2020 Low Carbon and Climate Change Evidence Base for the Greater Exeter Strategic Plan

CENTRE FOR ENERGY AND THE ENVIRONMENT

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MANAGEMENT SUMMARY

The Greater Exeter Strategic Plan (GESP) is being developed to cover East Devon, Exeter, Mid Devon and Teignbridge districts for the period to 2040. Very significant carbon dioxide emission cuts are needed during this period to meet the requirement of the UK Climate Change Act (2050 Target Amendment) which commits the UK government by law to reducing greenhouse gas emissions to net zero by 2050. As part of this reduction policies for lower energy use and the transition away from fossil fuels to low carbon and renewable energy sources need to be included in the GESP. The GESP also needs to incorporate measures to support the adaptation to inevitable change already locked into the climate system.

Analysis of local GHG emission data shows that across the GESP area in 2016 total emissions were approximately 3.6 $MtCO_2e$. Transport emissions are dominant (31%) followed by Buildings (23%), Agriculture (17%) and the Power sector (16%). Minor contributors (13% total) include Waste, F--gases and Industry. Total emissions were higher in Mid Devon and East Devon (29% and 28% respectively) and marginally less in Teignbridge (26%) when compared to lower emission in urban Exeter (16%). Overall emissions in the GESP areas have generally fallen over the period 2008-2016 both in absolute terms and per capita. However this decline is due to the reduction in the power sector elsewhere in the UK and, if power is excluded, emissions in the GESP area have not noticeably changed.

GHG projections shoe that in the absence of any carbon reduction policy, 2016 emissions of 3.6 $MtCO_2e$ these would rise to 4.2 $MtCO_2e$ in 2050 including an allowance for population growth. Low, medium and high risk policies to the end of the 5th Carbon Budget in 2032 would see emissions fall to 2.3 $MtCO_2e$ (or 2.0 $MtCO_2e$ if policy to meet the "policy gap" to and achieve the CCC's least-cost decarbonisation path was to be identified) compared to the 3.7 $MtCO_2e$ under business as usual. Of this carbon reduction, 12% is from "low risk" policy, 38% from "medium risk" policy and 23% from "high risk" policy. The final 23% is the current policy gap. Projecting to 2050, based on the CCC's Core scenario, emissions drop to 1.4 $MtCO_2e$, whilst delivering the measures in the Further Ambition scenario would see a further fall to 0.8 $MtCO_2e$. The inclusion of GHG removal technologies and offsetting would be required to achieve net zero emissions. The largest reductions in emissions are planned to come from the Power, Buildings and Transport sectors, with a significant amount of further abatement required from GHG removal technologies.

An analysis of new residential development has shown that if a standard of net zero carbon for emissions regulated by Part L of the building regulations ("regulated emissions") were to be set in the GESP area, then the additional cost would be approximately £3,000 per dwelling. This would be achieved by adding photovoltaic (PV) panels to a Future Home Standard (FHS) – the standard intended for new homes to comply with from 2025 – compliant home, which has been taken to have the same specification as the proposed Part L 2020 Option 2 (from the recent consultation on changes to Part L), but with an Air Source Heat Pump (ASHP) in place of a gas boiler. Setting a net zero primary energy target for regulated emissions is more challenging, and calculations have shown that to achieve this would require *Passivhaus* levels of energy reduction, in order to offset the balance of energy demand with the potential of PV generated electricity within available roof areas. This option costs £6,714 per dwelling, and may in fact not be deliverable for certain configurations of flats. In none of the cases was it possible to meet standards that achieved net zero carbon or primary energy for regulated and unregulated (from uses not covered by Part L) combined. When the magnitude of implementing such policies are viewed in the context of total GHG emissions in the GESP area, the cumulative GHG savings from a zero carbon standard to 2050 are approximately

68,300 tCO_2e whilst a net zero primary energy standard would save a further 1,300 tCO_2e. The effective abatement cost would be approximately £2,500/tCO_2e saved for a net zero carbon standard, or £5,500/tCO_2e in the case of a net primary energy standard.

An analysis of new non-domestic development is awaiting the Government's forthcoming consultation on non-domestic building standards.

The order in which the carbon and energy impacts of strategic new developments are considered has key impact on their eventual emissions. A number of potential policies could potentially be enacted to promote this hierarchy. The recommended order is as follows:

Priority	Measure	Key aspects
1	Development location	Reduces transport need and gives access to sustainable transport
2	Site master planning	Solar master planning optimises use of natural light and heat
3	Building fabric	High performance fabric gives maximum thermal efficiency
4	Building services	Low carbon building services support fabric measures
5	Clean onsite energy	Low carbon / renewable energy reduces unavoidable emissions
6	Offsite measures	Developer contributions finance offsite carbon reduction where onsite measure are not practical/viable
7	In-use performance	To ensure actual performance aligns with design intent.

The case for carbon emission reduction from concentrating development can be made for both transport and buildings. In a predominantly rural area such as Greater Exeter the qualitative case for transport carbon emission reductions in large scale new development can be made relatively simply:

- Large scale mixed use development, where there is the potential for home occupiers to work in local employment areas built as part of the development masterplan, has the potential to reduce travel to work distances.
- The provision of local education, health and recreational facilities has a similar effect on leisure miles.
- Public transport provision is potentially more efficient and cost effective when a large number of people can be served in a concentrated area.
- Where a large new development is sited next to a major area of existing employment (e.g. Exeter) those that work in this area will have shorter journeys than if commuting from dispersed development further afield.

The case for buildings is more complex. Low and zero energy/carbon buildings can be built at all scales. However, without regulation requiring reduced carbon emissions there needs to be an economic case in favour of low carbon concentrated development. This case can be made because concentrated development of hundreds or thousands of homes enable a site wide approach to energy provision. Evidence in the GESP area demonstrates that site wide low carbon heat networks with combined heat and power (CHP) and can be economic.

Modelling using this evidence shows that adjoining residential / mixed sites which individually or combined have over 1,200 homes and adjoining commercial/employment sites which individually or combined are over 10 hectares should be required to evaluate the use of heat networks and CHP. Where economic such schemes should be implemented. Where commercial/employment sites are in the vicinity of single or adjoining residential developments which combined have over 1,200 homes, the non-residential threshold should be reduced to 5 hectares and the combined potential for heat networks should be evaluated and implemented where economic.

Heat networks also enable the use of waste heat from new or existing industrial sources. New developments can therefore benefit from being located in the vicinity of such heat sources. Mapping has identified more than 25 potential heat sources across the GESP area some of which give the potential to contribute waste heat into existing and new development sites with heat networks.

Low carbon electricity supply from the GESP wind and solar resource has been mapped and quantified. The potential for up to 637 wind sites has been identified with potential capacity of 475 MWe and corresponding output of 1,166 GWh. The potential solar PV resource is an order of magnitude larger; potential capacity is up to 2,053 MWe with corresponding output of 1,987 GWh. Policy should encourage applications for large scale onshore wind turbine and PV sites in the areas identified provided such applications meet the policy set out in the National Planning Policy Framework (NPPF) and the relevant local and neighbourhood plans.

