instantaneous 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 on the PV farm 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, any carbon savings resulting from displaced fossil fuel derived electricity are calculated directly from generation yields rather than generation capacities.

schemes account for 50.2% of overall capacity[7]. Falling capital costs are rendering solar PV increasingly viable in a post-subsidy context, although as outlined above, at present developers are generally focusing on large developments in order to achieve economies of scale. Grid connection costs are also critical to determine viability.

Existing development within Cotswold District

LUC/CSE's review of the data available from BEIS[8] has identified the following ground-mounted solar PV projects currently consented or installed in Cotswold District:

- Cirencester Solar Farm: 26.2MW
- Crucis Park: 12.5MW
- Duke of Gloucester Barracks: 1.4MW
- Northwick Estate (Extension): 2.2MW
- Norton Hall: 2.8MW
- Springhill Solar Park (Northwick): 5MW
- The Rainbows Solar Farm: 4MW

The overall installed capacity of these developments is 54.1MW, equating to 11.6% of the authority's current electricity demand. In addition, there is 19.9MW of solar PV submitted and awaiting planning decisions. If consented, the total installed capacity of ground-mounted solar energy generation will be 15.9%.

In addition, a notable 49.9 MW scheme is being proposed by Aura Power southwest of Kemble and northeast of Chelworth in the south of the district[9]. The planning application for this scheme is due to be submitted in 2021.

Two operational solar developments (Springhill Solar Park (Northwick) and Northwick Estate (Extension)) are located within the Cotswolds AONB along the A44 road. The remainder are located outside of the AONB, three being located close to Cirencester, and two located on the northern edge of the district.

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[7] Department for Business, Energy & Industrial Strategy (May 2021) Solar photovoltaics deployment: Using March 2021 data within Table 2, considering all FiTs (standalone), RO (ground mounted) and CfDs (ground-mounted) within the UK. Available at: www.gov.uk/government/statistics/solar-photovoltaics-deployment.

[8] BEIS (2021) Renewable Energy Planning Database (REPD): March 2021. Available at: https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract.

[9] Aura Power (2020) Kemble Solar Farm. Available at: https://www.aurapower.co.uk/kemble-solar-farm/.

According to the most recent BEIS Renewable Energy Planning Database, within Cotswold District one 1MW scheme has been withdrawn and one 5MW scheme was granted but its planning permission has since expired.

Technical potential (i.e. results of the assessment)

Assumptions used to calculate technical potential

The assessment of technical potential for solar developments was undertaken using GIS involving spatial mapping of key constraints and opportunities. The assessment identified areas with potential viable annual solar irradiance and a series of constraints relating to physical features and environmental/heritage protection were then removed. The remaining areas have 'technical potential' for solar energy development.

Solar development is more 'modular' than wind (developments size is dictated by the number of panels, which themselves do not differ greatly in size) and constraints (i.e. noise buffers) are not affected by project scale in the way that they are for wind. Therefore, the identification of available land for solar has not been broken down into discrete project sizes but rather any land technically suitable for development has been identified. The GIS tool assessment assumptions are set out in Appendix D.

Landscape Sensitivity Assessment

Although the landscape and visual impacts of solar PV tend not to be so contentious as wind development, it is still often a key consenting issue, particularly at larger development scales.

As the degree of acceptable landscape and visual impact is generally a matter that needs to be considered within the context of the overall planning balance, no land was excluded from the GIS technical constraints assessment on landscape or visual grounds. Instead, a separate landscape sensitivity assessment was subsequently undertaken which considered all Landscape Character Types defined within the Gloucestershire Landscape Character Assessment and, in accordance with the wishes of the Council, excluded land within the Cotswolds AONB. This can be used alongside the output of the GIS assessment, which maps and quantifies technical capacity, to determine landscape sensitivity to different scales of solar developments.

Land within the AONB was not initially included in the LSA. The findings of a subsequent landscape assessment undertaken by Cotswold Council officers on the AONB was retrospectively included in the findings of this assessment.

The landscape sensitivity assessment considered solar PV, and as sensitivity varies in accordance with development scale, different development scales were considered based on land take:

- Very large solar PV installation: (50-120ha).

- Large solar PV installation: (20 to 50ha).
- Medium solar PV installation: (5 to 20ha).
- Small solar PV installation: (1 to 5ha).
- Very small solar PV installation: (Up to 1ha).

Please refer to the separate Landscape Sensitivity Assessment in Appendix C for further details.

Results

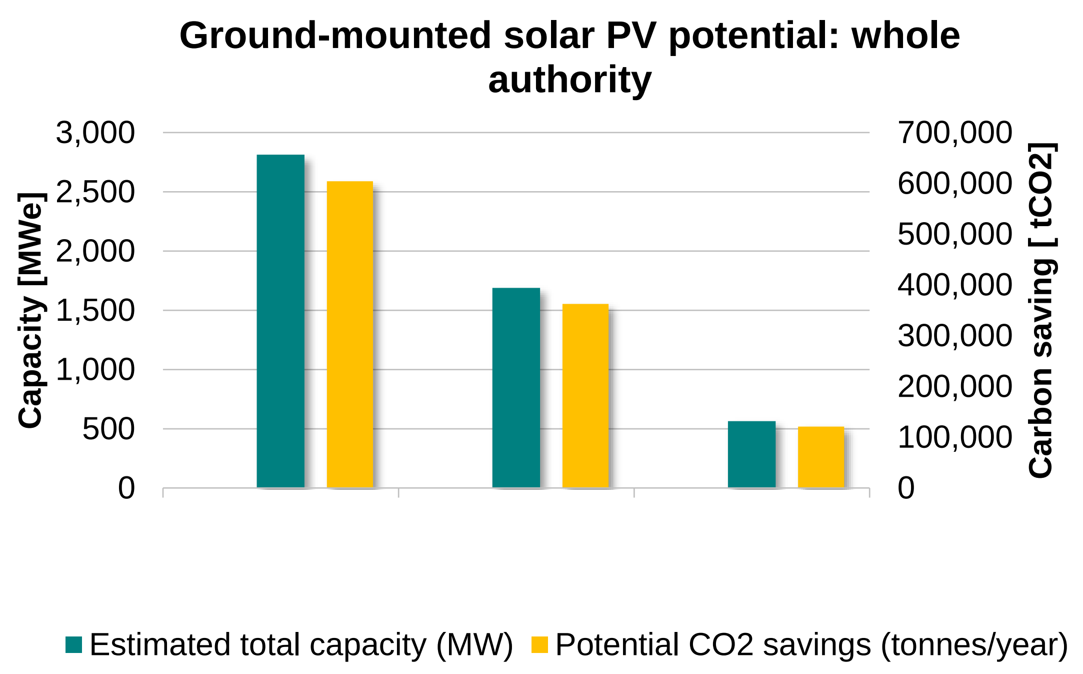
Technical potential

Figures Figure 5 to Figure 13 and

Table 4 below provide a summary estimate of the technical potential for ground-mounted solar PV within Cotswold District. As the full technical potential is very large, utilisation of 1%, 3% and 5% of the resource is also quantified. In addition, due to the potential planning constraints within the Cotswolds AONB, these values are also provided for only the land within the district located outside of the AONB, as well as within the AONB for reference. Adopting the 3% development scale would result in a total potential technical capacity from ground mounted solar PV across the district of 1,689MW, 363MW on land located outside of the AONB and 1,326MW within the AONB. This approximately equates to an area of 20.26km^2, 4.35 km^2 and 15.91km^2 respectively, and would provide 196%, 42% and 154% of the projected electricity demand in Cotswold District in 2050 respectively.

The calculation of potential energy yield requires application of a ‘capacity factor’ i.e. the average proportion of maximum PV capacity that would be achieved in practice over a given period. Capacity factors vary in practice in accordance with solar irradiation, which in turn is affected by location, slope and aspect. It was not possible to find suitable historic data on capacity factors taking into account these kinds of variations for the present study, and so a single capacity factor of 10.52% was used, as based on regional data[10].

Figure 5: Ground-mounted solar PV potential and carbon savings – within the whole of Cotswold District.



[10] BEIS (2020) Quarterly and annual load factors: Annual Regional PV Load Factors, averaged at 10.52% for the South West region over the last nine years. Available at: https://www.gov.uk/government/publications/quarterly-and-annual-load-factors.

Figure 6: Ground-mounted solar PV potential electricity output and current electricity demand within Cotswold District savings – within the whole of Cotswold District

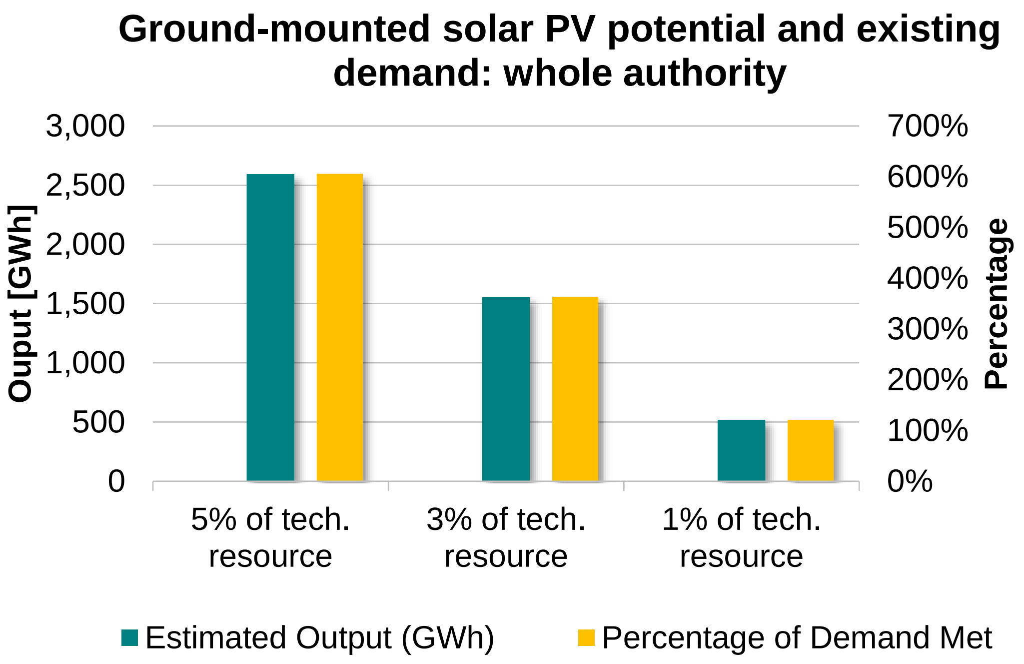


Figure 7: Ground-mounted solar PV potential electricity output and 2050 electricity demand within Cotswold District savings – within the whole of Cotswold District

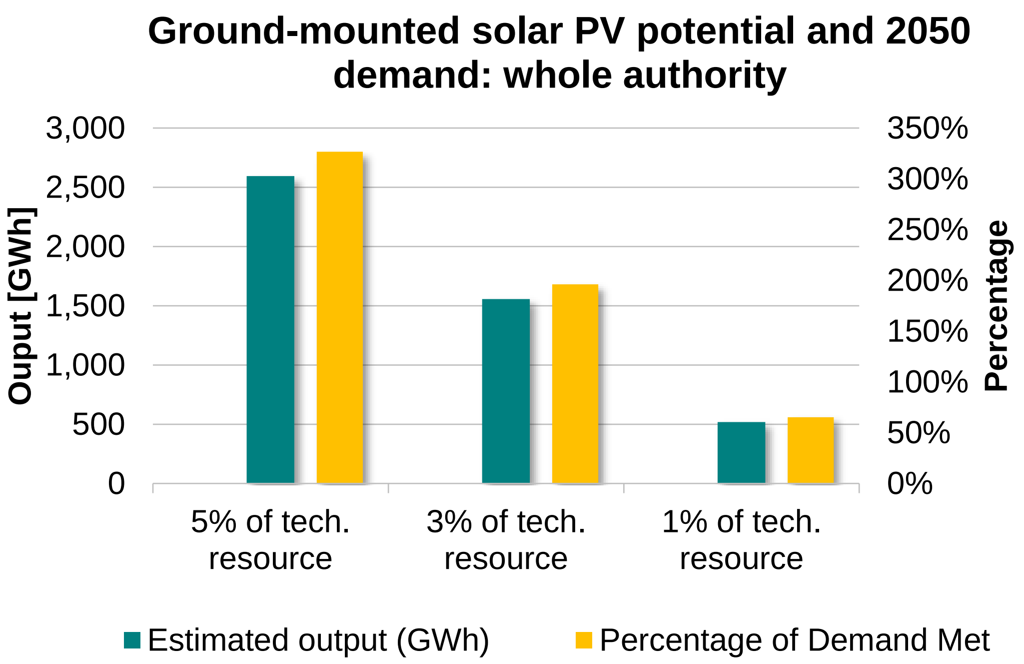


Figure 8: Ground-mounted solar PV potential and carbon savings – within land outside of the Cotswolds AONB

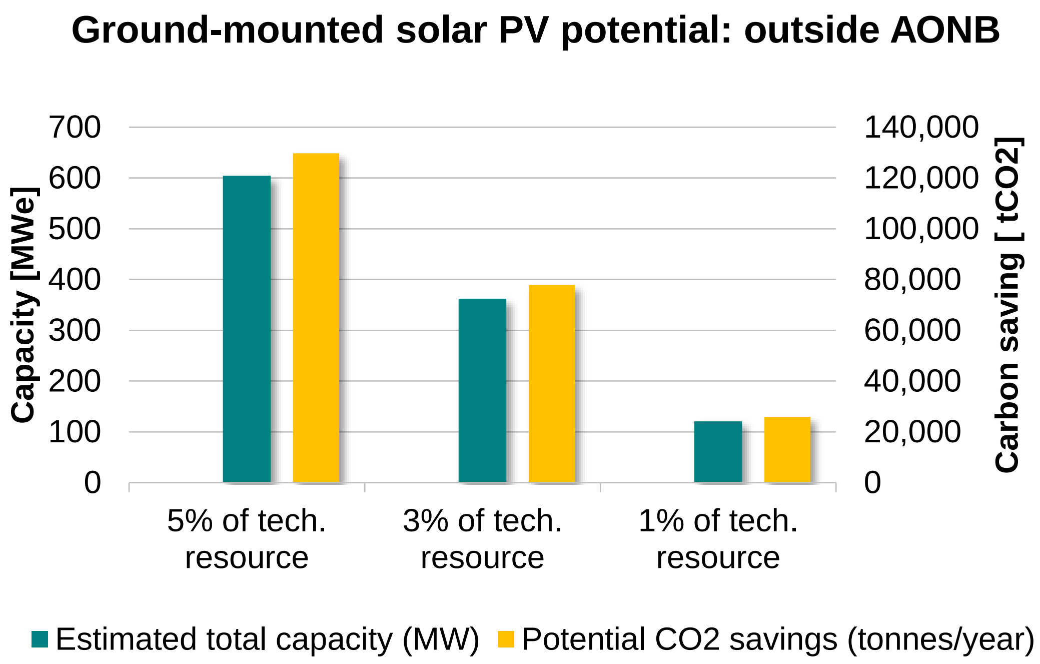


Figure 9: Ground-mounted solar PV potential electricity output and current electricity demand within Cotswold District savings – within land outside of the Cotswolds AONB

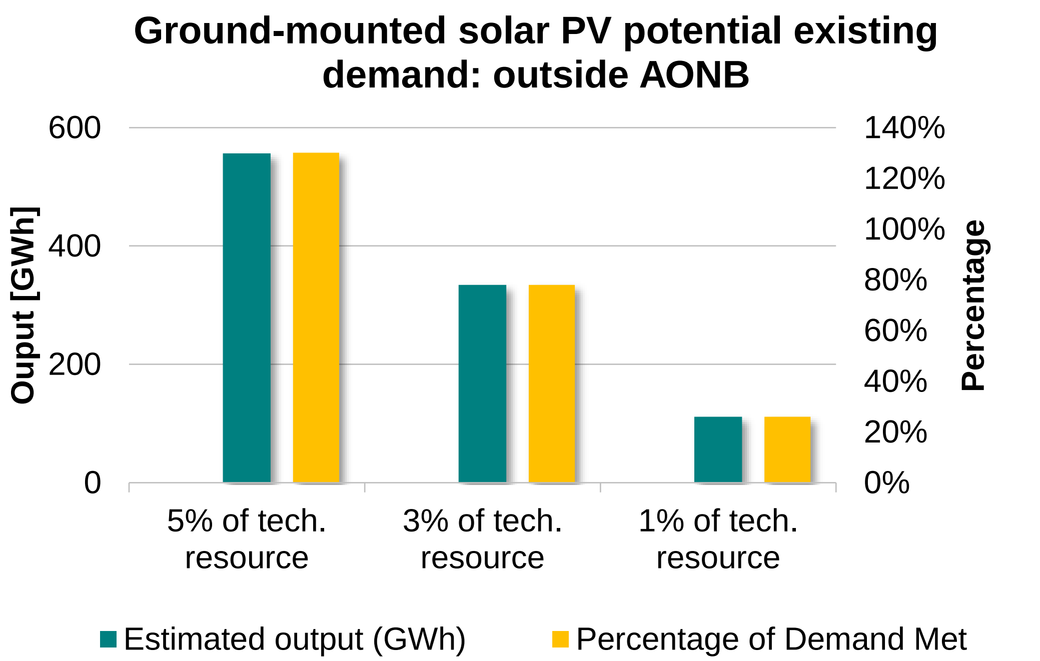


Figure 10: Ground-mounted solar PV potential electricity output and current electricity demand within Cotswold District savings – within land outside of the Cotswolds AONB