Technologies which provide heat and electricity, including thermal biomass and waste plants, need to be sited only where the facility can be demonstrated to utilise Combined Heat and Power (CHP) to enhance overall efficiency (useful energy output divided by fuel energy input) by more than 50% over the electricity only efficiency through the provision of useful heat (useful heat excludes unnecessary heat loads such as accelerated drying) or to provide efficient useful heat only.

Anaerobic digestion facilities should only be developed where they can either export biogas to the gas grid or use CHP (with the caveats above).

Developments which produce more than 1 MWth of heat that is not usefully used should, where viable, connect to any existing, or proposed, heat network in the locality to bring forward low and zero carbon energy supply and distribution. If no heat network is currently in existence or proposed, then such developments should be constructed so as to not preclude the future connection to and development of such a network.

Low temperature heat networks, where flow temperature is reduced from 80-90 °C to 50-60 °C, reduce heat losses and enable lower temperature heat sources such as waste heat and solar thermal to contribute more effectively and should therefore be required for new heat networks. In developments where low temperature heat networks are economic all buildings should be required to have suitable heat transfer surfaces to facilitate the correct return temperatures (typically through the use of underfloor heating, radiators with a larger surface area or space heating using warm air circulation).

Policy for solar thermal arrays should allocate sites for large scale solar thermal arrays up to 100 hectares on suitable land (identified by the PV mapping) adjacent to existing or planned heat networks.

The use of waste heat should be encouraged and developments that have a cooling load (i.e. waste heat) of more than 1 MWth which is not usefully used should have land allocated adjacent the waste heat source for the installation of a heat pump which could then upgrade the waste heat to serve a heat network.

Smaller scale renewable energy including run of river hydro should be encouraged subject to policy in national, local and neighbourhood plans.

Policy recommendations for nuclear, carbon capture and storage, deep geothermal and offshore renewables haven not been included as these technologies are either driven by national policy, geologically unsuitable or outside the GESP area.

It is estimated that over the GESP period temperatures may rise by 2 – 3°C and rainfall increase by 10 – 20%. Specific actions that should be considered for new development in the GESP area include; designing buildings using the approach set out in CIBSE TM59; especially for large developments and where there are flats, to consider designing constructions to meet the requirements for a "very severe" exposure zone; and to incorporate specific climate change uplift factors provided by the Environment Agency when undertaking flood risk assessments. Interrogation of outputs from a large scale research programme where design teams were left to develop their own approaches to adapting their residential developments to climate change resulted in overall cost uplifts ranging from 1% to nearer 10%, with one project as high as 68%. This very wide range is indicative of both the different approaches adopted by design teams in the absence of an official approach, together with the site specific aspect of climate change adaptation; flooding can be a very localised issue. A key observation was that low/zero cost design measures can be undertaken now that enable (or at the least do not preclude) the retrofitting of adaptive measures at trigger points in the future e.g. when building services or fabric elements like windows are due to be replaced.

CONTENTS

1. INTRODUCTION

A Greater Exeter Strategic Plan (GESP) is being developed for the Greater Exeter area, covering East Devon, Exeter, Mid Devon and Teignbridge District councils (excluding Dartmoor National Park) in partnership with Devon County Council. The GESP will be a new formal statutory document, providing the overall spatial strategy and level of housing and employment land to be provided in the period to 2040. When adopted, it will sit above Local Plans for each area which will continue to be prepared to consider local level issues. Neighbourhood Plans will also be promoted so communities can continue to be empowered to make the detailed planning decisions for the benefit of their area. The Centre for Energy and the Environment at the University of Exeter was commissioned to provide evidence relating to low carbon and climate change issues. Specifically, the following objectives were set:

1. Project forward a 'business as usual' greenhouse gas (GHG) emissions scenario for the GESP area that models the effect of existing Government policy on future emissions. This would demonstrate the scale of increased emissions arising from GESP development if it is built to current building regulations and no additional low-carbon projects were implemented.
2. Develop an evidence base showing why and how GHG emissions can be reduced with reference to specific scenarios and the elements of low carbon development that would need to be delivered to meet each scenario.
3. Establishing evidenced principles that will lead to flexible, low carbon development and identify methods to achieve maximum benefits of low carbon development by considering location, scaling and mix of uses
4. Develop consistent planning policy requirements for site energy strategies to accompany applications, following the energy hierarchy.
5. Evidence the most efficient strategy for location and concentration of development in terms of GHG emissions savings.
6. Map the potential opportunity areas for different low carbon and renewable energy technologies, both integral to new developments allocations and as standalone developments and evidence the contribution that such schemes could make to low carbon development.
7. Develop built environment (buildings and infrastructure) climate change adaptation evidence and policy guidance for adapting to climate change.
8. Consider opportunities for improving viability and attractiveness of low carbon and renewable energy technology through the creation and encouragement for a local industry based around these technologies.

To achieve the above objectives, a programme of work was developed structured into the following work packages (WPs):

1. New build energy hierarchy development
2. Development scale
3. Carbon Dioxide Emissions Trajectories
4. Low carbon energy supply
5. Low carbon marginal abatement assessment
6. Climate change adaptation
7. Impact of low carbon, energy & adaptation policies on the economy

In March 2018 the CEE produced an evidence base report[1] describing the methods employed and the outcomes. Since then several relevant policy changes have occurred:

- the GESP local authorities have declared Climate Emergencies and committed to achieving net zero carbon emissions in timescales ranging from 2025 to 2050
- The Committee on Climate Change (CCC) has published is Net Zero reports and the accompanying evidence base[2]
- the Government has committed the UK to net zero emissions by 2050
- The Government has published a consultation on the Future Homes Standard[3]

These changes have led to the update of the 2018 work in this report and this updated evidence will subsequently feed into a review of each site identified for the GESP which will be contained is a separate report once all the sites have been identified.

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[1] SWEEG, 2018, Internal Document 948 “Low Carbon and Climate Change Evidence Base for the Greater Exeter Strategic Plan”

[2] CCC, 2019, “Net zero, the UK’s contribution to stopping global warming”

[3] MHCLG, 2019 “The future homes standard, 2019 consultation on changes to Part L and Part F of the Building Regulations for new dwellings”

2. NEW BUILD ENERGY HIERARCHY DEVELOPMENT

2.1 WORK PACKAGE AIM

The aim of this work package was to address objective 4 as described in Section 1, which was to develop consistent planning policy requirements for site energy strategies to accompany applications, following the energy hierarchy.

2.2 GENERAL APPROACH

The approach taken was to consult the existing literature, including the National Planning Policy Framework (NPPF)[4], other existing Local Plans, academic literature and other studies with the aim of developing a robust framework for developers to follow when considering the energy performance of their new developments.

2.3 WORK PACKAGE OUTPUTS

The energy hierarchy is the order in which energy matters should be considered in the design of new developments. Following consultation with the literature (government documents and local plans), the following hierarchy has been developed. It should be considered sequentially.

1. Location
2. Site Masterplanning
3. Building Fabric
4. Building Services
5. Clean Energy
6. Offsite Measures
7. In-use performance

2.3.1 LOCATION

The NPPF paragraph 150 states that *"New development should be planned for in ways that… can help to reduce greenhouse gas emissions, such as through its location, orientation and design"*. In addition Section 9 of the NPPF (Promoting Sustainable Transport) contains a range of measures to address sustainable transport, including *"Significant development should be focused on locations which are or can be made sustainable, through limiting the need to travel and offering a genuine choice of transport modes"*.

Previous work[5] by the CEE for Teignbridge District Council developed a quantified method to predict carbon dioxide emissions associated with new domestic development. This method considered emissions from the dwellings that are captured by Part L of the Building Regulations, additional "unregulated" emission that fall beyond the scope of Part L, and emissions from transport (which again are unregulated). It was found that location is the single most important factor in determining potential emissions arising from new development (Figure 1). For example, of Teignbridge's allocated sites the location with the lowest baseline emissions was NA3 Wolborough (Newton Abbot) at 1.5 tCO_2/person per annum. The location with the highest emissions modelled was BT3 Challabrook (Bovey Tracey) at 2.7 tCO_2/person. In general, transport emissions were lower when development was closer to existing major urban areas. In addition to site location, a number of additional transport measures were considered including:

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[4] CLG 2018, National Planning Policy Framework (NPPF)

[5] SWEEG, 2013 Scientist's Report 145 , "The Development of a Method to Support Policies S7 and EN3 of the Teignbridge Local Plan 2013-2033"

- Proximity to bus and rail routes
- Connectivity of walking and cycling routes to local amenities
- Electric vehicle charging
- Cycling provision e.g. for bicycle storage
- Provision of space within dwellings for home-working

When taken cumulatively, these measures on average resulted in marginally greater carbon emission reduction than specifying that dwellings are “zero carbon” for regulated emissions (i.e. equivalent to the previous Code for Sustainable Homes [CSH] Level 5 Energy standard). Therefore, the location of a development and the range of sustainable transportation options available to prospective residents are clearly interlinked, however, transport emissions (and mitigating them through different interventions) are being dealt with separately in the GESP.

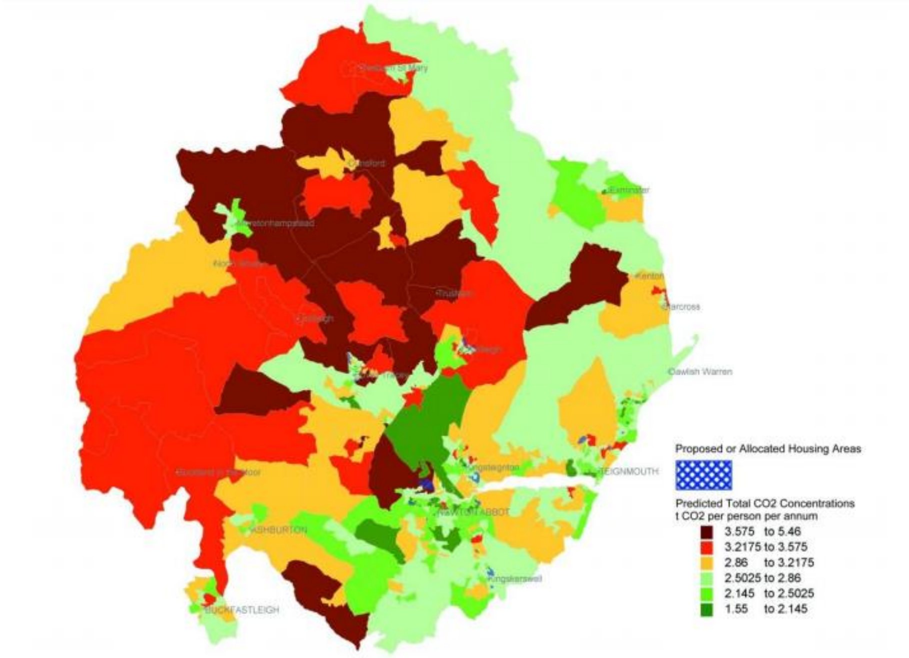

Figure 1: Emissions per person for an 80 m^2 dwelling at 11 kgCO$_2$/m^2 regulated emissions and a range of sustainable transport measures applied from previous work undertaken by the CEE for Teignbridge District Council

2.3.2 SITE MASTERPLANNING

The NPPF paragraph 153 states that *“local planning authorities should expect new development to… take account of landform, layout, building orientation, massing and landscaping to minimise energy consumption”*. In practical terms, this could include location of services within sites, movement strategies, minimising energy demand of site-wide systems e.g. water pumps or sub-stations etc. minimising of earthworks, retention of most effective parts of the site for renewable energy production etc. Transport and infrastructure/utilities elements are dealt with elsewhere in the GESP, and minimising earthworks is a matter that developers will already pursue as there is a financial incentive. Section 7 of this report discusses siting of large scale renewable energy infrastructure in the context of potential development sites in the GESP region. The vast majority of guidance on site masterplanning and energy consumption relates to solar issues.

Plymouth City Council[6] commissioned an analysis to quantitatively assess the effect of massing of development on solar gains (and therefore energy demand and overheating risk) and natural daylight. The study demonstrated that by using a quantitative approach at the masterplan stage, the layout generated was able to effectively save energy and carbon – by providing acceptable daylighting (with lower lighting costs and increased well-being), the opportunity for solar gain (subject to its utilisation), increased efficiency for passive solar collectors and better solar access to external amenity spaces. These results have informed the upcoming Plymouth and South West Devon Joint Local Plan[7], where the Pre-Submission Draft contains policy DEV32.4 which states that:

"Developments should reduce the energy load of the development by good layout, orientation and design to maximise natural heating, cooling and lighting, and reduce the heat loss area. For major developments, a solar master plan should show how access to natural light has been optimised in the development, aiming to achieve a minimum daylight standard of 27 per cent Vertical Sky Component and 10 per cent Winter Probable Sunlight Hours.".

The vertical sky component is ratio of vertical illuminance on a plane (the centre of a window) compared to the unobstructed horizontal illuminance. It accounts for obstructions (buildings – trees and in practice if one had a totally unobstructed view of the sky, looking in a single direction, then just under 40% of the complete hemisphere would be visible[8]. Annual probable sunlight hours (APSH) is a measure of sunlight that a given window may expect over a year period. Only windows with an orientation within 90 degrees of south need be assessed. BRE guidance recommends that the APSH received at a given window in the proposed case should be at least 25% of the total available, including at least 5% in winter[9].