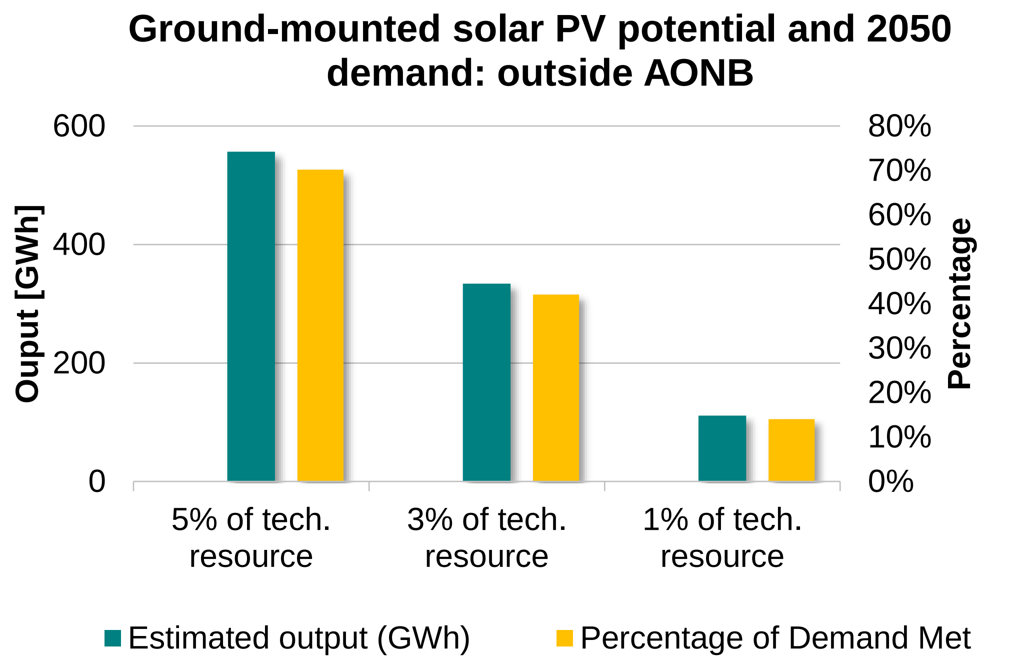


Figure 11: Ground-mounted solar PV potential and carbon savings – within land inside of the Cotswolds AONB

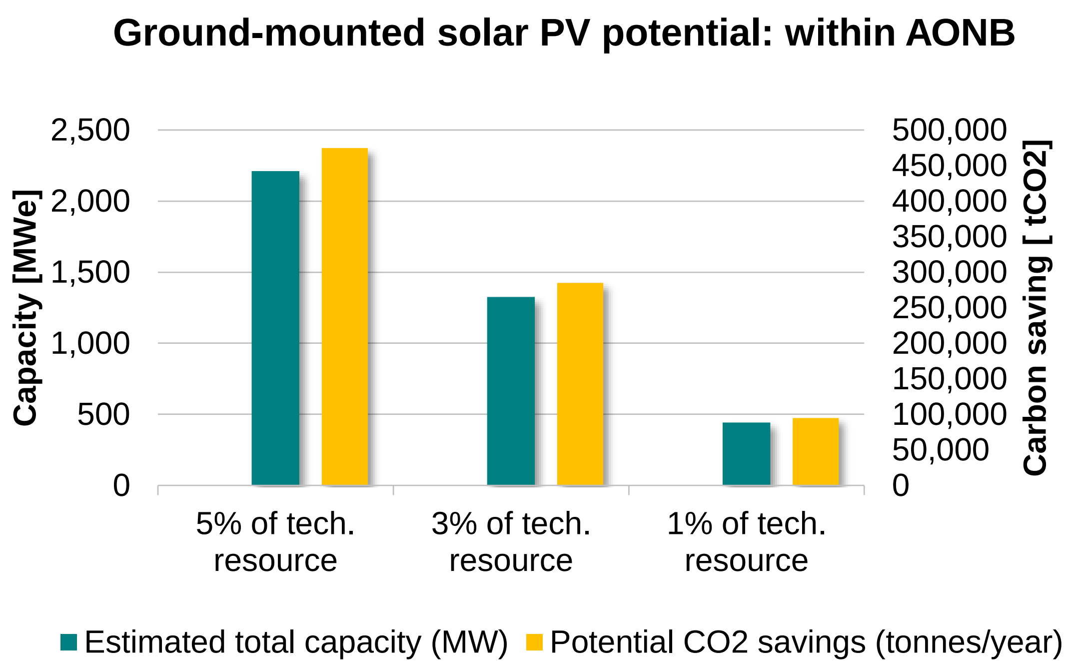


Figure 12: Ground-mounted solar PV potential electricity output and current electricity demand within Cotswold District savings – within land inside of the Cotswolds AONB

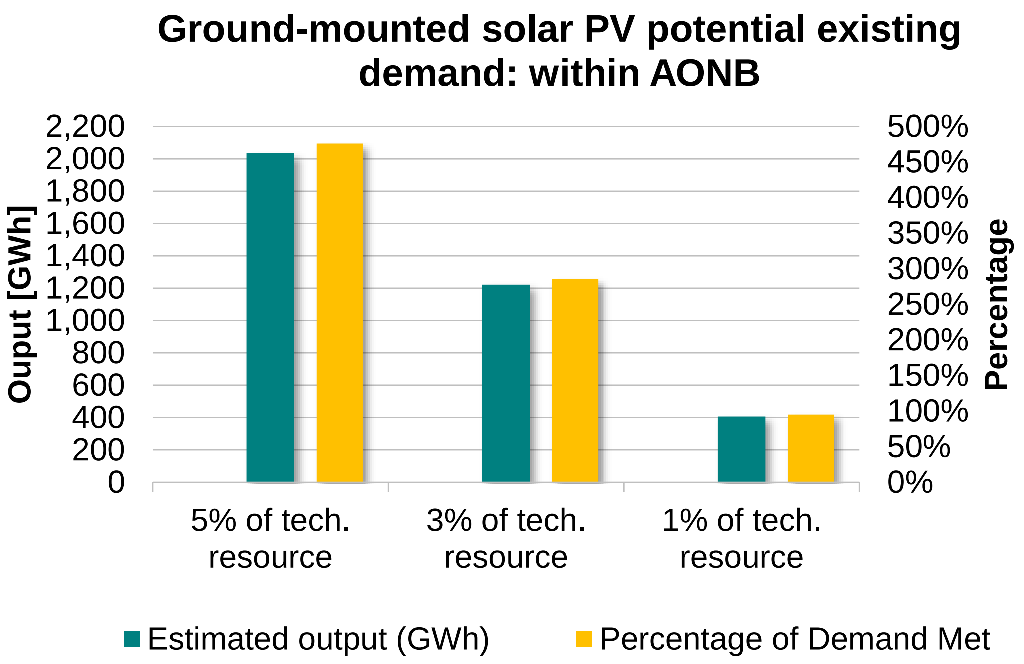


Figure 13: Ground-mounted solar PV potential electricity output and 2050 electricity demand within Cotswold District savings – within land inside of the Cotswolds AONB

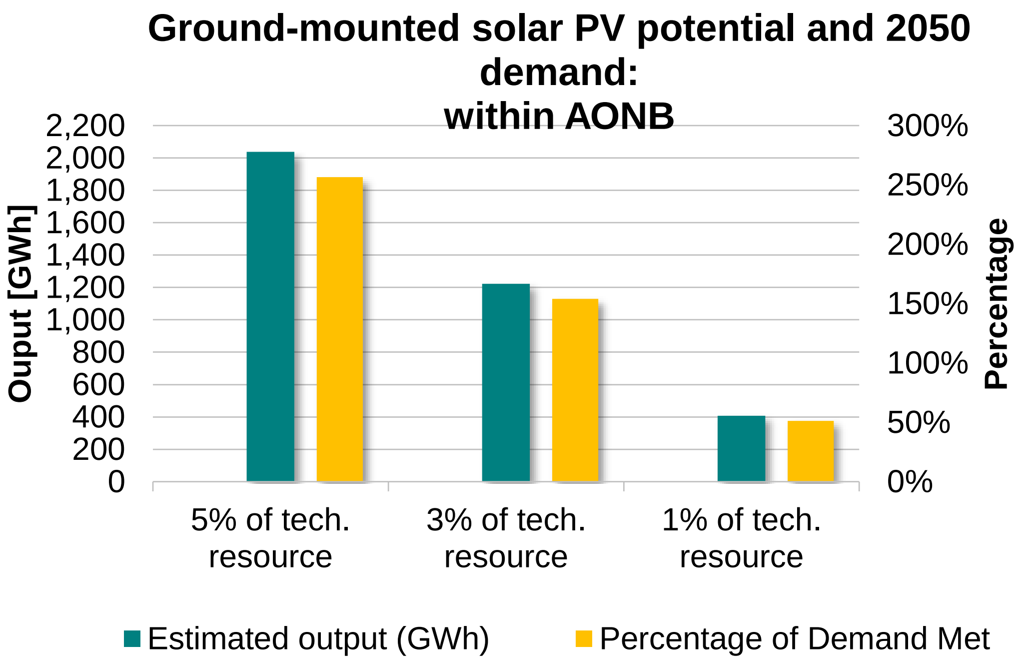


Table 4: Potential solar capacity and output

Location	Development Scale	Potential installed capacity (MW)	Electricity output (MWh/year)	Potential CO_2 savings (tonnes/year)	Percentage of existing electricity demand (428 GWh)	Percentage of 2050 electricity demand (794 GWh)
Whole Authority	100% of technical potential	56,288	51,872,131	12,086,207	12120%	6535%
	5% of technical potential	2,814	2,593,607	604,310	606%	327%
	3% technical potential	1,689	1,556,164	362,586	364%	196%
	1% of technical potential	563	518,721	120,862	121%	65%
Land outside of the Cotswolds AONB	100% of technical potential	12,084	11,135,714	2,594,621	2602%	1403%
	5% of technical potential	604	556,786	129,731	130%	70%
	3% technical potential	363	334,071	77,839	78%	42%
	1% of technical potential	121	111,357	25,946	26%	14%
Land within of the Cotswolds AONB	100% of technical potential	44,204	40,736,418	9,491,585	9518%	5132%
	5% of technical potential	2,210	2,036,821	474,579	476%	257%
	3% technical potential	1,326	1,222,093	284,748	286%	154%
	1% of technical potential	442	407,364	94,916	95%	51%

Maps showing the key constraints and resulting potentially suitable land for solar development are presented in Appendix B.

An assessment of this nature necessarily has certain limitations. Cumulative landscape and visual effects, in particular, would clearly occur if all the identified solar development potential were to be realised. Cumulative effects, however, cannot be taken into account in a high-level assessment of this nature and must be considered on a site by site basis. In addition, the current electricity networks would not support this scale of installed capacity, and as such installation would be dependent upon increasing the capacity of the network. Due to the less constrained nature of solar, relative to wind, in terms of the factors that can reasonably be considered within a high-level resource assessment, a large area of land has been identified as technically suitable for ground mounted solar; but in practice development of all or even the majority of this land would clearly not be appropriate.

Issues affecting deployment

Considerations, other than cumulative impact, that would reduce the deployable potential of solar PV in practice include landscape sensitivity, grid connection and development income. These are discussed in turn below:

Landscape sensitivity

The majority of Cotswolds District falls within the Cotswolds National Landscape, an Area of Outstanding Natural Beauty (AONB). As noted above, in agreement with the Council, this was initially excluded from the Landscape Sensitivity Assessment undertaken as part of this study. It is noted that all LCTs have a 'low' sensitivity to 'very small' solar PV developments, except for TV2, in which the sensitivity to solar VP developments of this type is 'low-moderate'. All LCTs have a 'low-moderate' sensitivity to 'small' solar PV developments except for VM1 and VM2, in which the sensitivity to solar PV developments of this scale is assessed to be 'moderate'. Sensitivity to 'medium' scale solar PV developments was mixed across the district. All accessed LCT were judges to have at least a 'moderate -high' sensitivity to 'large ' solar PV developments, whilst all LCTs had a The rest of the district has at least 'moderate-high' landscape sensitivity 'very large ' solar PV developments (see Figure 2.2-Figure 2.6 in Appendix C). Overall, the south of the district as well as VE1 tended to have a slightly lower sensitivity to solar development of all sizes when assessed at a Landscape Character Type (LCT) level.

As the sensitivity assessment notes, landscape sensitivity varies within LCTs in practice, and particular development sites may be identified within individual LCTs that have lower sensitivity than that of the LCT overall. Landscape and visual impact is also ultimately a consideration that needs to be weighed within the overall planning balance. The sensitivity assessment, however, can be used to guide development towards less sensitive areas in the first instance, and then to ensure that careful consideration is given to the choice of solar PV development locations, numbers and scales, particularly in areas identified to be of higher sensitivity. Please refer to the separate Landscape Sensitivity Assessment in Appendix C for further details.

Grid connection

A key consideration in relation to solar PV development viability is the interaction between development income and grid connection costs. As noted above, at the present time viable solar developments are generally larger scale. It is understood, however, that even larger scale solar developments will only generally be viable at present where a grid connection is available in relatively close proximity to the development site, and does not involve significant network reinforcement costs. Although connections can in principle be made either into existing substations or into power lines (a 'tee in' connection), proximity requirements alone would limit the deployable solar PV potential in much of Cotswolds District at the present time.

The generally constrained nature of the electricity network in Cotswolds District presents a further challenge, with no substations having been identified at the present time with over 30MW available capacity. DNOs upgrade the network to create extra capacity which can be applied for in advance, even when these upgrades take years to come online. It is therefore worth periodically checking with the DNO on capacity at a specific site of interest.

Further details on network capacity within the District are provided in section **Error! Reference source not found.**.

Development income

The current lack of financial support for solar PV will particularly constrain the deployable potential of smaller schemes and schemes at greater distances from potential grid connection points. The present assessment cannot, however, rule out the potential for such schemes, bearing in mind that the financial context for solar is changing – for example solar is to be included in the next round of the Contracts for Difference (CfD) auctions. Renewable generators located in the UK that meet the eligibility requirements can apply for a CfD by submitting what is a form of 'sealed bid'. Round 4 of auctions is due to open in December 2021, and the Government has confirmed that this will include Pot 1 technologies, such as solar and onshore wind.

Over recent years solar panel costs also have reduced significantly, and as such subsidy-free solar energy schemes in the right locations are financially viable at larger scales. Solar PV module prices have dropped in price by 89% since 2010. Forecasting published by the BEIS also places solar as the cheapest source of new power generation for the coming years. Between 2025 and 2040, it is anticipated that solar parks will be more cost effective than offshore or onshore wind, gas, nuclear and other technologies[11]. It is noted however that at present developers are mostly interested in pursuing large scale commercial ground mounted solar PV schemes to ensure viability via economies of scale.

With regards to smaller scale solar developments, the Smart Export Guarantee has been introduced since January 2020[12]. This is an obligation set by the Government for licensed electricity suppliers to offer a tariff and make payment to small-scale low-carbon generators for electricity exported to the National Grid, providing certain criteria are met. This could help to increase the financial viability of solar energy developments of up to 5MW capacity. However, the obligation does not provide financial benefits equal to the previous FiT scheme, as it only provides payments for electricity export, not generation, and it does not provide a guaranteed price for exported electricity. In its first year of operation, several new tariffs were launched, up to a peak of 11p/kWh, and the scheme is running smoothly, and enables customers to shop around for the best tariff, incentivising suppliers to increase their prices to compete[13]. However, in April 2021 the Environmental Audit Committee wrote a letter to the Business Secretary raising concern about the lack of clarity from the Government on the role of community energy in decarbonising the energy sector, and called for the introduction of a floor price above zero for the Smart Export Guarantee to help support such community energy[14]. It may therefore be that future changes to the Smart Export Guarantee or introduction of additional schemes may increase the potential developer income on solar PV developments.

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[11] Solar Trade Association – Solar Energy UK Impact Report 2020.

[12] Ofgem (2020) About the Smart Export Guarantee (SEG). Available at: www.ofgem.gov.uk/environmental-programmes/smart-export-guarantee-seg/about-smart-export-guarantee-seg.

[13] Solar Power Portal (2021) Ticking along: How the SEG has fared in its first year. Available at: https://www.solarpowerportal.co.uk/blogs/ticking_along_how_the_seg_has_faired_in_its_first_year.

[14] UK Parliament (2021) Regulatory barriers and lack of Government strategy stalling UK community energy on path to net zero. Available at: https://committees.parliament.uk/committee/62/environmental-audit-committee/news/154954/regulatory-barriers-and-lack-of-government-strategy-stalling-uk-community-energy-on-path-to-net-zero/.

Wind power

Description of technology

Onshore wind power is an established and proven technology with thousands of installations currently deployed across many countries throughout the world. The UK has the largest wind energy resource in Europe.

Turbine scales do not fall intrinsically into clear and unchanging size categories. At the largest scale, turbine dimensions and capacities are evolving quite rapidly. The deployment of turbines at particular ‘typical’ scales in the past has also been influenced by changing factors which include the availability of subsidies of different kinds. As defined scales need to be applied for the purpose of the resource assessment, the assessment has used five size categories based on consideration of current and historically ‘typical’ turbine models:

- Very large (150-200m tip height).
- Large (100-150m tip height).
- Medium (60-100m tip height).
- Small (25-60m tip height).
- Very small (<25m tip height).

An assessment of technical potential for very small wind (<25m height) was not undertaken as it is not possible to define areas of suitability for these using the same assessment criteria. Notional turbine sizes for the purposes of the present resource assessment are approximately intermediate within each class size (Table 5).

Table 5: Notional turbines used for the resource assessment.

Scale	Typical Turbine Installed Capacity	Electricity output (MWh/year)[15]	Typical Turbine Height (maximum to blade tip)	Average number of UK household's electricity demand that could be met per turbine[16]
Very large	4MW	10,021	175m	2,657
Large	2.5MW	6,263	125m	1,660
Medium	500kW	1,253	80m	332
Small	50kW	125	45m	33

Most turbines above the smallest scales have a direct connection into the electricity network. Smaller turbines may provide electricity for a single premises via a 'private wire' (e.g. a farm or occasionally a large energy use such as a factory), or be connected to the grid directly for export. Typically, turbines will be developed in larger groups (wind farms) only at the larger scales. The amount of energy that turbines generate will depend primarily on wind speed but will be limited by the maximum output of the individual turbine (expressed as 'installed capacity' in Table 5).