2.3.3 BUILDING FABRIC

Improving the efficiency of the thermal envelope of a building will reduce its demand for space heat (and in some instances cooling). Limits are set for the worst acceptable performance levels for walls, roofs, floors, windows and doors in this regard in criterion 2 of Parts L1A (new dwellings) and L2A (new non-domestic buildings) of the Building Regulations. In order to meet those regulations in full (namely criterion 1 which requires an overall carbon target to be met), it is likely that these minimum standards would be significantly improved on. This is because the carbon target is assessed by comparing the calculated carbon emissions of the proposed building against a reference building that has the same form as the proposed building, but fabric standards that are in advance of criterion 2 of the building regulations. Therefore, in order to achieve compliance if a design was to only specify the worst allowable fabric efficiencies then carbon gains would need to be made elsewhere in the scheme e.g. increased renewable energy. In practice, this does not happen and in general the fabric efficiency of new buildings tends to be in advance of the criterion 2 limits.

Once constructed, it is highly unlikely that the thermal performance of the building envelope would be improved upon further, and so the point of construction remains a critical juncture at which to

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[6] Solar Optimisation Report: Plymouth Development Sites 2014, Julian Brooks and Gary Jackson http://web.plymouth.gov.uk/solar_optimisation_report.pdf

[7] Plymouth and South West Devon Joint Local Plan 2014 – 2034 Adopted March 2019 https://www.plymouth.gov.uk/plymouthandsouthwestdevonjointlocalplan/plymouthandsouthwestdevonjointlocalplanadoption

[8] https://www.rbkc.gov.uk/idoxWAM/doc/Other-1400520.pdf?extension=.pdf&id=1400520&location=volume2&contentType=application/pdf&pageCount=1

[9] https://www.london.gov.uk/file/14949/download?token=Slu5Dx--

lock in demand reduction measures that could persist for decades. Consideration should therefore be given by developers to incorporate better fabric standards for their developments, for example the Passivhaus standard. The Passivhaus standard is an approach that was developed in Germany and relies on super-insulation of the building fabric together with mechanical ventilation with heat recovery to drastically reduce the heating energy consumption of buildings. Whilst uprating the specification of the fabric may add capital cost, there are initiatives underway that are seeking to capture the whole life benefit of energy savings within financial instruments. For example, the LENDERS project[10] which is also referenced in the UK Government's Clean Growth Strategy[11] aims to link energy bills to mortgage affordability[12] calculations, meaning that improvements to the building fabric may mean that any increase to the cost of a home may be offset by the ability of potential buyers being able to access mortgages.

2.3.4 BUILDING SERVICES

As with the building fabric, Part L of the Building Regulations set minimum performance standards for the fixed building services (heating, cooling, ventilation and lighting) within buildings. As is the case with the building fabric it is likely that to meet those regulations in full, these minimum standards would need to be significantly improved on.

2.3.5 CLEAN ENERGY

The NPPF paragraph 151 states:

To help increase the use and supply of renewable and low carbon energy and heat, plans should:

> *a) provide a positive strategy for energy from these sources, that maximises the potential for suitable development, while ensuring that adverse impacts are addressed satisfactorily (including cumulative landscape and visual impacts);*
>
> *b) consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure their development; and*
>
> *c) identify opportunities for development to draw its energy supply from decentralised, renewable or low carbon energy supply systems and for colocating potential heat customers and suppliers.*

In terms of the energy hierarchy it is preferable to meet (and potentially exceed) energy/carbon targets using the demand reduction measures discussed in the previous sections rather than through prioritising low and zero carbon (LZC) generating technologies. This is because demand reduction measures are more likely to be integrated into the building and are less likely to be retrofitted post-construction. Renewable energy is more readily retrofitted e.g. photovoltaic panels, provided consideration has been paid to optimally orienting roofs to enable this. In addition to this, by reducing the need to use energy, you reduce the need to produce it.

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[10] UKGBC 2015 The role of energy bill modelling in mortgage affordability calculations, http://www.ukgbc.org/sites/default/files/The%20role%20of%20energy%20bill%20modelling%20in%20mortgage%20affordability%20calculations.pdf

[11] BEIS 2017 The Clean Growth Strategy Leading the way to a low carbon future

[12] http://www.worldgbc.org/sites/default/files/EeMAP%20Technical%20Report%20on%20Building%20Performance%20Indicators%20that%20Impact%20Mortgage%20Credit%20Risk_0.pdf

A common means of encouraging renewable energy in new development is through the adoption of policy that requires that a certain proportion of energy needs (typically 10 to 20%) to be met through the specification of LZCs. This is often referred to as a "Merton Rule". The Joseph Rowntree Foundation undertook research[13] that surveyed 30 Local Planning Authorities (LPAs) responses, plus analysis of 39 further Local Plans (8 of which overlapped with the survey) to establish what climate change mitigation policies are included in their Local Plans. The results can be seen in Figure 2. It can be seen that 37% of LPAs included a local target for renewable energy generation, and 30 – 36% included a carbon target.

In addition, the CEE consulted each of the 37 Local Plans of the LPAs within the SW region to establish what mitigation and climate change adaptation policies are in place. The results can be seen in Figure 3. It can be seen that 41% (15 LPAs) have a quantified renewable energy policy in place[14] with a further 19% (7 LPAs) having qualitative renewable energy policies and the remaining 41% (15 LPAs) having no relevant policy. A quantitative target is much more likely to result in the uptake of renewable energy as it commits a developer to install a minimum amount of renewable energy. A qualitative target does not commit a developer to install a set amount of renewable energy and therefore the policy could be met with either a token amount of renewable energy, or even none at all.

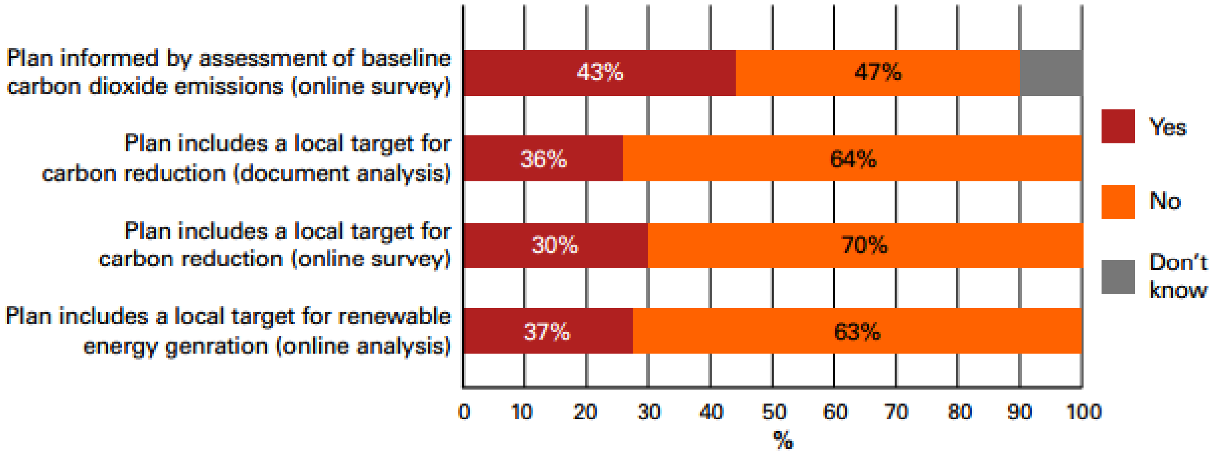

Figure 2: Climate change mitigation policies within Local Plans as studied via surveys and document analyses (Source: JRF 2016)

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[13] Joseph Rowntree Foundation 2016, Planning for the climate challenge? Understanding the performance of English local plans

[14] Those authorities are: Bournemouth, Bristol, Exeter, South Hams, West Devon, Christchurch/East Dorset (shared plan), Purbeck, Cheltenham/Gloucester/Tewkesbury (shared plan), Forest of Dean, North Somerset, Plymouth and Poole

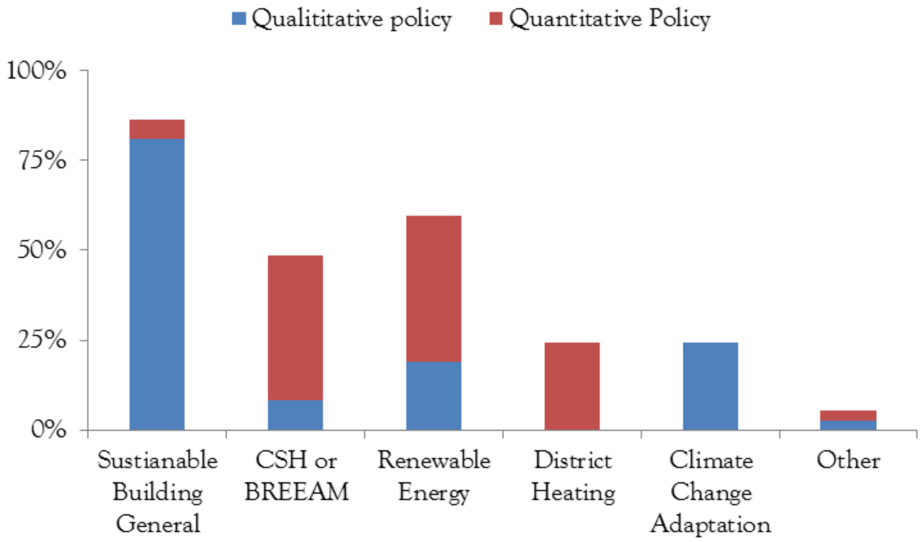

Figure 3: Climate change mitigation and adaptation policies within Local Plans in LPAs in the South West of England

2.3.6 OFFSITE MEASURES

As an alternative to reducing carbon on-site using energy efficiency and renewable energy, recent national and local policies have proposed offsetting carbon emissions from new development by funding carbon reduction measures elsewhere. This approach was intended to be implemented in Part L of the Building Regulations from 2016 via Allowable Solutions. The approach has also been embedded in various local plans including the existing East Devon Local Plan, with perhaps the greatest uptake being in the London boroughs. In London, this has been underpinned by Policy 5.2 of the London Plan which since April 2014 has applied a 35% carbon reduction target beyond Part L 2013 of the Building Regulations, a flat percentage across both residential and non-domestic major developments. It is stated that *"where this improvement cannot be met on-site, any shortfall should be provided off-site or through a cash-in-lieu contribution to the relevant borough, ring-fenced to secure delivery of carbon dioxide savings elsewhere"*. The London Mayor's Housing SPG, published recently in March 2016 confirms the authority's policy commitments to zero carbon development. The adopted Plymouth Plan includes "delivering carbon reductions through off-site measures" within the energy hierarchy. The National Energy Foundation has undertaken a thorough review[15] of the different approaches in London which should be consulted for further detail. From this review, key outcomes of relevance to the GESP include:

- Policy: Allowable solutions were introduced as they were expected to bridge the gap between onsite carbon reduction and achieving the Government's Zero Carbon Homes policy. As this policy was dropped there is uncertainty as to the ability of LPAs to stipulate Carbon Offset measures in local plans. Nonetheless, and underpinned by the London Plan's zero carbon requirement, boroughs in London have been (with varying degrees of success) collecting carbon offset payments from new development.
- Approaches: In London, 22 LPAs are collecting offsetting payments, 2 have imminent plans to do so, and 11 do not. The reasons the 11 that are not collecting gave included uncertainty on ZCH policy, the local plan being at an early stage in the review process,

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[15] National Energy Foundation 2016, Review of Carbon Offsetting Approaches in London

viability issues, preference for onsite measures, and lack of identified projects for offset funding. Fifteen of the 22 LPAs set the payment level at £1,800/tonne (i.e. based on the middle scenario presented by the ZCH of £60/tonne for 30 years [the lower and upper values set being £36 and £90 respectively, with the ZCH also having experimented with a value of £46/tonne]). Of the remaining 7 LPAs, 4 set values based on other values put forward by the ZCH, and 3 based on local analysis of the cost of carbon reduction measures. Interestingly, these varied widely. At Islington there is a one off payment of £920/tonne, whilst in Lewisham and Westminster the values are much higher at £3,201 (derived from Lewisham's own Cost of Carbon 2014 report) and £7,560 (derived from a local assessment carried out by consultants on of the cost of delivering a range of carbon saving measures in the Borough which are costly due to large number of heritage buildings and designations making energy efficiency measures more expensive) respectively. Most LPAs have developed their own additional policy mechanisms to support their approach to offsetting, either through local plan policy and/or through Supplementary Planning Documents (SPDs). The requirements apply to all residential developments of over 10 dwellings or any non-residential with an area greater than 1,000 m^2. These thresholds correspond to the definition of major development[16]. In addition to this, 3 (Enfield, Islington and Waltham Forest) out of the 22 LPAs apply a requirement to minor developments as well. Enfield apply the offsetting policy to minor works "where it is demonstrated that this is technically feasible and economically viable". Islington sets a flat rate of £1,500 per house or £1,000 per unit for minor works and is confident in its approach, however a Written Ministerial Statement in December 2014 stated that tariff style contributions should not be sought for minor developments. Waltham Forest's local plan applies offsetting policy to all developments, but in practice compliance is only being applied to major developments.