A review of wind turbine applications across the UK found that tip heights range from less than 20m up to around 200m, with larger turbine models particularly in demand from developers following the reduction in financial support from Government. The majority of operational and planned turbines range between 80m and 175m, with the majority at the larger end of the scale.

As of 2020, the UK had 14,282 MW of installed onshore wind capacity, providing 34,948 GWh electricity during the year[17]. Since the removal of financial support and the restrictive policy requirements in the National Planning Policy Framework (NPPF) onshore wind development activity has moved overwhelmingly away from England

[15] Assuming a single capacity factor of 28.6%, as based on regional data (see paragraph **Error! Reference source not found.**).

[16] Assuming an annual consumption of 3,772kWh. BEIS (2021) Energy consumption in the UK. Available at: https://www.gov.uk/government/statistics/energy-consumption-in-the-uk.

[17] Department for Business, Energy & Industrial Strategy (March 2021) Energy Trends: UK renewables: Table 6.1 - Renewable electricity capacity and generation (ET 6.1 - quarterly). Available at: www.gov.uk/government/statistics/energy-trends-section-6-renewables.

towards Scotland and Wales, where it is focusing particularly on sites with high wind speeds and the ability to accommodate larger numbers of tall turbines.

Existing development within Cotswold District

Cotswold District Council planning application data[18] indicates that there are four granted wind turbine schemes within the district, totalling 36kW and averaging at 12kW per scheme, equating to 0.02% of the authority's current electricity demand. In addition, one scheme was refused[19] within the district and three additional schemes withdrawn; one 10kW scheme and two 55kW schemes.

Technical potential (i.e. results of the assessment)

Assumptions used to calculate technical potential

The assessment of technical potential for very large, large, medium and small turbines was undertaken using GIS involving spatial mapping of key constraints and opportunities. The assessment identified areas with potential viable wind speeds (applying a reasonable but relatively generous assumption in this respect, bearing in mind that only the highest wind speeds are potentially viable at the present time) and the number of turbines that could be theoretically deployed within these areas. A series of constraints relating to physical features and environmental/heritage protection were then removed. The remaining areas have 'technical potential' for wind energy development. The key constraints and opportunities considered are set out in detail in in Appendix D.

Landscape Sensitivity Assessment

Landscape and visual impact has historically often been one of the defining consenting considerations for planning applications for wind developments, and has therefore been a particularly important influence on the choice of turbine scales and locations by developers. The landscape sensitivity assessment therefore also considered wind developments of differing scales.

Please refer to the Landscape Sensitivity Assessment in Appendix C for further details.

Technical potential

Table 6Table 8 provides a summary of the technical potential for wind energy within Cotswold District. The analysis examined the potential for very large, large, medium and small turbines. Where potential existed for more than one size of turbine, it was assumed that the larger turbines would take precedence i.e. it was assumed that the

[18] Note: This excludes anything below 10kW.
[19] The capacity of this application is unknown.

largest potential turbine in each case would be installed. This was in order to calculate the most realistic technical potential for wind, as to ensure viability, developers usually seek to install the largest capacity turbines.

This was in order to calculate the maximum technical potential for wind. The calculation of wind capacity involved applying an assumption concerning development density. Turbines are spaced within developments in practice based on varying multiples of the rotor diameter length (on different axes). Although separation distances vary, a 5 x 3 x rotor diameter oval spacing[20], oriented 135º, (greater in the prevailing wind direction, taken to be southwest as the 'default' assumption in the UK) was considered a reasonable general assumption at the present time in this respect. In practice, site-specific factors such as prevailing wind direction and turbulence are taken into account by developers, in discussion with manufacturers. Bearing in mind the strategic nature of the present study, the density calculation did not take into account the site shape and minimum site size, and a standardised density was used instead:

- Very large: 4 turbines per km^2.
- Large: 8 turbines per km^2.
- Medium: 22 turbines per km^2.
- Small: 167 turbines per km^2.

The calculation of potential energy yield then required application of a 'capacity factor' i.e. the average proportion of maximum turbine capacity that would be achieved in practice over a given period. Capacity factors vary in practice in accordance with wind speed, terrain and turbine scale. It was not possible to find suitable historic data on capacity factors, taking into account these kinds of variations for the present study, and so a single capacity factor of 28.6% was used for all turbine scales, as based on regional data[21]. It is noted that this averaged capacity factor will vary depending on turbine size as larger turbines can access higher windspeeds at greater elevations whilst smaller shorter turbines may suffer reduced wind speeds due to surface roughness of the ground. This variation in capacity factor between turbine scales is however beyond the scope of this strategic assessment and is not considered.

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[20] To mitigate impacts on the productivity of wind turbines located close to one another caused by wind turbulence, it is standard practice for developers to maintain an oval of separation between turbines that is equal to 5 times the turbine rotor diameter (the cross sectional dimension of the circle swept by the rotating blades) on the long axis, and 3 times the rotor diameter on the short axis.

[21] BEIS (2020) Quarterly and annual load factors: Annual Regional PV Load Factors, averaged at 28.6% for the South West region over the last six years. Available at: https://www.gov.uk/government/publications/quarterly-and-annual-load-factors.

The assessment results indicate that there is a technical potential to deliver up to around 4,506MW of wind energy capacity in Cotswold District, with 862MW capacity within land outside of the AONB and 3,643MW within the AONB, with the greatest potential for small turbines (see Figure 14 to Figure 22 and Table 6). This would provide 1,422%, 272% and 1,150% of the projected electricity demand in Cotswold District in 2050 respectively).

Table 6: Onshore technical wind potential capacity, output and carbon savings within Cotswold District

Location	Development Scale	Estimated total capacity (MW)	Electricity output (MWh/year)	Potential CO_2 savings (tonnes/year)	Percentage of existing electricity demand (428 GWh)	Percentage of 2050 electricity demand (794 GWh)
Whole Authority	Small	2,084	5,221,675	1,216,650	1220%	658%
	Medium	847	2,121,332	494,270	496%	267%
	Large	556	1,392,669	324,492	325%	175%
	Very Large	1,019	2,553,185	594,892	597%	322%
	Total	**4,506**	**11,288,860**	**2,630,304**	**2,638%**	**1,422%**
Land outside of the Cotswolds AONB	Small	426	1,067,148	248,646	249%	134%
	Medium	159	398,644	92,884	93%	50%
	Large	91	227,130	52,921	53%	29%
	Very Large	187	467,869	109,014	109%	59%
	Total	**862**	**2,160,792**	**503,465**	**505%**	**272%**
Land inside of the Cotswolds AONB	Small	1,658	4,154,526	968,005	971%	523%
	Medium	688	1,722,688	401,386	402%	217%
	Large	465	1,165,539	271,571	272%	147%
	Very Large	832	2,085,315	485,878	487%	263%
	Total	**3,643**	**9,128,068**	**2,126,840**	**2,133%**	**1,150%**

Figure 14: Onshore wind potential capacity and carbon savings – within the whole of Cotswold District

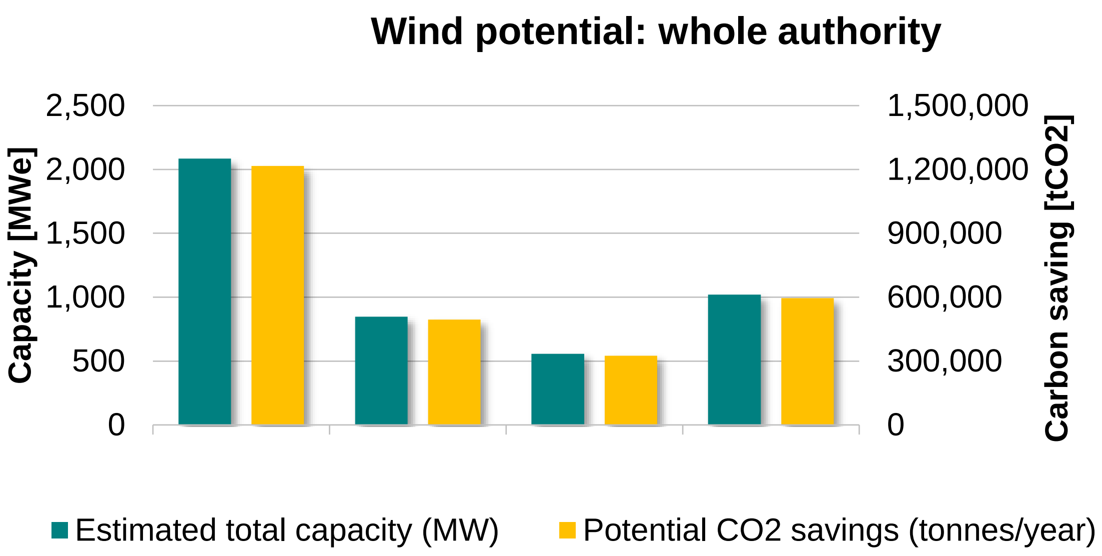


Figure 15: Onshore wind potential electricity output and current electricity demand within Cotswold District savings – within the whole of Cotswold District

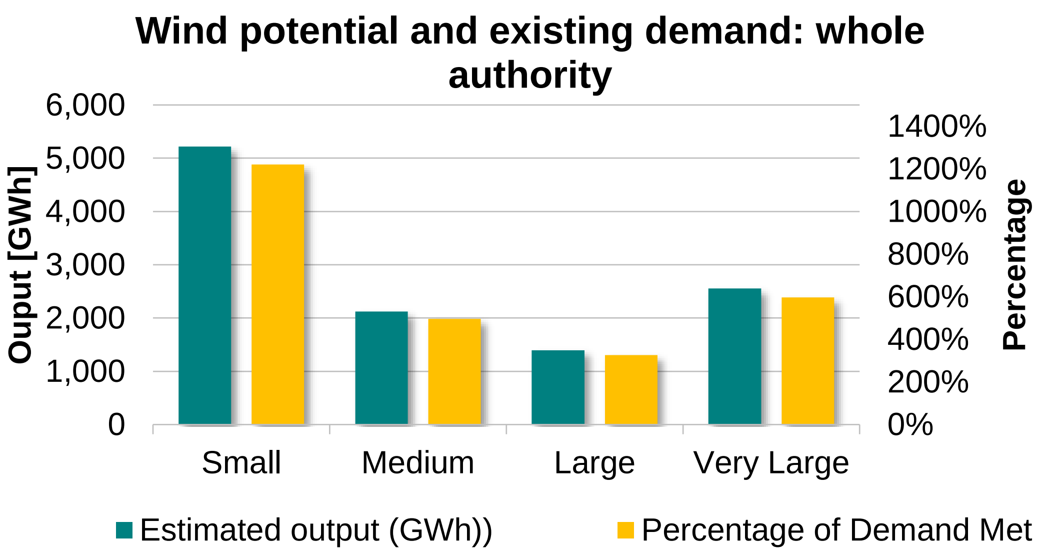


Figure 16: Onshore wind potential electricity output and 2050 electricity demand within Cotswold District savings – within the whole of Cotswold District

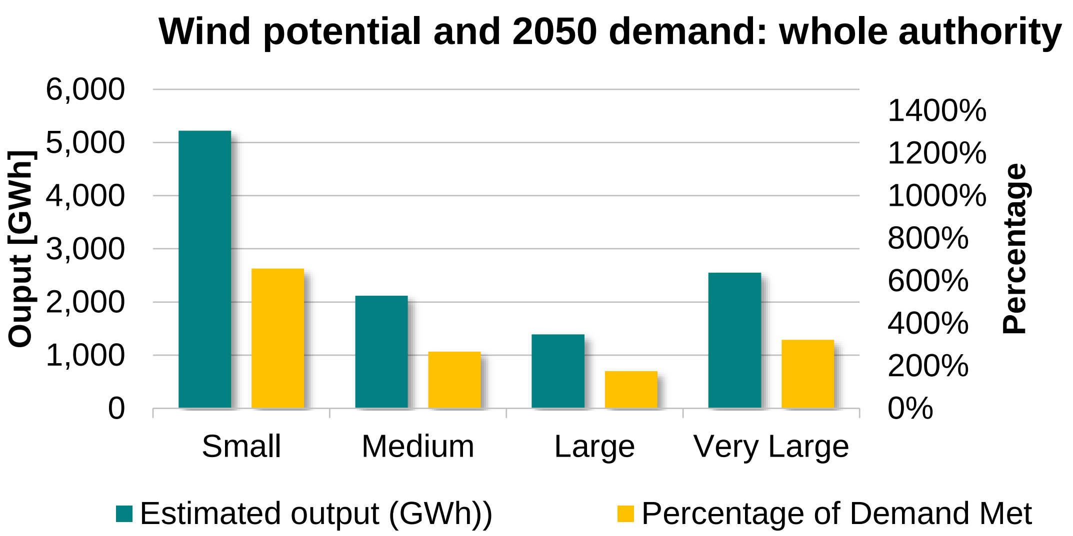


Figure 17: Onshore wind potential capacity and carbon savings – within land outside of the Cotswolds AONB

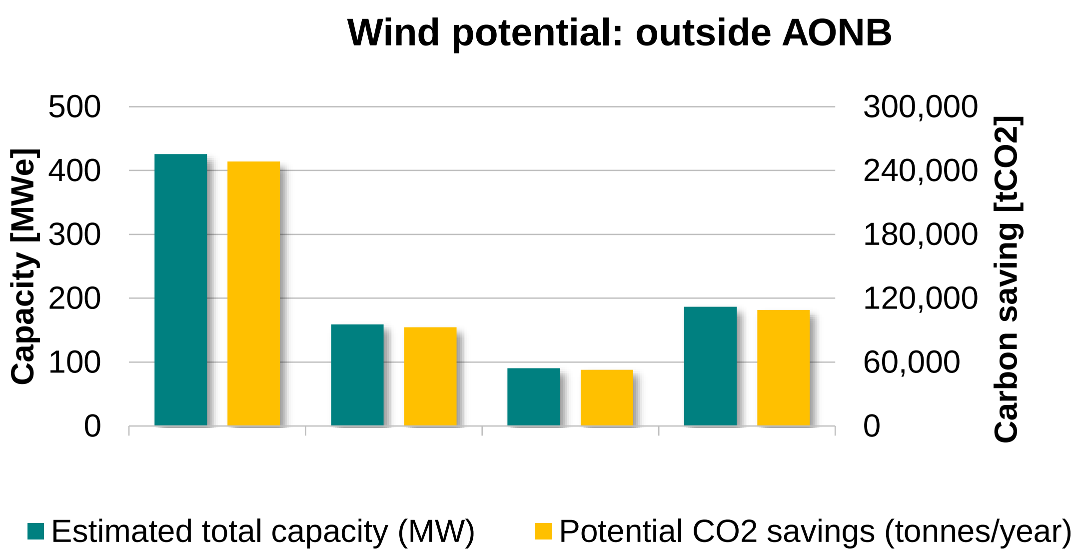


Figure 18: Onshore wind potential electricity output and current electricity demand within Cotswold District savings – within land outside of the Cotswolds AONB

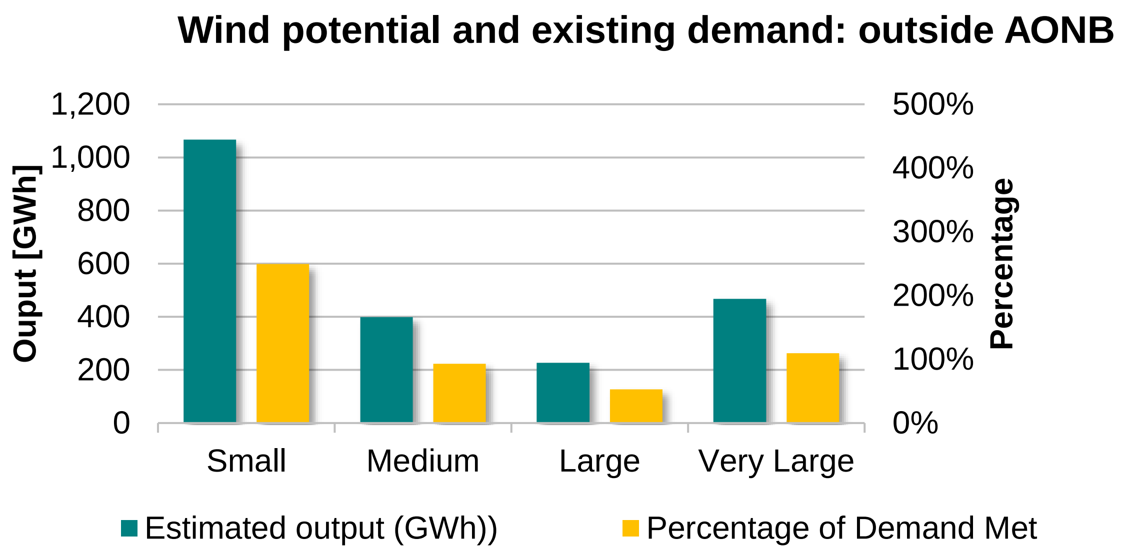


Figure 19: Onshore wind potential electricity output and 2050 electricity demand within Cotswold District savings – within land outside of the Cotswolds AONB

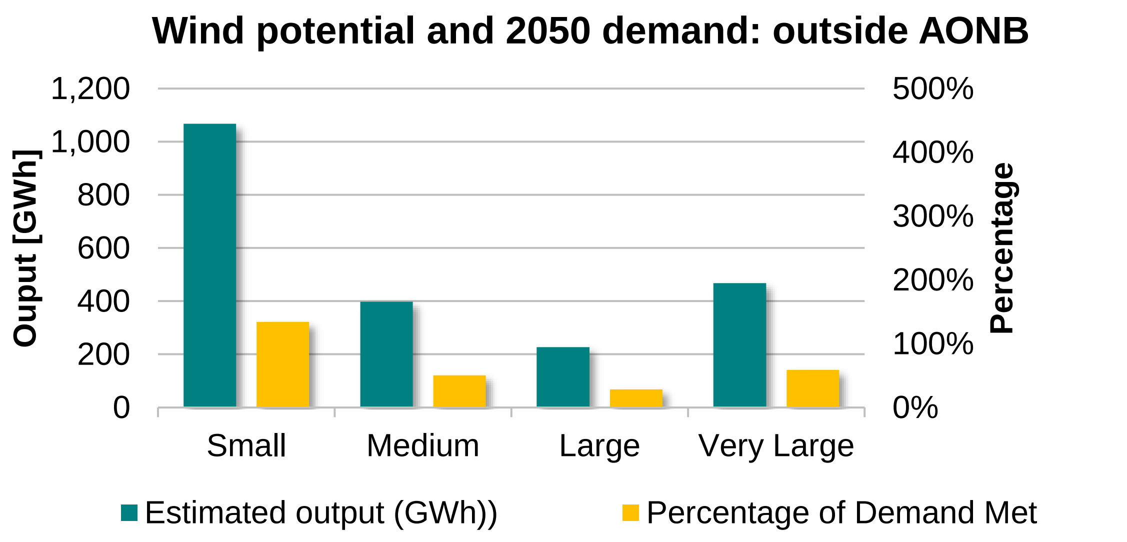


Figure 20: Onshore wind potential capacity and carbon savings – within land inside of the Cotswolds AONB

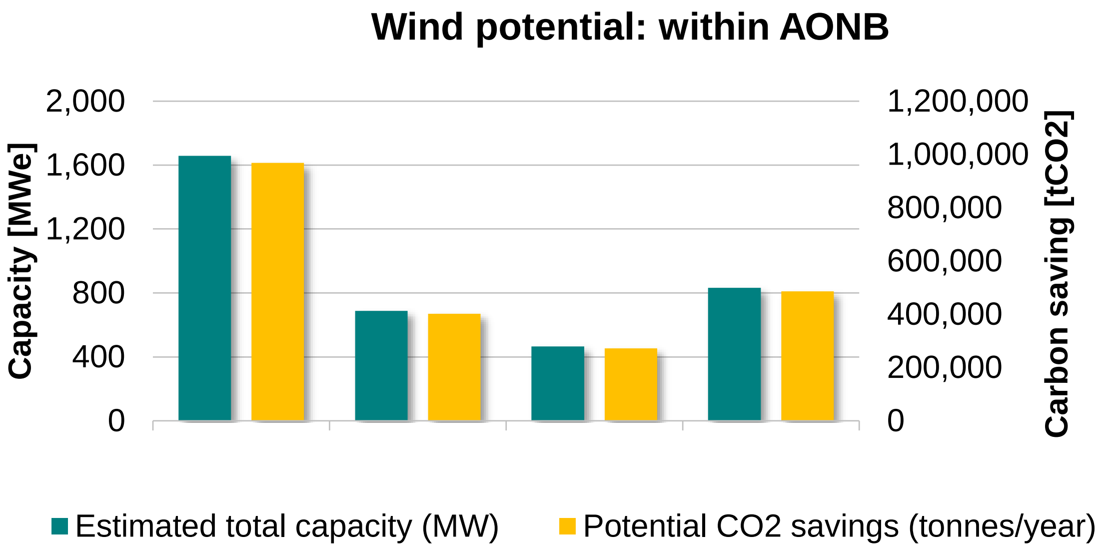


Figure 21: Onshore wind potential electricity output and current electricity demand within Cotswold District savings – within land inside of the Cotswolds AONB

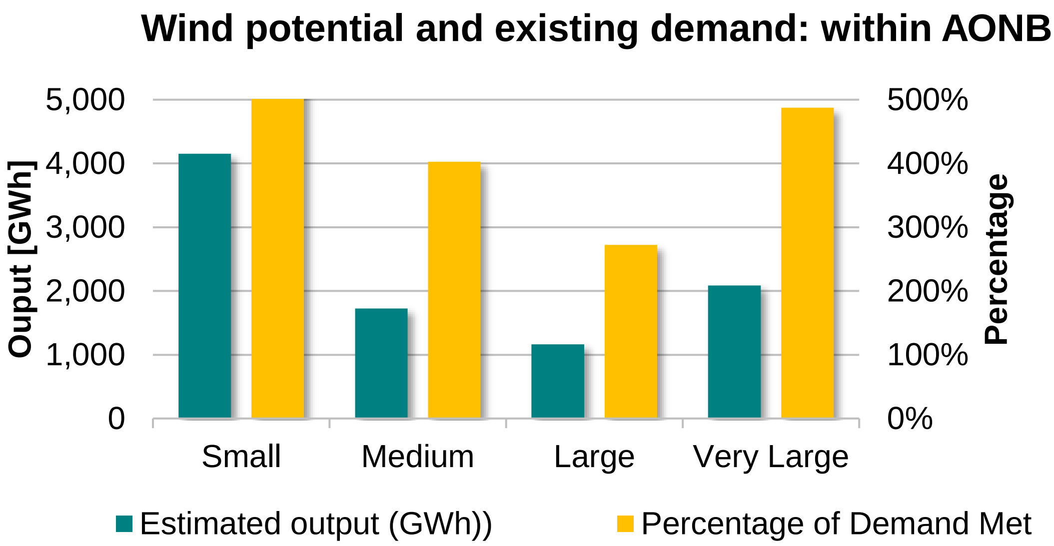
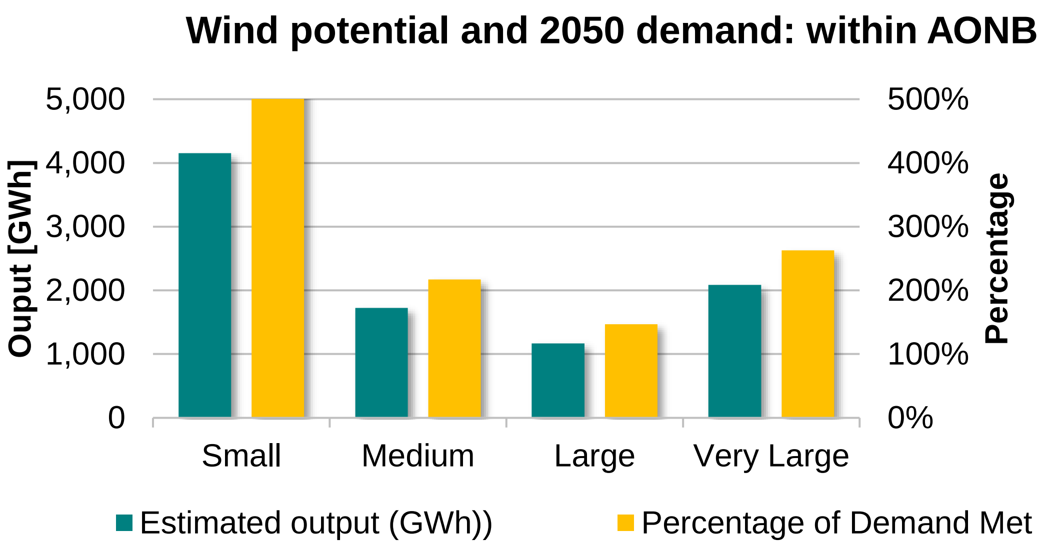


Figure 22: Onshore wind potential electricity output and 2050 electricity demand within Cotswold District savings – within land inside of the Cotswolds AONB



The maps included in Appendix B show the areas which have been identified via the GIS analysis to have technical potential for wind development at each considered turbine scale. These figures indicate that there is greatest potential for wind generation in the centre and north of the district.

In order to illustrate the GIS tool parameters, a series of opportunity and constraints maps were also produced (Appendix B):

- Figure 1.6: Wind Speed at 50m above ground level
- Figure 1.7: Wind constraints – Natural heritage
- Figure 1.8: Wind constraints – Cultural heritage
- Figure 1.9: Wind constraints – Physical constraints for small scale
- Figure 1.10: Wind constraints – Physical constraints for very large scale
- Figure 1.11: Opportunities and Constraints: small scale wind development
- Figure 1.12: Opportunities and Constraints: medium scale wind development
- Figure 1.13: Opportunities and Constraints: large scale wind development
- Figure 1.14: Opportunities and Constraints: very large scale wind development
- Figure 1.15: Opportunities for Wind Development – All scales

Figure 1.6 in Appendix B shows the wind speed within the district at 50m above ground level (agl).

This shows that the highest winds speeds are predominantly located in the northwest of the district, with the lowest wind speeds located along the river valleys and in the south of the district. Other mapped constraints that have influenced the assessment outcomes are included in Appendix B. It is noted that maps depicting the physical constraints are only included for small and very large turbines for illustrative purposes, showing the minimum and maximum buffer distances applied to physical features depending on turbine size.

An assessment of this nature will necessarily have certain limitations, including:

Wind data – it is important to note that the macro-scale wind data which was used for this assessment can be inaccurate at the site-specific level and therefore can only be used to give a high level indication of potential capacity and output within Cotswold District. Developers will normally require wind speeds to be accurately monitored using anemometers for an extended period (typically at least one to two years) for commercial scale developments.

Cumulative effects – multiple wind turbine developments can have a variety of cumulative effects. Cumulative landscape and visual effects, in particular, would clearly occur if all the identified small wind development potential were to be realised. Cumulative effects, however, cannot be taken into account in a high-level assessment of this nature and must be considered on a development-by-development basis.

Site-specific features and characteristics – in practice, developments outside protected areas may potentially impact on amenity and sensitive 'receptors' such as protected species. These impacts can only be assessed via a site-specific survey.

Aviation – although operational airports and airfields, as well as MOD land, were considered to be constraints on wind development, aviation interests were not used to define potentially suitable land as impacts and mitigation need to be considered on a development by development basis.

Development Allocations – due to the timing of the resource assessment in relation to Cotswold District's next Local Plan programme, all site allocations from the adopted Cotswold District Local Plan were considered to be a constraint on wind development due to the presence of built development.

Issues affecting deployment

The technical wind development potential within Cotswold District, as estimated through application of reasonable constraints within a GIS tool, is not the same as the development capacity that may be expected to be deployed in practice.

Certain limitations of the resource assessment with respect to deployable wind potential have already been noted in the previous section. For example, cumulative impacts can only be considered fully when developments come forward in practice, but would generally be expected to reduce the overall deployable capacity. However, there are four particular issues that affect the deployable wind potential that merit individual consideration including: landscape sensitivity, grid connection, development income and planning issues. These are discussed in turn below:

Landscape sensitivity

The majority of Cotswolds District falls within the Cotswolds Area of Outstanding Natural Beauty (AONB). As noted above, in agreement with the Council, this was initially excluded from the Landscape Sensitivity Assessment undertaken as part of this study.

All LCTs have a 'low' landscape sensitivity to 'very small ' wind energy developments, except for VM1 an VM2 in which sensitivity was assessed to be 'low-moderate'. The northeast of the district has moderate sensitivity to at least ‘small’ scale wind development whilst all land outside of the AONB has at least moderate sensitivity to ‘medium’ scale wind developments (see Figure 2.7-Figure 2.11 in Appendix C). All land outside of the AONB has high sensitivity to ‘very large’ scale wind developments. Generally, the south of the district tended to be less sensitive to wind energy developments of all scales, with VM1 and VM2 in the north-east as well as the smaller scale TV4 LCTs tending to be more sensitive to wind energy developments of any scale.

As the sensitivity assessment notes, landscape sensitivity varies within Landscape Character Types (LCTs) in practice, and particular development sites may be identified within individual LCTs that have lower sensitivity than that of the LCT overall. Landscape and visual impact is also ultimately a consideration that needs to be weighed within the overall planning balance. The sensitivity assessment, however, can be used to guide development towards less sensitive areas in the first instance, and then to ensure that careful consideration is given to the choice of turbine locations, numbers and scales, particularly in areas identified to be of higher sensitivity. Please refer to the separate Landscape Sensitivity Assessment in Appendix C for further details.

Grid connection

Historically, it has been possible to connect a variety of wind energy development scales into the distribution network at a wide range of distances from the nearest connection point. This situation has changed dramatically over recent years due to two factors in combination:

- The distribution network, and even the transmission network, have become increasingly congested, to the point at which connections in many cases cannot take place without extremely expensive network enforcement costs (which fall to the developer) being incurred, or generation being curtailed, or both.
- The Government’s cancelling of subsidies for onshore wind in 2016 has reduced wind development incomes to the point at which previously affordable reinforcement works would now render many developments unviable, particularly those of smaller scale.

It is possible that, over the next Local Plan period, strategic changes to the network and its management may open up new connection opportunities. In particular, District Network Operators (DNOs) are making the transition to become District Service Operators (DSOs), and as DSOs, will have a greater range of tools that they will be able to use to manage the network. They may, for example, be able to facilitate an enhanced role for energy storage in balancing out the effects of increasing grid penetration of intermittent renewable generators. Further details on network capacity within the district are provided in section **Error! Reference source not found.**.

Development income

Financial support mechanisms in the form of Government subsidies (such as the Renewables Obligation (RO) and FiT) previously allowed onshore wind to be developed at a variety of scales and at a variety of wind speeds. The RO closed to all new generating capacity on 31 March 2017 and the FiT closed to new applicants from 1 April 2019.

The Contracts for Difference (CfD) scheme is now the Government's main mechanism for supporting low-carbon electricity generation[22]. The first auction included 'Pot 1' technologies; 'established' technologies, including onshore wind. The successful applicants of Round 1 auctions, as announced in February 2015, included onshore wind developments. Since then, Round 2 and Round 3 of the auctions in September 2017 and September 2019 excluded Pot 1 technologies including onshore wind developments.

Round 4 of auctions is due to open in December 2021, and the Government has confirmed that this will include Pot 1 technologies, such as onshore wind[23]. As a result of the general decline in financial support for onshore wind, developers are predominantly interested in developing wind turbines in locations with high wind speeds, such as Scotland, Wales and northern England, to enable schemes to be financially viable.

Developers have found that CfDs do not make schemes financially viable in southern England where wind speeds are typically lower, and any potentially financially viable developments require a number of very large turbines to maximise the power output. These schemes are however, unlikely to be acceptable in most locations in southern

[22] Department for Business, Energy, and Industrial Strategy (2020) Contracts for Difference. Available at: www.gov.uk/government/publications/contracts-for-difference/contract-for-difference.

[23] Department for Business, Energy, and Industrial Strategy (2020) Contracts for Difference for Low Carbon Electricity Generation: Government response to consultation on proposed amendments to the scheme. Available at: www.gov.uk/government/collections/contracts-for-difference-cfd-allocation-round-4.

England at the present time. Moreover, the resource assessment indicates that there are few opportunities of this scale in Cotswolds District, which is unsurprising considering its location and geographical characteristics. The main opportunities are instead at the small scale, and almost all planning applications for wind turbines within the district to date have been for small or very small scale developments, designed to connect 'behind the meter' to meet on-site demand rather than export to the grid. However, small scale developments are not considered by most developers to be financially viable at the present time.

Various initiatives can in theory improve wind development viability beyond the provision of subsidy. These could include, for example, establishment of local supply companies that can 'capture' the uplift from wholesale to retail energy prices. The signing of Power Purchase Agreements (PPA), such as between a developer and the Council, agreeing that the developer will sell the electricity generated to the Council, may make individual turbines viable such as on an industrial estate.

Capital costs such as turbine prices may also continue to fall[24], potentially driven in part by the loss of subsidy itself – although the migration of demand to larger turbines in a post-subsidy context is likely to limit any effect in this regard on smaller turbine sizes.

In addition, the Smart Export Guarantee has been introduced since January 2020[25]. This is an obligation set by the Government for licensed electricity suppliers to offer a tariff and make payment to small-scale low-carbon generators for electricity exported to the National Grid, providing certain criteria are met. Wind developments of up to 5MW capacity could benefit from this obligation. However, as mentioned above, the obligation does not provide equal financial benefits to the previous FiT scheme (which provided funding for smaller scale renewable energy developments), as it only provides payments for electricity export, not generation, and it does not provide a guaranteed price for exported electricity.

Overall, viability challenges, based on reduced income relative to capital costs, are a systemic challenge for wind development at all scales within southern England at the present time – to the extent that, if this challenge is not addressed by Government, the deployable wind potential within Cotswold District is likely to be and remain close to zero.

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[24] IRENA (2020) Renewable Power Generation Costs in 2019. Available at: www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019.

[25] Ofgem (2020) About the Smart Export Guarantee (SEG). Available at: www.ofgem.gov.uk/environmental-programmes/smart-export-guarantee-seg/about-smart-export-guarantee-seg.

Planning issues

In addition to the lack of financial support mechanisms, the NPPF requires that wind energy development may only be permitted within areas identified suitable for wind energy developments within Local Plans and where the development has the backing of the local community. The legitimate interpretation of this provision has not been definitively established via case law. However, it has had a discouraging influence on developers. Larger developers are therefore currently not interested in pursuing wind farm developments within southern England, although there may be scope for small scale, single turbine installations implemented by farmers or community energy groups. The assessment of technical potential within this study however could be used within the local plan to identify those areas which are potentially suitable for wind energy development.

Hydropower

Overview

Hydropower is a well-established and proven technology and there are few technological constraints to its use other than ensuring that water course heads (height difference) and flow rates are adequate throughout the year, the site has adequate access and 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.

Hydropower makes 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 an established 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).