- Funding and project selection: Twelve LPAs have set up a dedicated carbon offset fund, six administer the funds through their s106 processes, and four have not yet set up a fund, primarily because payments have not yet been received as developments have not yet commenced or reached the trigger point for payment. At the time of the repot, Islington had far and away the highest current balance in the fund at £2.8 million with only two other LPAs having balances in excess of £200,000. Seven out of the 22 LPAs applying offsetting have spent funds on projects with Islington anticipating spending funds on projects imminently. The remaining 14 LPAs are experiencing a range of barriers to spending the offset fund. The most common barrier is the time taken waiting for payment trigger points to commence, or for payments to be pooled to a required threshold to be sufficient to deliver projects. The restrictions placed on pooling of S106 obligations by the CIL Regulations a potential barrier to the setting up of offset schemes. For some LPAs it was found to be a major barrier, whilst for others it was not a hindrance i.e. where the fund is not used to deliver infrastructure projects. The NEF acknowledge there is an absence of guidance on the matter.
- Monitoring and Reporting: Seven of the 22 LPAs do not currently have a list of projects for funding. The reasons are primarily due to a lack of funds to date; projects identified in s106 agreements or lack of internal resources and departmental awareness of the fund. The remaining LPAs either have published in-house lists or general project descriptions in SPDs, or have specific projects (e.g. Croydon – fuel poor home energy awareness scheme; Havering – PV on community run buildings; Islington – fuel poverty projects e.g. high rise solid wall insulation; Merton – Leisure Centre CHP and City Farm PV – Westminster – feasibility studies for district heating, and community and residential building retrofits). The majority of LPAs (13) calculate offset payments at the planning application stage. Merton has assessed two offset contributions following the committee approval stage. Five authorities

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[16] 2015, Statutory Instrument 595 Town and Country Planning, England

revisit the energy assessment calculation, either following amendments to the application at the detailed design stage, or when planning conditions are discharged. Three authorities recalculate at the "as built" stage (note: "as built" refers to the calculated emissions when the building is handed over as opposed to the actual performance of the building in-use).

- Case studies: The NEF report provides further details for five case study schemes (Ashford, Islington, Milton Keynes, Tower Hamlets, Southampton) of which three are outside London.

In addition, a number of management issues were identified when considering schemes operational in London and beyond:

- Additionality: Funds must be directed towards projects that would not have otherwise happened. In some cases, the funds have been used in conjunction with other schemes e.g. ECO, and in these cases the carbon claimed to be saved by the offset fund can only apply to the fraction of the overall funding derived from the offset fund.
- Offset amount, price and ratio: The payments in the three case study LPAs outside London ranged from £200 - £265/tonne which is significantly less than the most commonly used value of £1,800/tonne used in London. Those three LPAs have had the policy in place prior to the national ZCH work on allowable solutions, and it is claimed that the amount is based on the cost of actually delivering carbon reduction in those areas. It is not clear whether the measures identified are "quick wins", or if a 30 year multiplier has not been applied. However, these prices are now under review through the Local Plan process. The "offset ratio" (the ratio of the actual identified cost to save a tonne compared to the levied cost per tonne) is also a factor in London, with the Mayor's SPD stating that the ratio does not need to be 1:1 as *"offset price set generally does not fully cover the cost of saving carbon dioxide in order to ensure the price is viable for development"* and that *"The benefit of the fund is in unlocking carbon dioxide saving measures. If a 1:1 ratio is set, only the simplest retrofitting measures are likely to be carried out. This would potentially leave the more complicated measures without adequate funding and could result in a property requiring further retrofit works in the future, resulting in further disturbance to the occupier".* In London, the approach to collection has been via s106 payments, ensuring that no projects are also on the CIL Regulation 123 list as this would constitute double charging.
- Viability: Development must still remain viable, after the charging for any carbon offsetting. The NEF concluded that whilst there has been some resistance, where LPAs have followed the London Plan SPG developers have been unlikely to challenge, due to the weight of evidence behind the plan. However, land values are significantly higher in London than in the GESP area and so this may be a factor.
- Management: Generally the collected funds are managed by the local council, though there are some example cases where this function has been outsourced.

2.3.7 IN-USE PERFORMANCE

Compliance with Part L of the building regulations (including any standards that rely on subsequent improvements) is based on passing a theoretical calculation. There is a significant body of evidence that in practice buildings do not perform as well when they are completed as was anticipated when they were being designed. The difference between anticipated and actual performance is known as the performance gap[17] with actual energy use and carbon emissions being potentially several times greater than estimated at the design stage. This is in spite of some efforts to aim to close the gap, for example with the introduction of mandatory air pressure tests in Part L. There are many reasons for

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[17] https://www.designingbuildings.co.uk/wiki/Performance_gap_between_building_design_and_operation

the performance gap including design issues, quality of construction, problems with commissioning of building systems and handover, and poor building readiness for occupants. Monitoring and addressing this performance gap should be a key driver of policy to ensure that in-use performance meets designed performance and as such energy use and carbon emissions are as close to what was expected and permitted as possible.

Milton Keynes's draft policy SC1 states that *"Development proposals should include a quantified explanation of how the targets for carbon dioxide emissions reduction and renewable energy generation outlined above are to be met, and realised in practice"*. For homes, a means of demonstrating this could be to target specific areas within BRE's Home Quality Mark Scheme[18] such as "26 Commissioning and Performance", "27 Quality Improvement", "32 Aftercare" and "35 Post-Occupancy Evaluation". For non-domestic buildings a means of demonstrating this could be to implement the Soft Landings Framework[19] or to achieve specific credits within BREEAM such as "Man 01 Project Brief and Design", "Man 04 Commissioning and Handover" and "Man 05 Aftercare".

2.3.8 The Future Homes Standard consultation 2019

In October 2019 the Government published an initial consultation on the Future Homes Standard (FHS) which also contains proposals for changes to Part L of the Building Regulations. The consultation is the first part of a proposed FHS process extending to 2025 which is illustrated in Figure 4.

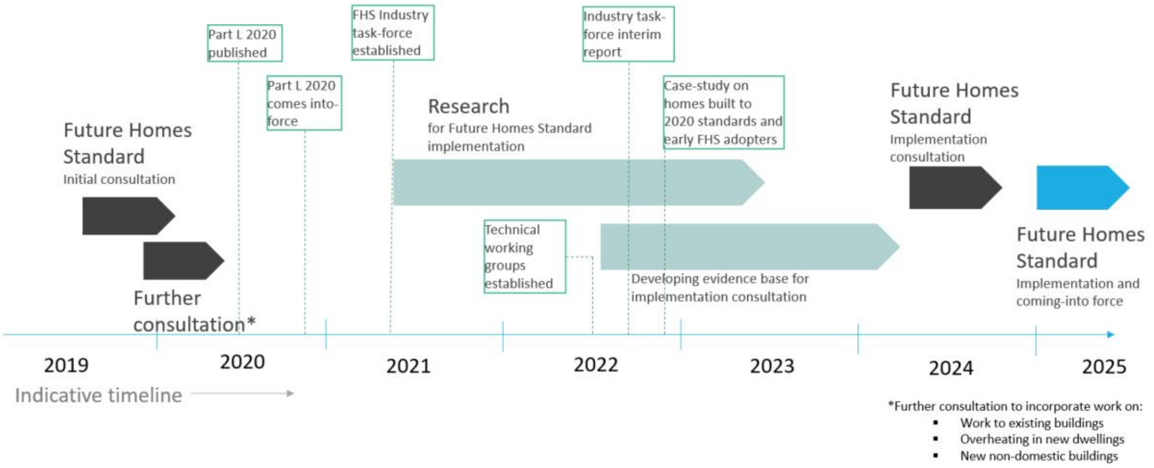

Figure 4: MHCLG's Future Homes Standard roadmap

The time line suggests that the changes to Part L being consulted on may come into force in towards the end of 2020. This would be followed by a 5 year process to establish and implement the FSH.