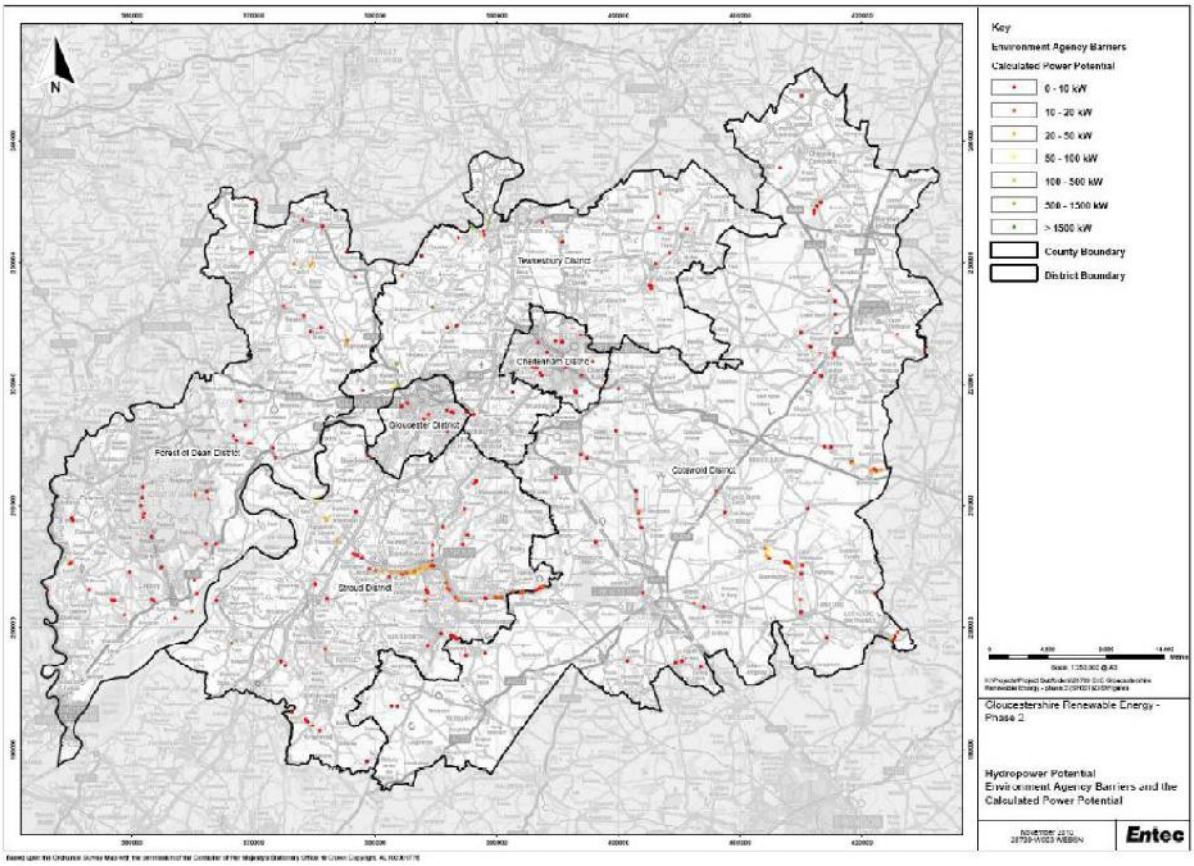
Small-scale hydro schemes will typically include dams, weirs, leats, turbine houses and power lines, which will have a visual impact on the locality, but which can usually be minimised by careful siting and design. Other important considerations include hydrology and the river ecology. Hydro plants may 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.

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.

In the Cotswold District as of 2019 there was a total of 7kW of Hydropower as reported in Feed-in Tariffs – sub-national statistics. This is made up of one non-domestic and one domestic installation (domestic 1.5kW and non-domestic 6.0kW).

Conducting a new assessment for Cotswold District's hydropower resource is outside of the scope of this study, and so the information presented below is taken from an assessment undertaken by Entec in 2011 covering the whole of Gloucestershire[26]. The report reviews the potential hydropower resource across the county and identifies a number of barriers (a feature which restricts the movement of groundwater across it) and associated power potential per local authority district. Within the Cotswold district 88 potential barriers were found, as shown in Figure 23 and described in Table 7, Table 8 and Table 9.

Figure 23: Gloucestershire Potential Hydropower Barriers[26]



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[26] Gloucestershire County Council Renewable Energy Study: Phase 2 – Resource Assessment February 2011

Table 7: Types of barrier within Cotswold District

Type of Barrier	Cotswold District
Dam	1
Mill	9
Sluice	0
Waterfall	5
Weir	72
Unknown	1
Total	88

Table 8: Number of barriers in power categories in Cotswold District

Power Potential (kW)	Number of Barriers
0-10	68
10-20	11
20-50	7
50-100	1
100-500	1
500-1000	0
Total	88

Table 9: Power potential of barriers in power categories in Cotswold District

Power Potential categories (kW)	Power potential (kW)
0-10	199
10-20	147
20-50	240
50-100	58
100-500	227
500-1000	0
Total	868

Table 7, Table 8 and Table 9 show the large number of opportunities for hydropower systems in Cotswold District. However, the majority (68%) of sites are predicted to yield a power output of under 50kW which is small. Additionally, many of the schemes under 10kW (199; 23%) may not be a viable proposition given the very low output. Opportunities for systems over 100kW should be prioritised.

Future deployment

The identified resource indicates that the majority is made up of small (<50kW) sites, most of which are unlikely to be of sufficient scale to be economically viable and so future deployment is likely to be significantly constrained.

There have previously been proposals for a Cotswold Canals Severn – Thames Transfer (CCSTT) scheme to convey water from the west of the country to the south east, which could potentially create opportunities for hydro generation through a pumped hydro storage facility. This option appears to have been discounted by Thames Water in favour of a pipeline option as it was considered likely to perform less well in terms of the key criteria of water resources and water quality, normalised cost and ease of construction and operation.

Biomass and waste

Description of resource

Biomass can be generally defined as material of recent biological origin, derived from plant or animal matter. It is often categorised as either ‘dry’ or ‘wet’ biomass, with the former more commonly combusted either to generate heat or to produce electricity, and the latter anaerobically digested to generate ‘biogas’ or used to produce a transport ‘biofuel’.

Biomass materials such as wood are widely used in many countries as a feedstock for modern heating systems. Modern biomass heating technology is well developed and has been used to provide heat to buildings of all sizes, either through individual boilers or via district heating networks. Biomass has also often been used to fuel electricity plant or combined heat and power (CHP) plant due to the low carbon emissions associated with its use.

More recently however concerns have been raised over the impacts of biomass heating on local air quality and more scrutiny has been placed on the sustainability credentials of sourcing, processing and transporting biomass feedstocks in terms of net carbon emissions and sustainable land management. Changes in land use, for example from cultivating purpose-grown energy crops, also need careful consideration in terms of impacts on biodiversity and whether the activity is the most efficient use of the land compared to alternative sustainable energy or carbon reduction/sequestration measures.

Organic wastes can also be considered as a low carbon resource if their use in energy production has prevented them from otherwise decomposing i.e. potentially releasing methane - a potent greenhouse gas.

The most common types of biomass feedstocks for energy production include:

- Virgin woodfuel, including forestry and woodland residues, and energy crops.
- Waste residues, including municipal and commercial solid waste, recycled wood waste, agricultural residues and sewage.

Virgin woodfuel

The woodfuel resource considered here includes virgin, untreated wood residues (from forestry, arboriculture, tree surgery, etc.) and the energy crops Miscanthus and Short Rotation Coppice (SRC). There is some overlap with waste where virgin wood is present in certain waste streams, but this can be difficult to segregate from non-virgin (contaminated) wood. The distinction between virgin or contaminated wood will determine the areas of legislation that will apply to its use regarding emissions permits. Woodland residues and energy crops are generally considered to be clean or ‘untreated’ whereas other waste wood residues may contain contaminants such as paint, preservative, etc. and would fall under stricter emission and pollution prevention controls.

Wood is generally considered to be a sustainable fuel if it can be shown to have been sustainably sourced, which usually means it is renewable through re-growth as part of local sustainable woodland management and does not carry excessive 'embodied' carbon from processing and transport. Logs and woodchip in particular are bulky fuels and should be sourced as locally as possible to their end-use. Wood from a sustainable source has therefore often been classed as a low carbon energy source as the carbon emissions released when combusted are balanced by that absorbed during its re-growth. Its use as part of a net-zero carbon future however is likely to require that any adverse impacts on land use and local air quality are avoided, the amount of woodfuel being burnt is genuinely replaced by re-growth or re-planting within an acceptable timescale, and that carbon emissions resulting from growing, processing and transport processes have been mitigated.

Various processes are used to prepare the wood feedstock prior to it becoming suitable for use as fuel in a range of forms including logs, woodchips, pellets and briquettes. These processes largely dictate the final specification of the biomass in terms of moisture content, size and form. Quality control of these parameters is vital for use in specific types of boiler and thermal conversion processes. Both woodland residues and energy crops can be used to produce either heat-only or electricity and heat (combined heat and power) via a range of energy conversion technologies including direct combustion, gasification and pyrolysis.

Existing development within Cotswold

As of July 2020 there were 34 domestic biomass systems in Cotswold accredited under the Renewable Heat Incentive (RHI) scheme. Taking an average capacity of 26kW[27] per installation gives a total installed capacity of nearly 0.9MW. No further data was identified on use of woodfuel within the District although there will be significant amounts used domestically in open fires, stoves and wood burners.

Results

Technical potential of forestry and woodland resource

Woodland and arboricultural residues are normally sourced as the residues of the sustainable management of existing woodland. The technically available resource can be assessed by calculating the total area of woodland in the study area and assuming a sustainable yield, which in this case is two odt/year (oven-dried tonnes/year) – a generally accepted figure across the industry. Annual tonnage of wood can then be obtained and its heat delivery potential estimated.

[27] https://www.gov.uk/government/collections/renewable-heat-incentive-statistics

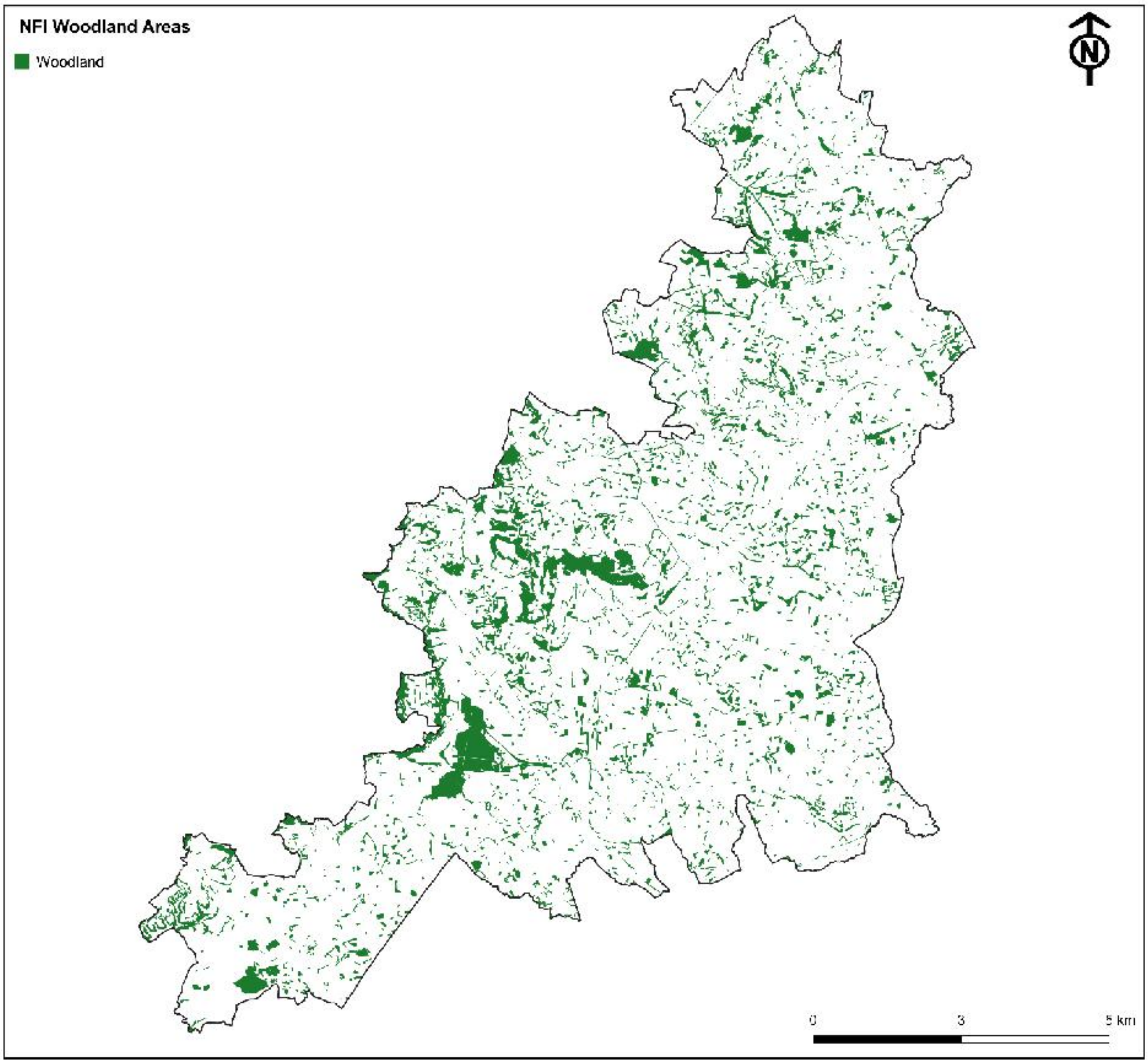
The Forestry Commission's National Forest Inventory (NFI) dataset has been used for this analysis. The NFI is produced by using satellite images to identify and classify areas of woodland, alongside ground surveys of sample areas[28]. It classifies areas of woodland into the following categories:

- Broadleaved
- Coniferous
- Mixed
- Shrub
- Young trees
- Felled
- Ground prepared for planting
- Low Density

Felled areas, ground prepared for planting, low density, shrub and young trees are excluded from the analysis because they cannot provide a sustainable source of woodfuel. They have been mentioned here because they are in the NFI, and because felled areas may be replanted in the future, while young trees will mature over time into a viable resource. Figure 24 shows areas of woodland as mapped for the study area.

[28] This means that there are occasional errors where patches in photographs have been erroneously identified.

Figure 24: Areas of woodland within Cotswold (all categories)



Using the GIS data used in the above map, the technically available resource by woodland category is shown in the table below. This estimates the annual tonnage of wood and its delivered heat potential – this has been assessed by using assumptions about the sustainable yield that can be obtained, heating plant efficiency and the energy content of wood. All assumptions are included in Appendix D.

Table 10: Woodfuel assessment of forestry and woodland resource

Woodland category	Area (Hectares)	Sustainable woodfuel yield (odt/year)	Delivered heat (MWh/year)	Proportion of estimated Cotswold building heat demand (%)	Potential CO_2 savings (tonnes/year)
Broad-leaved	10,320.53	20,641.06	92,482.25	14.45%	19,226.15
Coniferous	1,754.74	3,509.47	15,724.18	2.46%	3,268.90
Felled	152.53	305.06	1,366.83	0.21%	284.15
Mixed	1,278.14	2,556.27	11,453.37	1.79%	2,381.04
Shrub	69.30	138.60	621.02	0.10%	129.10
Young trees	942.00	1,884.00	8,441.27	1.32%	1,754.86
Ground prep	111.25	222.49	996.88	0.16%	207.24
Low density	6.20	12.39	55.53	0.01%	11.54
Total	**14,947.18**	**29,894.36**	**133,941.70**	**20.92%**	**27,845.16**
Total excl. felled, ground prep, low density, shrub and young trees	**13,783.35**	**27,566.70**	**123,512.58**	**19.29%**	**25,677.05**

The above figures relate to the resource within Cotswold only, but there is potential for surplus woodfuel to also be sourced from further afield if the cost and environmental impact of transporting the feedstock or final product is suitably assessed. The resource shown in Table 10Table 10: would increase by more than 35 times if a 40km search radius was applied from the boundary of the District. This includes the Forest of Dean area. It is likely however that a significant proportion of this resource is already being utilised for the woodfuel requirements of domestic log stoves and open fires.

A further potential source of woodfuel is from the cutting of hedgerows – however it has not been possible to assess this resource because there is no reliable yield factor for the amount of woodfuel that can be obtained from a given area or length of hedgerow.

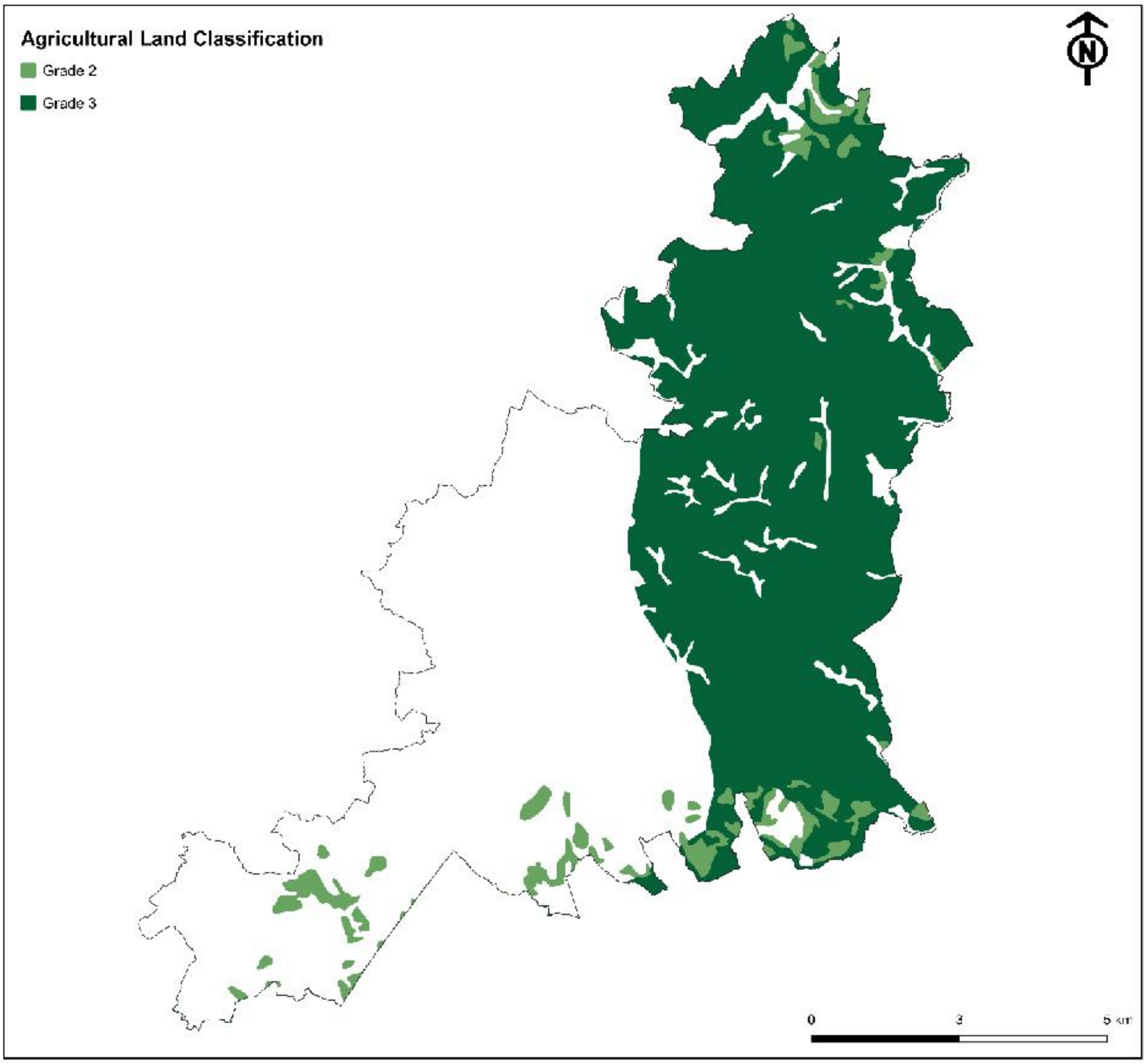
Technical potential of energy crops

The two main woodfuel energy crops are Miscanthus and Short Rotation Coppice (SRC), which are planted specifically for heat and/or electricity production. This is usually distinct from ‘biofuel’ crops such as sugar cane, maize and oilseed rape which tend to be used for transport fuels.

Miscanthus cultivation has the advantages of being able to use existing machinery, is higher yielding than SRC, undergoes annual harvesting with a relatively dry fuel product when cut, but it is more expensive to establish. SRC (commonly willow) is easier and cheaper to establish, is better for biodiversity and suitable for a wider range of boilers. However, it requires specialist machinery, is harvested every three years, and produces a wetter fuel that needs to dry before it can be used. Both crops have similar lead in times with around 4 years until they produce commercial harvests. Miscanthus will reach its peak yield in year 5 and SRC will achieve its peak yield in the second rotation which is harvested in year 7.

The technical resource for energy crops assumes that they can be grown on agricultural land of grades 2 or 3 (arable land), which for Cotswold District totals 59,552 hectares (around 51% of total land area) – see Figure 25 and Table 11Error! Reference source not found.. Grade 1 land is excluded from the analysis as it is assumed that food crops will be prioritised over energy crops in these areas. Typical constraints will preclude areas having certain types of permanent pasture and moorland, public rights of way, woodland, historic parks and gardens, and for Miscanthus, exposed areas with high average wind speeds.

Figure 25: Agricultural land classification in Cotswold



Annual yields are typically around 16-18 odt/ha for miscanthus and 8-10 odt/ha for SRC. Potential energy outputs and emissions savings are shown in Table 11. This shows two scenarios: the resource for if 1% (595 hectares) of all suitable areas was utilised and if 10% (5,955 hectares) was utilised. In the 10% scenario this could fulfil 40% of Cotswold Districts estimated building demand (if cultivating miscanthus).

Table 11: Potential yields and CO_2 savings for energy crops

Scenario Area cultivated (Hectares)		Sustainable woodfuel yield (odt/year)	Delivered heat (MWh/ year)	Proportion of estimated Cotswold building heat demand (%)	Potential CO_2 savings (tonnes/ year)
Miscanthus	595.52	10,123.82	4.07%	26,068.83	8,209.94
	5,955.19	101,238.17	40.72%	260,688.28	82,099.43
SRC	595.52	5,359.67	2.16%	13,801.14	4,346.44
	5,955.19	53,596.68	21.56%	138,011.44	43,464.40

Issues affecting deployment

Assuming there is sufficient demand, the sourcing of clean recycled wood as woodfuel will depend on suitable management of waste streams and separation processes whereas the constraints on producing woodfuel from woodlands will depend on how much woodland can be brought under active management and the incentives available for landowners to extract and process woodfuel. In both cases, competing alternative end-uses for wood such as for construction and building materials and any inherent carbon storage benefits will also be a factor. The virgin woodfuel market is currently dominated by demand from domestic log-burners or stoves with woodchip and pellet boilers still only playing a minor role. Economic viability for the latter is better in off-gas areas due to the higher cost of predominant fuels such as oil, LPG and electricity (for direct heating), and the on-going Renewable Heat Incentive scheme. Woodfuel heating systems however will increasingly need to compete with heat pumps as the electricity grid decarbonises and will also have to contend with additional constraints such as space for fuel storage, solid fuel flue regulations and maintenance requirements.

Deployment of energy crops will be influenced by economic viability, end-use/market, land ownership, existing farming activities, potential biodiversity impacts, protected landscapes, the presence of water-stressed areas and net carbon reductions achieved. In particular, conflicts over land use for alternative activities such as food production will need to be considered in relation to the relative costs and benefits of each option. There may also be land use conflict when comparing the appropriateness of different renewable technology options, for example in terms of whether more benefit could be gained from the use of a particular parcel of land for the growing of energy crops compared to the installation of a ground-mounted solar array. For the purpose of comparison, the potential heat generation from one hectare of Miscanthus could be in the region of 43MWh per year, plus 26MWh per year electricity generation (assuming CHP), whilst a solar farm covering the same hectare of land might generate around 384MWh per year of electricity.

The production of energy crops will also be dependent on landowners and farmers being offered sufficient incentive to grow and harvest the crops, with longer-term supply contracts often needing to be arranged well in advance with end-users. As with woodland residues, the logistics of fuel processing and establishing supply chains may initially act as a barrier to the widespread take-up of this resource. Other issues that may limit exploitation include the requirement for Environmental Impact Assessment (EIA) of energy crop projects, the planning and permitting of energy generating plant and the question of alternative markets for Miscanthus and SRC.

Overall there is ambition at national level for biomass to play a key role in decarbonising the UK's energy supplies. Both the Government's Clean Growth Strategy (2017) and *'Net Zero – the UK's contribution to stopping global warming'* (Committee on Climate Change, 2019)) both acknowledged the significant opportunities offered by biomass, particularly if it is used alongside carbon capture and storage (CCS) technology to both sequester carbon from the atmosphere via plant growth and capture that subsequently released in bioenergy conversion processes. The Committee on Climate Change have also reviewed the carbon and wider sustainability impacts of biomass production and use and concluded that sustainable low-carbon bioenergy is possible, but that this can only be achieved in certain circumstances, if certain practices and criteria are applied[29].

Since the 1960s, agricultural subsidy under the EU's Common Agricultural Policy (CAP) has significantly shaped farming practices in the UK, including the extent to which bioenergy initiatives have been deployed. The UK's 25-year Environment Plan and planned exit from the CAP now provide a new context for policies and strategies to scale up biomass production, not least by the Government's new Environmental Land Management (ELM) scheme which will pay farmers to deliver beneficial outcomes.

Energy from Waste

Municipal and commercial solid waste

Description of technology

Generally referred to as Energy from Waste (EfW), this technology involves extracting energy using a process undertaken on the non-recyclable residual elements of waste streams. Solid dry materials can be processed into Refuse-Derived Fuel (RDF) and are usually incinerated to produce heat and/or electricity. A proportion of this fuel could be considered as 'renewable' depending on its organic,

[29] See 'Biomass in a low carbon economy' (2018), Committee on Climate Change, p12, Box 2

non-fossil fuel content, for example as set out by Ofgem for the purposes of the Renewables Obligation.

Another form of energy from waste technology uses anaerobic digestion (AD) to process food waste. One of the by-products of the process is biogas which is then either combusted to generate electricity or processed into biomethane and injected directly into the gas grid.

Existing development within Cotswold District

Waste management in Cotswold District comes under the framework of the Gloucestershire Joint Municipal Waste Management Strategy (JMWMS), developed in 2008 in partnership with all seven District Councils[30]. Set against an overall objective of zero waste to landfill, Gloucestershire is achieving a recycling rate of around 52% for waste (2016/2017 figures), and has a target of 60% recycling by 2020 and 70% recycling and composting by 2030.[31]

All post-recycling residual household waste generated in Gloucestershire and collected by the District Councils or taken to Household Waste Recycling Centres is treated by the new Javelin Park EfW facility, located near Haresfield in Stroud District. The facility has a capacity of 190,000 tonnes of waste per year including commercial waste and is expected to generate around 14.5MW of electricity and is enabled to generate heat as a Combined Heat and Power (CHP) plant (although currently supplying electricity only). The site opened in October 2019 and in the first 12 months of operation the facility processed 177,582 tonnes of waste, which generated 118,920 MWh of electricity that was exported to the grid (equivalent to power 25,000 homes)[32]. Around 50% of the energy recovered may be called 'renewable' due to the organic composition of the waste feedstock.

However, it should be noted that the facility will remain a significant source of carbon emissions, which are associated principally with the plastic content of the waste streams. Reaching net zero carbon emissions from the District's waste by 2030 will therefore require the removal of the plastic from the residual waste stream, or cessation of incineration altogether.

Recycled wood waste

The waste wood resource is difficult to quantify and would require a detailed survey to assess material collected at Community Recycling Centres and that present within

[30] https://www.gloucestershirerecycles.com/partnership-and-strategy/partnership-and-strategy/

[31] www.recycleforgloucestershire.com/recover/dealing-with-gloucestershires-waste/

[32] https://www.ubbgloucestershire.co.uk/news/2021/3/15/gloucestershire-energy-from-waste-facility-passes-first-anniversary

commercial, industrial and construction waste streams. This will typically consist of clean, untreated material mixed with that contaminated with paint, preservative, fixings and other foreign materials. While clean waste wood can potentially be sourced directly from saw mills, carpenters, joineries, etc., a large proportion of this resource will be mixed with contaminated material in mainstream commercial and municipal solid waste streams and so it is likely that a significant amount is currently being treated as residual waste and may therefore end up at the Javelin Park waste facility.

Due to toxic emissions and air quality concerns contaminated waste wood is generally not suitable to be used in small or medium scale thermal energy installations due to the lack of suitable exhaust gas clean-up equipment; these clean-up systems are costly and tend to be viable on large scale plant only.

Note – the wood resource from woodland and arboricultural arisings are considered in section 0.

Food waste

Much of Cotswold District's food waste is sent to an anaerobic digestion plant in Bishops Cleave, near Cheltenham. This takes delivery of around 34,000 tonnes of domestic and commercial food waste annually to produce biogas, some of which is used in a CHP engine with 1.6MW generation capacity to provide all the site's power needs, with the remaining gas processed for injection to the national gas grid. This biogas is classed as a renewable source of energy although it has not been possible to quantify the annual amounts produced.

Agricultural residues and sewage

With Cotswold being a predominantly rural district, agricultural waste represents a potential renewable energy resource, particularly from using livestock slurry as a feedstock for the anaerobic digestion process. Using estimates from Defra statistics on animal numbers for 2016 and resulting slurry and biogas yields, an estimate has been made of the potential emissions savings in Table 12. Heat delivered from cattle slurry would supply just over 1% of the Cotswold district estimated building heat demand and just under 1% of the total electricity demand. The total livestock slurry resource would meet 1.84% of estimated building heat demand and 1.65% of electricity demand in Cotswold District.

Table 12: Assessment of livestock slurry

Livestock	Numbers in Cotswold District[33]	Volume of slurry (tonnes/year)[34]	Biogas yield (m^3/tonne)	Delivered electricity (MWh/year)	Delivered heat (MWh/year)	Delivered energy (MWh/year)	Potential CO_2 savings (tonnes/year)
Cattle	25,293	101,172	20	4,067	6,779	10,846	2,573
Pigs	11,179	8,060	20	324	540	864	205
Poultry	679,163	26,492	50	2,662	4,437	7,100	1,684
Total				**7,054**	**11,756**	**18,810**	**4,463**

Biogas generation from anaerobic digestion of sewage is also classed as renewable form of energy with most large sites generating heat and/or electricity for the site's own needs. Heat recovery systems can also be used with sewage or waste water infrastructure to provide heat to local users, although this application is not yet widespread.

[33] www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

[34] www.organics-recycling.org.uk/uploads/category1060/10-010%20FINAL_Andersons_NNFCC_AD2010.pdf

District heating and ambient heating (heat pumps)

Introduction

The decarbonisation of heat supply is a major challenge on the route to a Net Zero future and will involve a radical departure from the fossil fuels we currently use to heat the vast majority of our buildings. The approach now being proposed by the UK Government involves the roll-out of district heating networks, where a centralised plant supplies low or zero carbon heat and/or cooling to two or more buildings via a network, and the deployment of individual heat pumps to supply low or zero carbon heat and/or cooling within buildings not served by heat networks.

To assess which areas are best suited to heat networks, the Government is currently trialling a zoning methodology by working with six major UK cities as part of a pilot programme to help local authorities develop local heat decarbonisation plans, identify heat network zones, and understand how they can use supportive policy measures to reinforce connection to networks. The Government consulted on heat network zoning in late 2021.[35]

The following sections consider the potential for district heating within Cotswold District and the accompanying role heat pumps may play in decarbonising heat supplies to buildings.

District heating

District heating is a system for distributing heat from one source (i.e. plant room or energy centre) to multiple properties. Instead of each property having its own individual heating system, a group of properties connected to a district or 'community' heating network all receive heat (in the form of hot water or steam) from a central source, via a network of insulated pipes. This can offer a number of benefits compared to individual heating systems within each property including:

- Potential for lower costs for consumers and long-term price stability through use of local low or zero carbon energy resources such as waste heat.
- Longer lifespans and higher system efficiencies than many older individual heating systems through economy of scale, better control and lower temperature heat distribution.
- Heat networks are technology-neutral and can connect to different heat sources over time with minimal disruption to consumers.
- Less space needed within properties compared to traditional individual heating systems and reduced maintenance requirements.

[35] https://www.gov.uk/government/consultations/proposals-for-heat-network-zoning

Low or zero carbon district heating is seen as playing a key role in the UK's path to achieving an affordable decarbonised heat supply and features largely in the Government's Clean Growth Strategy from 2017 and the Committee on Climate Change's Net Zero report from 2019. The latter's core Net Zero scenario suggests that around 5 million homes across the UK will need to be connected to heat networks by 2050, equivalent to around 18% of heat demand. In this context, the Clean Growth Strategy suggests that around one in five buildings will have the potential to access a largely low carbon district heat network by 2050.

The heat source of many older district heating systems is a basic fossil-fuel fired boiler, although over recent years gas-fired combined heat and power (CHP) plants have been commonly used to increase efficiency and reduce emissions. CHP produces both heat (sometimes with cooling) and electricity, so with a CHP district heating system, as well as a network of pipes distributing heat/cooling, there is also a grid connection or network of wires to distribute electricity to one or more local users. In the latter case, where the output is not grid-connected, this is referred to as a private wire network. However, the emissions savings potential of gas-fired CHP has rapidly decreased as a result of the decarbonisation of mains electricity at national scale and will continue to do so. Tightening regulations around the energy performance of buildings and their emissions now mean that supply technologies for new or refurbished heat networks will tend to be limited to low or zero carbon forms of heat generation such as heat pumps or waste heat.

Deployment of large-scale ground, water or air source heat pumps to supply heat networks is likely to become significantly more widespread as grid-supplied electricity continues to decarbonise. The use of ground source heat pumps to supply multiple properties may incorporate a ground loop array which collects the heat needed to supply a centralised large scale heat pump plant which then distributes heat via a heat network. Alternatively, a shared ground loop array may instead collect heat to serve individual heat pumps in each property. One advantage of the latter system is that all pipework which carries hot water (i.e. at temperatures ready for heating) is confined to within the properties so heat losses are minimised.

For the purposes of this study geothermal heat for building heating has not been analysed. However, there may be large potential for this across the district, as there is carboniferous limestone geology underlying it[36]. This potential should be investigated as a geothermal borehole could supply a large heat network such as the scheme in Southampton[37].

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[36] https://www.bgs.ac.uk/news/unlocking-the-deep-geothermal-energy-potential-of-the-carboniferous-limestone-supergroup/

[37] https://www.geographysouthwest.co.uk/wp-content/uploads/2020/10/Geothermal-UK-2020.pdf

Heat mapping and district heating networks

Viability of district heating

A large part of the cost of developing a district heating network is laying pipes, due to the need to excavate roads or other land, 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. Overall costs vary widely depending on the number and type of buildings connected and the area covered. Installing a heat network in a new development is usually cheaper than installing it in an existing development because pipes can be laid at the same time as other infrastructure when roads are built. In this way, new developments often act as a trigger for a network, but with the potential to also supply existing heat demands from buildings in the vicinity which may improve economic viability.

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, known as the linear heat density; the higher the amount of heat delivered per metre of pipe, the better. Linear heat density is a critical factor in heat distribution economics, but this can only be calculated at the stage when a route has been defined.

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 by means of an ‘overlay analysis’, which can then be investigated in more detail. Spatial density is the amount of heat per area (for example, per square metre).

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. This analysis uses data from the heat demand model of the THERMOS project[38], which has been produced as part of an EC Horizon 2020-funded research project led by CSE. The THERMOS model incorporates a hierarchical approach to estimating demand, with the method used depending on the available input data. This starts with a basic heat demand estimation method using a 2-D representation of a building’s polygon (e.g. where only OpenStreetMap data is available) or, as in the case of Cotswold, this can be improved using a more detailed model which uses LIDAR data to estimate the 3-D shapes of buildings.