The main Part L 2020 proposals contained in the consultation are as follows:

- A requirement for a 20% "fabric" or a 31% "fabric plus technology" reduction in CO_2 emissions from new dwellings as a "stepping stone" to a 75% to 80% reduction proposed for the FHS.

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[18] https://www.homequalitymark.com/what-is-the-hqm
[19] https://www.bsria.co.uk/services/design/soft-landings/

- Exchanging the current fabric energy efficiency and minimum standards (for fabric and fixed building services) to a primary energy target and householder affordability rating. The current CO_2 emissions target remains.
- Minimum standards for fabric elements to remove the worst performing 25% currently being built.
- Removal of fuel factors (these give relief for more carbon intensive fuels).
- Increased minimum efficiencies for building services (boilers, heat pumps, air conditioning and lighting).
- 55°C flow temperature in the final heating circuit.

While it seem likely that there will be some tightening of the Building Regulations in 2020 the outcome will only be know after the consultation is completed.

The consultation proposes that the performance gap found in new homes is addressed by the a build quality sections in Annex C including specific wording on thermal bridging at junctions and four categories of airtightness (service penetrations, structure, openings and internal services.

Measures are suggested to reduce the abuse of transitional arrangements to ensure that developers do not use old standards for "longer than is appropriate". In 2020 it is the consultation proposes that transitional arrangements apply only to individual buildings when work has started within a "reasonable period" not entire sites. If building of and individual building has not started within a reasonable period the latest energy efficiency standard would apply. Stricter rules are proposed for the FHS.

Last and perhaps most importantly, the consultation also includes proposals to curtail the ability of local authorities to set energy efficiency standards for new homes by enacting the Planning and Energy Act 2008 either with the changes to Part L in 2020 or when the FSH is introduced.

3. DEVELOPMENT SCALE

3.1 WORK PACKAGE AIM

The aim of this work package was to address objective 5 as described in Section 1. This requires an assessment of the impact of the scale at which development is pursued across the GESP area in particular the carbon dioxide emissions savings that can be achieved by concentrating new development into a smaller number of large sites than dispersing development across a larger number of small sites.

3.2 GENERAL APPROACH

The case for carbon emission reduction from concentrating development can be made for both transport and buildings.

3.2.1 TRANSPORT

In a predominantly rural area such as Greater Exeter the qualitative case for transport carbon emission reductions in large scale new development can be made relatively simply:

- Large scale mixed use development, where there is the potential for home occupiers to work in local employment areas built as part of the development masterplan, has the potential to reduce travel to work distances.
- The provision of local education, health and recreational facilities has a similar effect on leisure miles.

- Public transport provision is potentially more efficient and cost effective when a large number of people can be served in a concentrated area.
- Where a large new development is sited next to a major area of existing employment (e.g. Exeter) those that work in this area will have shorter journeys than if commuting from dispersed development further afield.

The impact on the transport emissions from the location of new development has been demonstrated in Teignbridge[2].

3.2.2 BUILDINGS

The case for buildings is more complex. Low and zero energy/carbon buildings can be built at all scales. Building all new homes in the GESP area to the Passivhaus standard (see Section 2.3.3) would achieve similar energy/carbon savings in both concentrated and dispersed development models (i.e. wherever they are located). However, the Passivhaus standard significantly exceeds the current Part L of the building regulations (and the proposed 2020 changes in the FSH consultation) and building to the standard incurs significant additional cost for developers. There is currently uncertainty[20] regarding the ability of local authorities to set energy standards in advance of the building regulations through the planning process. The Housing Standards Review in 2015 announced the withdrawal of the Code for Sustainable Homes (CSH). A Written Ministerial Statement (WMS) in 2015 confirmed that local authorities would still be able to require higher energy performance standards (up to CSH4) until commencement of amendments to the Planning and Energy Act 2008. The powers (in the 2008 Act) have not yet been enacted. Therefore the WMS 2015 does not yet preclude the setting and application of energy standards above those set out in the Building Regulations. The February 2017 Housing White Paper said that Government will clarify various WMS, and in 2019 the FSH standard consultation included proposals to curtail the ability of local authorities to set energy efficiency standards for new homes by enacting the Planning and Energy Act 2008 either with the changes to Part L in 2020 or when the FSH is introduced Until the time when developers are required to meet higher standards there will need to be an economic case in favour of low carbon concentrated development.

Concentrated developments of hundreds or thousands of homes enable a site wide approach to energy provision and carbon reduction. This was highlighted in 2008 in a strategic analysis of energy and carbon dioxide (CO_2) emissions from the new developments in Exeter and East Devon Growth Point over the period to 2020[21]. The Element Energy report made the economic case for a district energy solution (heat network) for the emerging Cranbrook new community in East Devon's West End. It was found that in larger scale development, adopting a site-wide solution would be significantly cheaper than abating carbon at a household level when targeting zero carbon regulated and total zero carbon homes (levels 5 and 6 of the Code for Sustainable Homes). Whilst a heat network was not planned for the first phase of development at Cranbrook, it was argued that early investment in a district heating network would benefit the economics of future phases.

Since the 2008 study considerable progress has been made delivering heat network schemes in the large scale new developments planned and underway in the Exeter area:

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[20] https://www.ukgbc.org/wp-content/uploads/2017/09/171027-Sustainability-Standards-in-New-Homes-consultation.pdf

[21] Element Energy 2008, East of Exeter Growth Point: Energy Strategy

- The study formed the basis of a successful application for £4.1m of grant funding for the Cranbrook biomass CHP scheme; one of the few zero carbon on-site developments in the country. E.ON, the scheme operator, has currently connected over 2,000 homes and the first commercial buildings on the neighbouring Skypark.
- A private wire electricity supply is being made to the Lidl distribution warehouse built adjacent to the Cranbrook energy centre.
- The scale of development in the West End of East Devon has grown. Element Energy considered 3,500 homes at Cranbrook whereas a swath of up to 12,000 homes and business premises are now being planned from Monkerton (in Exeter just west of the M5) out to the eastern extension of Cranbrook.
- A second E.ON district heating and CHP scheme is now underway at Monkerton. Importantly this scheme went ahead without grant funding.
- Private wire electricity supply from the Monkerton energy centre to the Met Office supercomputer on Science Park is being pursued.
- Other heat networks schemes are being considered elsewhere in the Exeter area including a retrofit scheme connecting the major public sector heat loads in the city and a separate heat network to use steam from the Marsh Barton energy from waste plant to supply heat to some 2,500 new homes in the south west of the city and across the boundary in Teignbridge.