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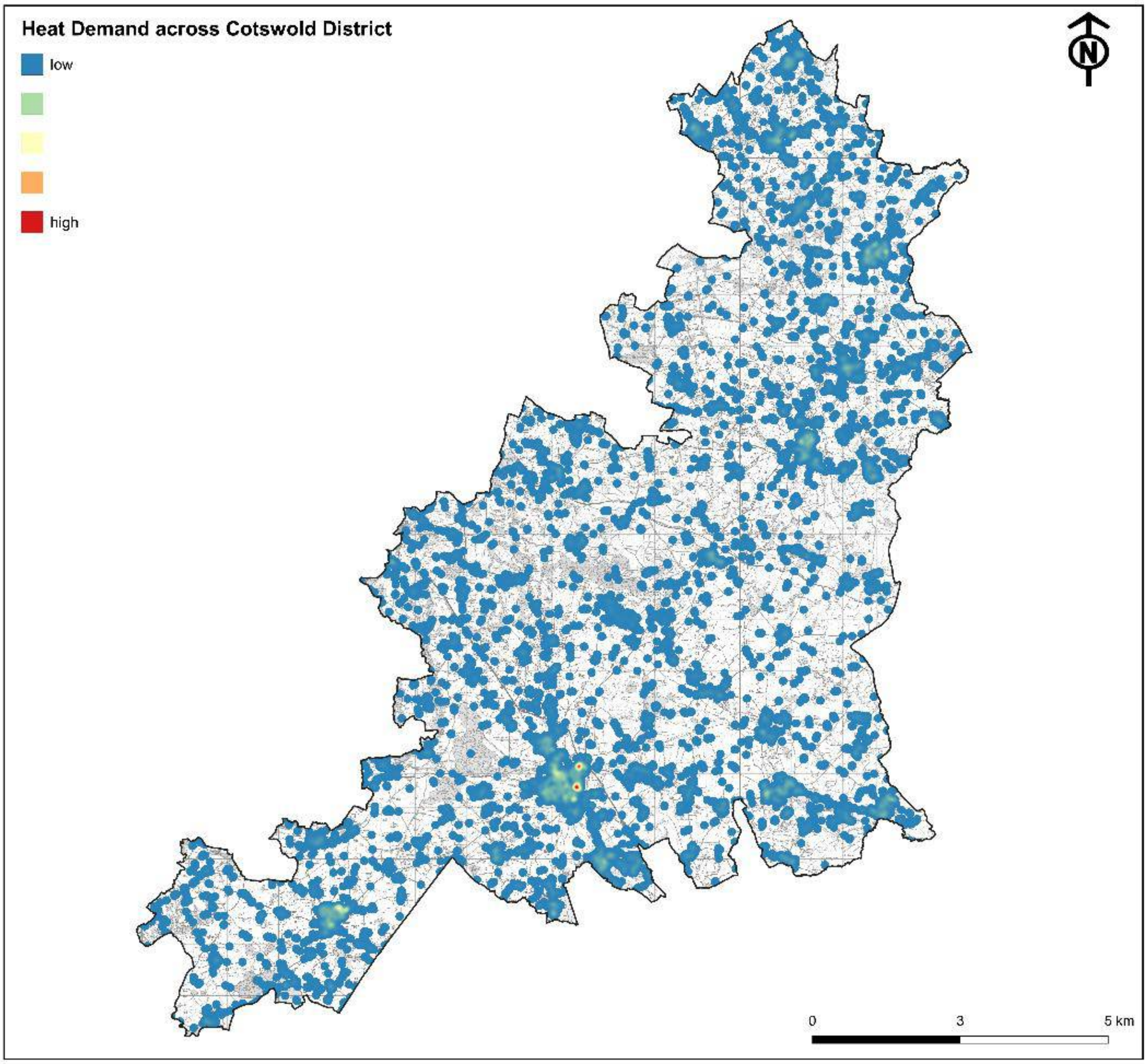
[38] www.thermos-project.eu/home/

For this analysis, address-level heat demand data across the Cotswold area was first estimated using the THERMOS tool and a Geographic Information System (GIS) was then used to analyse the spatial distribution of heat demand. All addresses in the study area, along with their associated heat demand, were mapped using their OS Grid coordinates. A heat demand density map was then produced covering the study area – see Figure 26. This is a map layer which gives the estimated heat demand per unit of land area, based on the address-level heat demand data

Figure 26: Heat density in Cotswold



Areas with high concentrations of heat demand have higher spatial density values. Heat density is shown on the map from blue to red, with blue areas being low density and red areas high density.

As would be expected, the heat map shows heat demand density to be greatest in the more urban areas of the district. The most prominent clusters are located in Cirencester.

District-wide overlay analysis

With a large area to explore, a useful way of initially identifying areas which are more 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 5% 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 50,000kWh per year
- Areas must be within 200m of potential anchor loads

Anchor loads are defined as those types of buildings likely to have relatively high and stable heat demands and/or be in sectors more likely to participate in heat distribution projects. For the purpose of this study, this includes all buildings with an annual demand for heat of above 50,000kWh that fall within the following categories within the THERMOS heat demand model:

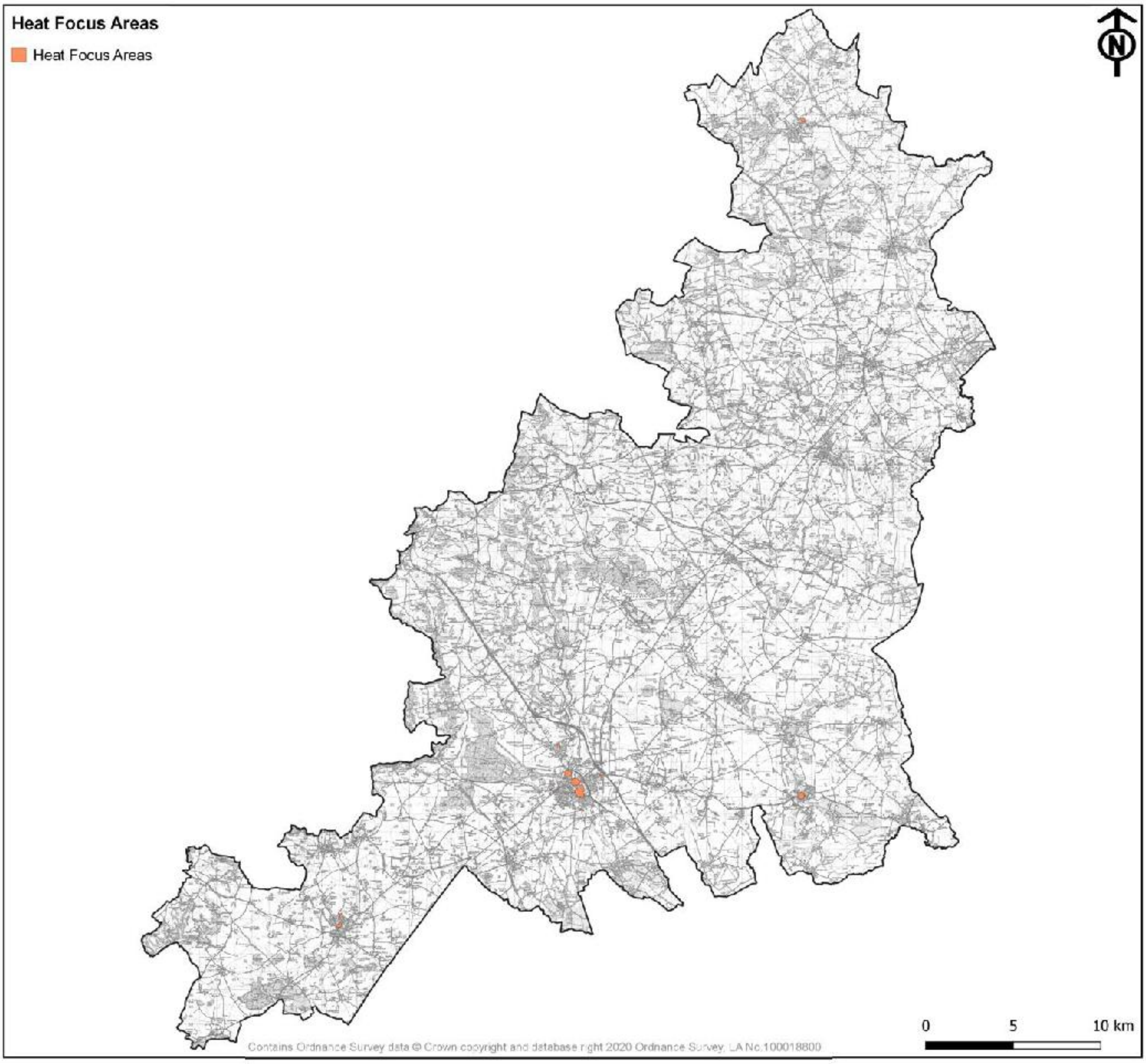
- Office
- Commercial
- Sport and Leisure
- Industrial
- Medical
- Hotel
- Prison

The THERMOS heat demand model 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 (particularly in the case of industrial buildings). However, they provide a good basis for establishing the initial area of search. When these areas are established, the locations identified and the areas around them can be checked for suitability by examining Ordnance Survey maps and Google Streetview to find out more about the types of buildings and their appropriateness (for example, high heat demand can be caused by dense terraced housing, which is less suitable than larger loads due to the number of connections which would be required).

In the Cotswold district only a small number of areas met all three of the above criteria, and these were located close to or within the larger settlements of Cirencester, Tetbury, Moreton-in-Marsh and Fairford. For the purpose of this study, the areas identified through the overlay analysis can be termed as ‘Heat Focus

Areas', and may be worthy of further consideration. These areas should also be considered alongside planned large new development sites which offer particular opportunities for heat networks.

Figure 27: Heat focus areas in Cotswold District



In addition to the geographical aspects of heat demand, location of heat supply will also be a factor in planning a network. This is particularly the case when a specific building or piece of land may be under Council ownership and has the space to host an energy plant, or where waste heat from sources such as industrial processes or data centres have been identified as potentially available.

Note – no such opportunities for heat supply had been identified prior to the following analysis for the areas considered.

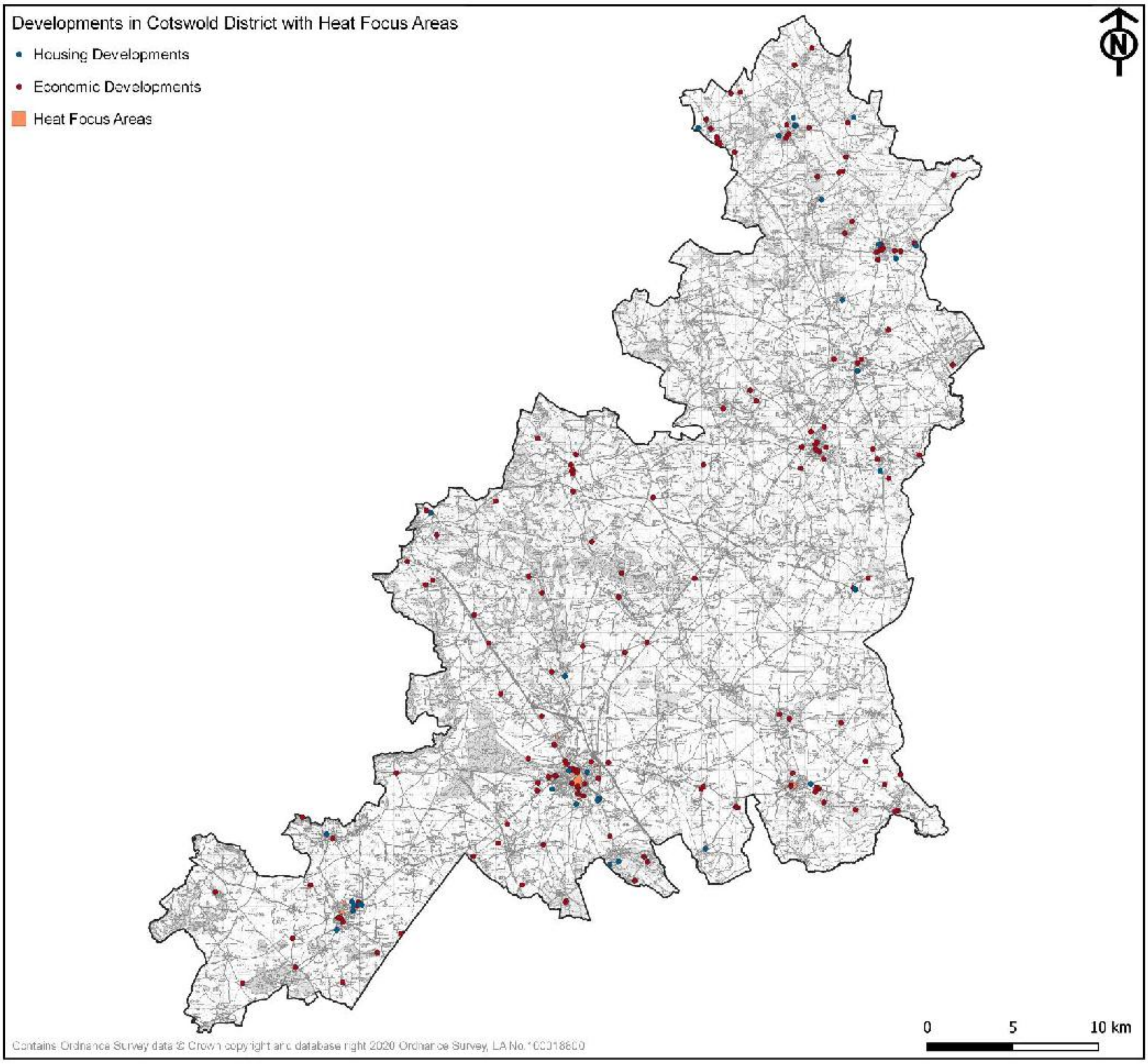
New development

When considering heat networks, new development creates an additional demand for heat and power, as well as an opportunity to find a more flexible site for an energy centre and to lay heat distribution pipework. Existing development in the close vicinity can also act as additional heat demands which may improve the economic viability of a network, particularly where anchor loads may exist along with other heat demand profiles which can smooth out the overall heat demand profile.

Sites that have already been earmarked for new development in the Cotswold area were mapped in GIS using information provided by the Council. This included Housing Allocations, Employment Allocations and the Strategic Site at Chesterton (now known as 'The Steadings') as set out within the Local Plan, as well as information on committed dwellings (including those with outline or full planning permission, reserved matters or other firm commitment) and economic developments, as provided by CDC. It should be noted that where full planning permission is not yet in place, the proposals may be subject to change.

This information was added alongside identified Heat Focus Areas in order to provide an indication of where new development might have a positive impact on the viability and layout of a heat network in the priority areas identified – see Figure 28.

Figure 28: Heat focus areas and planning applications



Focused analysis using the THERMOS tool

Following overlay analysis, the area in central Cirencester was selected for further analysis using the THERMOS tool. This is a high-level pre-feasibility analysis, assessing network route options, energy supply options and outline costs. It is based primarily on modelled data and indicative cost assumptions have been used for these examples. The model incorporates a feature where insulation can be applied (and specified by the user), or users can directly adjust heat demands of individual buildings to run before/after type scenarios. Should the Council wish to review and adjust the parameters or create new networks based on better local knowledge then access to the online analysis can be provided[39]. The analysis is indicative and is intended to be a starting point for more in-depth analysis. More information on the tool, including training materials, can be found on the THERMOS website.

The THERMOS software finds the optimal heat network layout in a given area based on one of two objectives:

- Maximise Network NPV (net present value) - the goal is to choose which demands to connect to the network so as to maximize the NPV for the network operator. This is the sum of the revenues from demands minus the sum of costs for the network.
- Maximise Whole System NPV - The goal is to choose how to supply heat to the buildings in the problem (or abate demand) at the minimum overall cost. The internal transfer of money between buildings and network operator is not considered, so network revenues and tariffs have no effect. Alternative individual heating systems (such as air source heat pumps) and building fabric insulation can be offered where this may be considered a more financially viable option.

For the purposes of this case study, both objectives have been explored. Phase 1 refers to the smaller site selected for the start of a heat network, and Phase 2 refers to a slightly expanded option at the same location. For the purposes of this interim report new developments have not been included in the THERMOS analysis, however these could be included at a later date.

The tool allows the user to select specific buildings to be considered within the analysis, and these can be marked as ‘required’ or ‘optional’ depending on user preferences. A building must also be selected to act as a supply point (i.e. the location of an energy centre to house the required plant to supply the network with heat).

As noted above, assumptions have been applied within the THERMOS application. The supply points have been set a maximum capacity of 5 MW. The capacity cost is set to £45 per kW, which is indicative of the capital cost of a gas boiler at this scale. The supply cost is set to 2p/kWh to provide a cheaper alternative to individual gas central heating. No decision needs to be made on what theoretical heat source is supplying the network. Other defaults within the software include but are not limited to the pipe costs, standard tariff for customers on the network and costs for individual heating systems to be installed.

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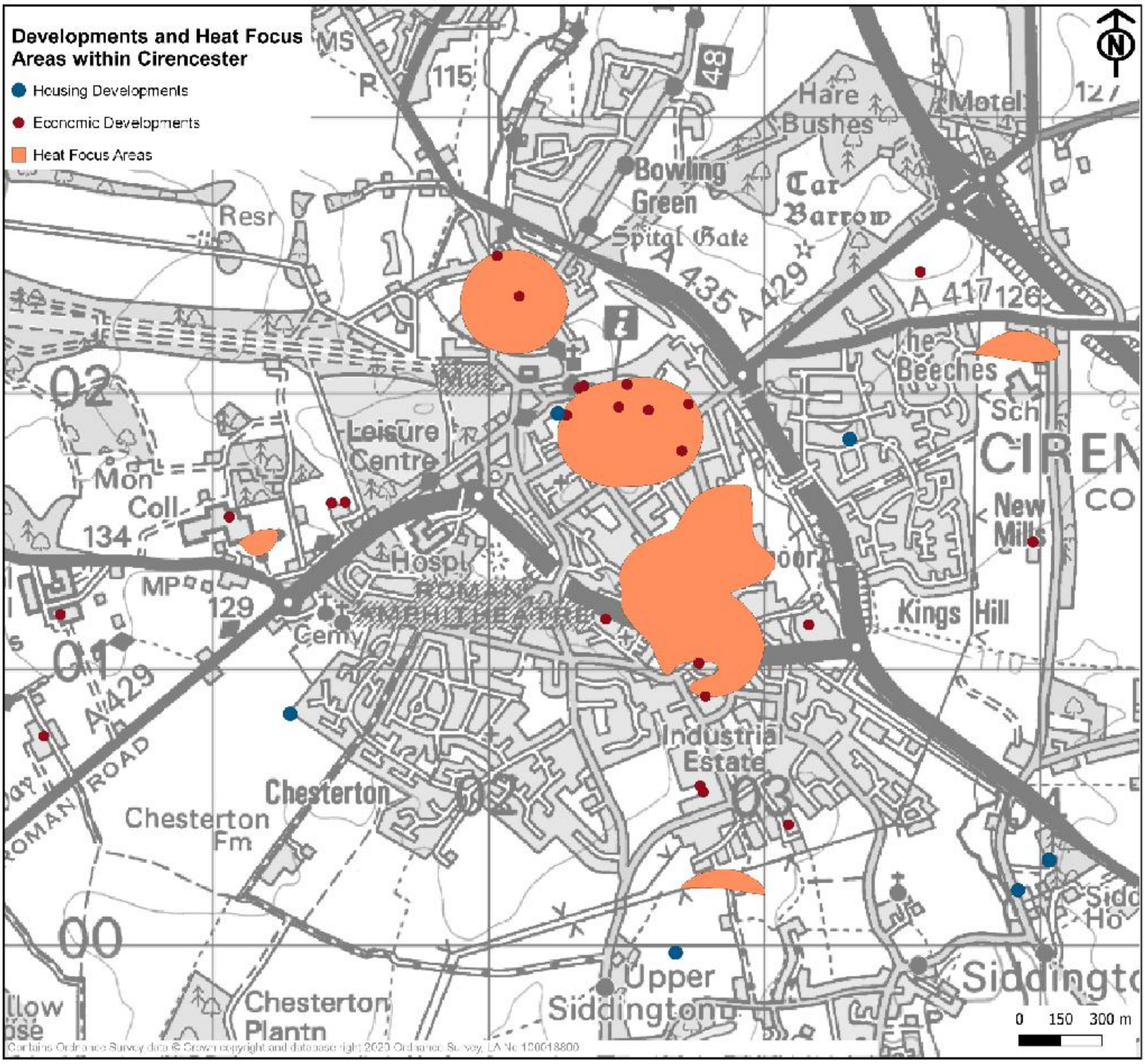
[39] THERMOS is a web-based tool and has been designed for use by local authorities, consultants and other stakeholders. It allows secure online collaboration through the sharing of projects via individual email addresses.

Cirencester

Cirencester is the largest urban area and a number of HFAs have been identified within its limits (shown in Figure 29).

Figure 29: Cirencester heat focus areas and planning applications

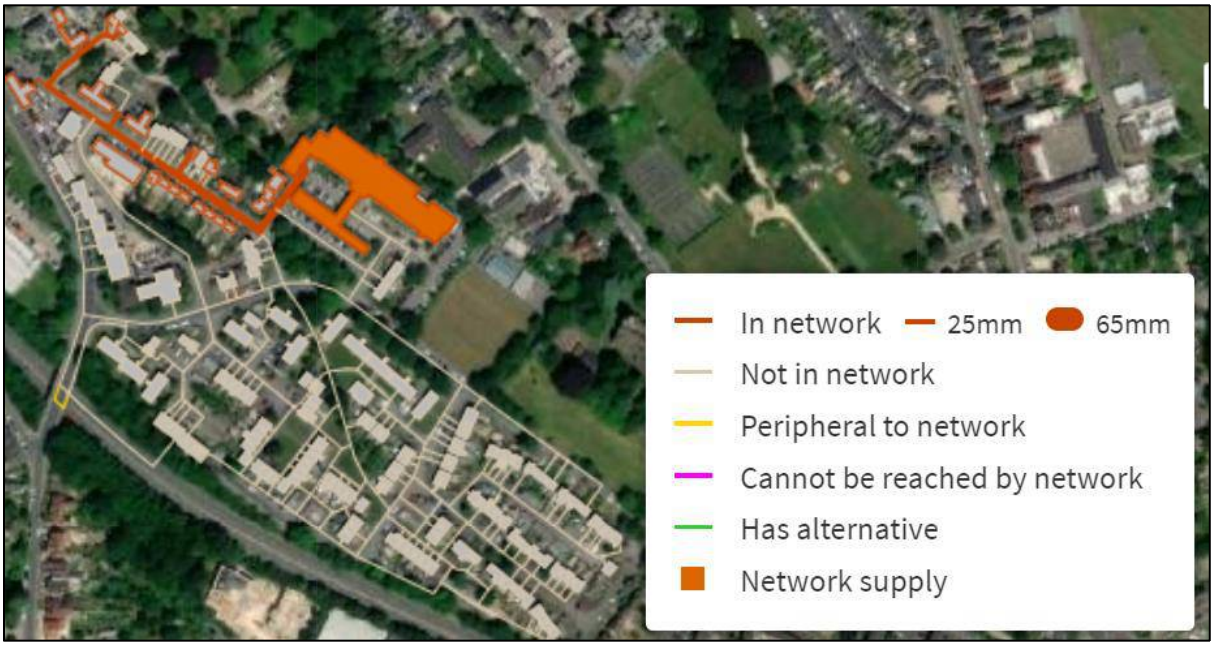


The area for heat network analysis surrounds the Cotswold District Council Trinity Road office building as a supply point. The scale of public sector land ownership in this area is likely to be of significant benefit in any attempt to coordinate a heat network development project. Potential anchor loads and buildings of particular interest include Cirencester Hospital, Cotswold Leisure Centre and Waitrose and Partners.

As discussed above, all buildings have had heat demand (MWh) and heat peak estimated by the model. However, as there is actual heat demand (gas consumption) data for CDC offices, the heat demand has been updated to reflect the actual figures (from April 2019 to March 2020). The heat peak was increased proportionally in line with the new figures. The heat demand is 1,057 MWh and peak is 579 kWp.

Figure 30 provides an example of a possible network layout surrounding the CDC offices.

Figure 30: Cirencester example: Phase 1 network NPV



In the above example the analysis is aiming to maximise the network NPV by allowing all buildings to be ‘optional’. This means that buildings will not be added if it is not optimal for the network operator. For the purpose of this exercise, it has been assumed that the plant will be housed within the building highlighted in orange (CDC office). There is the option for the network to join 176 demands (buildings) with a total of 3.25 GWh/year heat demand (heat peak 5.51 MWp). The suggested network includes the CDC office and supplies some residential properties as well as industrial buildings. Only 845kW of the supply capacity (up to 5MW for the purposes of this study) is being used. The buildings included in the network have a heat peak of 1.32 MWp.

In Figure 31 the analysis aims to include all buildings (these have been selected as ‘required’). The analysis will be aiming to provide the cheapest scenario between properties connecting to the network and using individual heating systems. All buildings have been added to the network, meaning that it is financially better to be part of the network compared to having an individual heating system. The supply capacity is almost maxed out at 5.51 MWp. It is able to use more than the 5MW supply capacity due to the peak being undiversified (in reality it won’t peak at 5.51 at the same time).

Figure 31: Cirencester example: Phase 1 whole system NPV

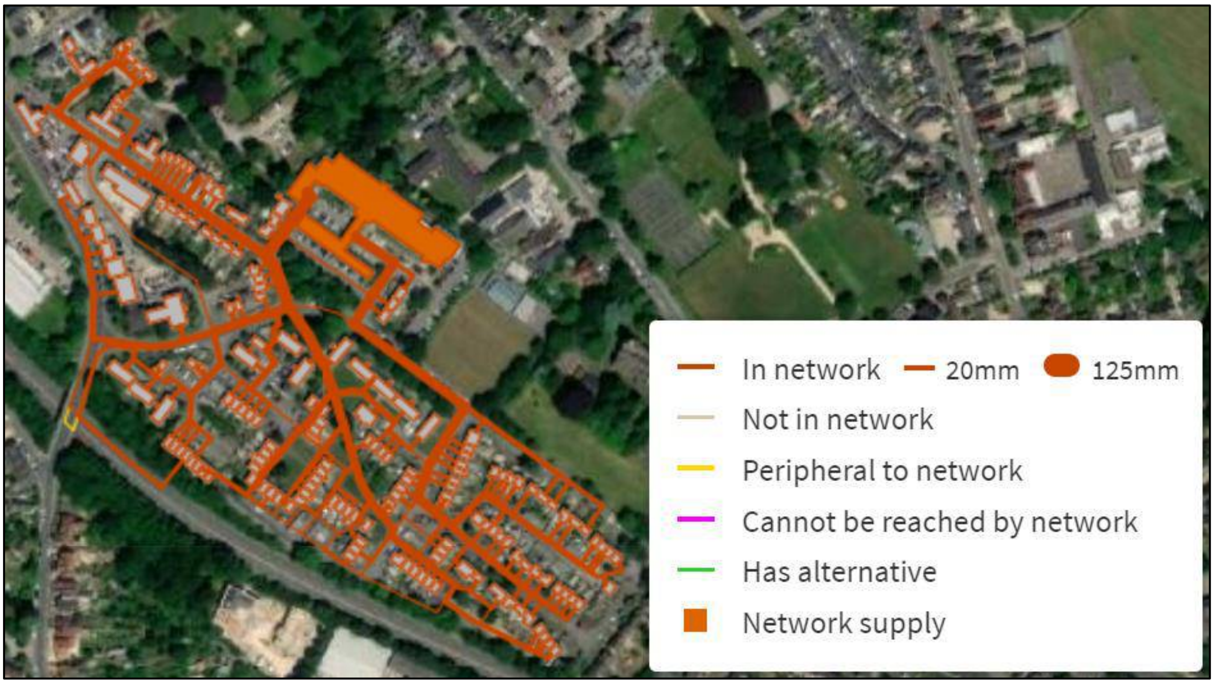


Figure 32 shows the CDC offices network extended (Phase 2) with the addition of Cirencester Hospital, Cotswold Leisure Centre and Waitrose and Partners. The model now has the option to include up to 243 demands (buildings) and the heat peak of these is 9.12 MWp. With the supply capacity at 5MW, the network would not be able to join all buildings even if it was financially viable.

The network is now using 2.28 MW of its 5MW capacity, with 52 demands connected. The hospital has a peak of 412 kWp.

Figure 32: Cirencester example: Phase 2 network NPV

Using the whole system NPV with Phase 2 results in no network.

Table 13: Andover summary of results

Andover	Phase 1 network NPV	Phase 1 whole system NPV	Phase 2 network NPV
Net Present Value			
Network NPV (£k)	£771.78	-£1.01	£1,140
Whole System NPV (£M)	-£1.14	-£5.09	-£4.75
Network Size			
Buildings	22	176	243
Paths	54	419	677
Pipework Solution			
Length (km)	0.429	4.36	11.13
Base Cost (£M)	£0.264	£2.86	£6.84
Maximum pipe diameter (mm)	65	125	125
Total Capital Cost (£M)	£0.351	£3.22	£2.18
Demand Solution			
Total Undiversified Peak Demand (MWp)	1.32	5.51	9.12
Total Demand (GWh/year)	1.58	3.25	7.58
Revenue (£k/year)	£80.3	£171.5	£247.2
Supply Solution			
Total Capacity Required (MW)	0.845	3.42	2.28
Heat Production Costs (fuel) (£M)	£1.33	£3.14	£4.32

Next Steps

The heat mapping overlay analysis presented above provides a high level indication of areas within the district where heat networks are likely to be most viable, based on the demand for heat from existing buildings. The subsequent analysis using the THERMOS tool illustrates some potential networks within Cirencester which have been selected by considering the building clusters involving high heat demands and potential anchor loads. Due to limitations of the scope of this study, the analysis is principally intended to illustrate how the tool can be easily used to model a group of buildings with a chosen energy supply location and provide a useful basis for further study. As such, the buildings chosen and parameters used will need to be reviewed in more detail using local data and knowledge as far as possible, which will require additional work outside the scope of the current study. THERMOS is an open-source web-based tool and has been designed specifically to allow local authorities, consultants or other stakeholders to input local data to improve the accuracy of its outputs. It also allows secure online collaborative working through the sharing of maps and projects. The network scenarios modelled above for example could easily be shared with an officer at the Council, who could then view and edit the maps and parameters via the tool's user interface with minimal training.

THERMOS is mainly designed to assist the pre-feasibility phase of heat network planning, but given a robust set of input data it will also usefully contribute to, and help justify the need for a detailed techno-economic analysis. At this next stage, initial consideration should also be given to business planning around ownership, phasing, delivery and operation of the network. It is also important to explore at an early stage which stakeholders may be involved along the way and how to engage with them - particularly the heat customers. Further information on the development of heat networks is available from Government guidance[40]. Local authority funding towards the early stages of heat network development, including energy masterplanning, techno-economic feasibility and detailed project development is potentially available through the Government's Heat Networks Delivery Unit (HNDU).

Ambient heat (heat pumps)

Description of technology

Heat pumps operate by using electricity to transfer ambient heat from the ground, air or bodies of water via a standard refrigeration process to heat or cool buildings. They can range from small scale domestic sized units up to large scale systems which may be used in conjunction with district heating networks. Overall efficiency is sufficiently high in well-designed systems to make the technology a viable low carbon alternative to conventional heating or cooling systems.

Ground source heat pumps require space for either vertical bore holes or a larger area for the horizontal trenching of refrigerant pipes. By contrast air source heat pumps are physically similar to standard air conditioning units and are typically mounted on an external wall of a property. 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

[40] https://www.gov.uk/guidance/heat-networks-overview#:~:text=A%20heat%20network%20%E2%80%93%20sometimes%20called,domestic%20or%20non%2Ddomestic%20buildings

developments with high thermal insulation standards, but upgrades may need to be carried out with retrofit projects before heat pumps are considered a viable option.

Issues affecting development

The successful roll-out of heat pumps as a low or zero carbon heat supply option will be highly dependent on the on-going decarbonisation of UK grid electricity. Such widespread electrification of heat supplies will also place increased demands on local electricity supply infrastructure, in addition to increased demands from the growth of electric vehicles.

The potential for retrofitting heat pumps to existing development will also be largely dependent on capital cost reductions through mass production and the extent to which energy efficiency retrofits can be undertaken to ensure compatibility with a heat pump system. To place this in context, the Government's Clean Growth Strategy sets out an aspiration "for as many homes as possible to be EPC Band C by 2035 where practical, cost-effective and affordable" with only around 30% of UK homes currently meeting this target. Available space may also be a constraint, particularly for ground source systems in built up areas where land area is limited. For trenched systems, an area equivalent to twice the total floor area of the building to be heated may typically be needed. For borehole systems, ground conditions and the presence of groundwater can impact their feasibility and cost as they are typically installed to a depth of 70-150m.

Heat pumps on domestic premises are generally considered to be permitted development and do not normally need planning permission, although air source heat pumps need to meet specific criteria which include size and positioning. Water source heat pumps take their heat from rivers or other bodies of water and may therefore require permission from the relevant authorities to install the necessary equipment. Heat pump installations in Conservation Areas or on listed buildings will also be subject to additional criteria. For example, in Conservation Areas air source heat pumps must not be installed on a wall or roof which fronts a highway or be nearer to any highway which bounds the property than any part of the building.

The Government's Future Homes Standard and future tightening of Building Regulations may also dramatically impact the uptake of heat pumps in new development if they are perceived as a cost-effective and feasible technology to help meet the energy performance standards of the future. Heat pumps have the added benefits of working much more efficiently with the higher fabric thermal standards and the lower temperature heating distribution systems that are likely to feature within new development of the future. Ground source heat pumps also have the added advantage of having no visible external equipment and with new development can usually be factored into the footprint of larger sites to incorporate shared ground loop arrays serving multiple properties.

As discussed in section 0, due to the predominantly rural characteristics of Cotswolds District there are relatively few opportunities for district heating. This would imply that small-scale individual heat pumps are likely to play a leading role in transitioning away from fossil fuel heating across the District. Based on current fuel prices, uptake in areas off the mains gas network may be proportionally higher when competing against more expensive fuels such as electricity (for direct heating) or LPG.

Existing development within Cotswold District

According to deployment data from the Renewable Heat Incentive scheme, there were 201 air source heat pumps and 54 ground source heat pump domestic installations accredited in Cotswold District from April 2014 to July 2020. Assuming average system heat supply capacities of 9.9kW for air source and 13.6kW for ground source[41], resulting total capacities are estimated at 1.99MW and 0.73MW respectively. Figures for non-domestic installations have not been identified.

Technical potential

Theoretically, almost any building could have an air source heat pump and so the technical resource is very large and has not been specifically quantified. In terms of heat output, ground source systems are more efficient due to their heat being sourced from the ground which has more stable year-round temperatures. Air source heat pumps take their heat from ambient air which is subject to large seasonal temperature fluctuations; unfortunately heat demand is highest when the heat source temperature is at its lowest (winter), which means a significant drop in efficiency during this period.

The standard measure of operational efficiency for heat pumps is the Seasonal Performance Factor (SPF) which indicates year-round efficiency (as opposed to Coefficient of Performance, which usually indicates efficiency during optimum conditions only). Typical SPFs for air source and ground source heat pumps in the UK are 3.1 and 3.4 respectively[42].

Issues affecting deployment

The successful roll-out of heat pumps as a low or zero carbon heat supply option will be highly dependent on the on-going decarbonisation of UK grid electricity. Such widespread electrification of heat supplies will also place increased demands on local electricity supply infrastructure, in addition to increased demands from the growth of electric vehicles. Cumulative impacts of densely populated heat pumps

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[41] https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-july-2020

[42] As published in domestic RHI deployment data for July 2020, which includes average SPFs for all heat pumps installed under the RHI: https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-july-2020

within a relatively small area may also lead to localised excess heating or cooling of the ambient heat source.

The potential for retrofitting heat pumps to existing development will also be largely dependent on capital cost reductions through mass production and the extent to which energy efficiency retrofits can be undertaken to ensure compatibility with a heat pump system. To place this in context, the Government's Clean Growth Strategy sets out an aspiration "for as many homes as possible to be EPC Band C by 2035 where practical, cost-effective and affordable" with only around 30% of UK homes currently meeting this target. Uptake in areas off the mains gas network may be proportionally higher when competing against expensive fuels such as electricity (for direct heating) or LPG.

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