However, the Cranbrook and Monkerton heat networks are currently fuelled by gas. While gas CHP delivers carbon savings at present, it will not deliver on the zero carbon commitment at Cranbrook and in time wider grid decarbonisation will catch up and potentially surpass its performance. The CEE's work on "Heat Network Strategies for the West End of East Devon"[22] shows that there is further potential for significant energy and carbon savings. It demonstrates the ability of heat networks to collect heat from a variety of technologies and illustrates the potential for the migration from fossil fuel gas fired CHP towards renewable and waste heat resource which were not envisaged in the 2008 study.

In summary the evidence at Cranbrook and Monkerton shows that:

- Heat networks are viable in the large scale new developments around Exeter which are in the order of 2,500 homes (plus associated commercial development)
- The presence of heat networks provides opportunities for additional energy and carbon savings which are not foreseen at the outset
- Economic benefit is provided through investment in heat networks and the add on opportunities which heat networks can generate

This work package examines at what scale below 2,500 homes heat networks are likely to be viable.

3.3 WORK PACKAGE OUTPUTS

3.3.1 STAND-ALONE DEVELOPMENT HEAT NETWORK VIABILITY CALCULATOR

In recent years the CEE has undertaken a number of heat network feasibility studies for larger low density residential/mixed use development sites in Devon[23, 24, 25].

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[22] CEE, 2017, Heat Network Strategies for the West End of East Devon

[23] CEE, 2013, South west Exeter urban extension, an initial feasibility assessment of site wide district heating and combined heat and power

[24] CEE, 2015, Houghton Barton urban extension, Newton Abbot, an initial feasibility assessment of site wide district heating and combined heat and power

Input data to these studies has been used to develop a heat network viability calculator which provides an initial indication of heat network viability for stand-alone low density development. The calculator does not consider whether a development in its entirety is viable. It is also important to note that the calculator (and the assumptions it includes) is designed to give an initial indication of heat network viability which will serve as a trigger for a more detailed viability assessment which will be required to understand the specific viability of a specific network in a specific development.

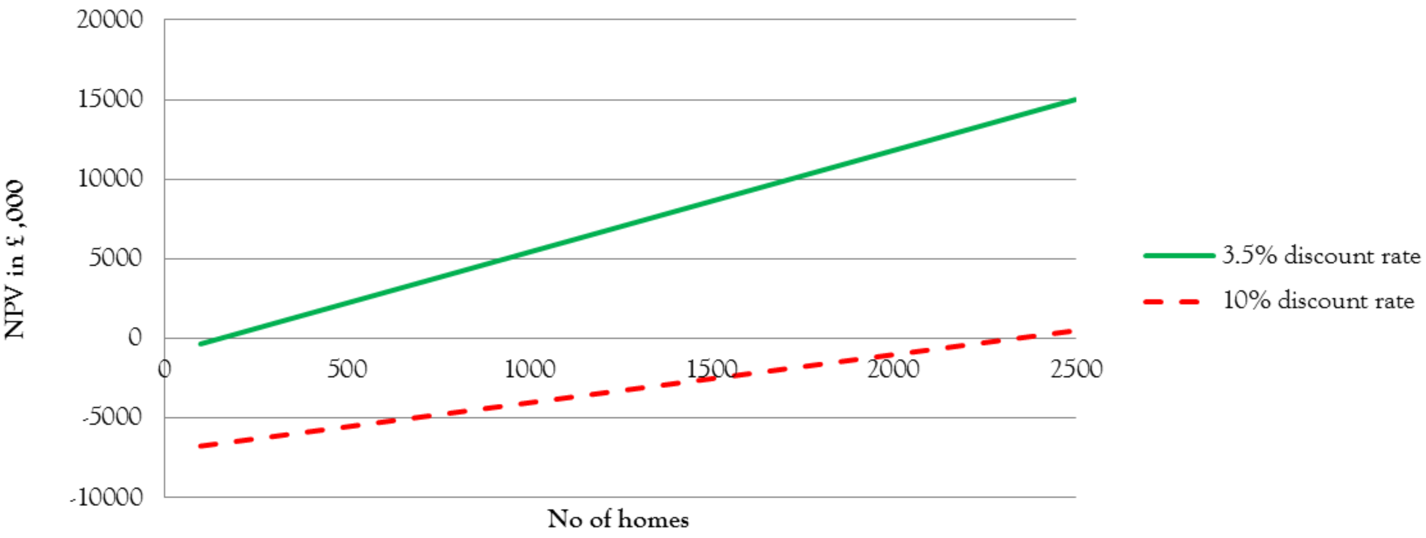
The input data to the calculator are:

- Number of homes
- Development start year

The calculator utilises the start year to provide assumptions on connection fees and energy prices and housing numbers to estimate capital costs (CHP plant and heat network), non-fuel operating costs (CHP and heat network) and the heat demand of the development. The heat demand estimate is combined with assumptions on the typical performance of a heat network and gas CHP to calculate energy revenue from which net revenue is calculated by deducting non-fuel operating costs. The Net Present Value (NPV) of net revenues is calculated over 40 years. Net capital costs are calculated by deducting total connection fees from the estimated capital cost. The overall NPV of the scheme is then calculated by deducing the net capital cost from the net revenue NPV. For further details see the heat network viability calculator documentation in Appendix B.

Where developments return a positive overall NPV it is recommended that a more detailed viability assessment is undertaken.

Results from the calculator are summarised in Figure 4 for two discount rates; the UK Treasury Green Book discount rate of 3.5% (in real terms) which assumes that the scheme will be financed by the public sector and a 10% real discount rate which is more representative of discount rates adopted by the private sector. Mixed finance or use of BEIS HNIP[26] funding will provide finance at rates between these examples.



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[26] The BEIS Heat Network Investment Project (HNIP) is delivering £320m of capital investment support to increase the volume of heat networks built, deliver carbon savings for carbon budgets, and help create the conditions for a sustainable market that can operate without direct government subsidy

Figure 5: Results from the heat network viability calculator

The calculator indicates that, with discount rate of 3.5% real, heat network viability should be further assessed in developments of more than 154 homes, whereas with at 10% discount rate, the threshold is 2,337 homes. Wholly public funded heat networks are unlikely in the GESP area so the policy threshold reflects a mid-point of 1,200 homes. Single and adjoining residential / mixed sites which, combined, have over 1,200 homes should therefore be required to evaluate the use of heat networks and CHP and implement such schemes where feasible.

Guidance for the size of commercial / employment development where it is appropriate to evaluate the viability of heat networks can be obtained from the scale of development where heat networks are proceeding in the GESP area. These include Skypark (35ha), Science Park (25ha) and Matford Phase 3 (15 ha). A threshold of 10 ha would therefore seem appropriate and such sites should be required to evaluate the use of heat networks and CHP and implement such schemes where feasible. However, where commercial/employment sites are in the vicinity of single or adjoining residential developments which combined have over 1,200 homes this threshold should be reduced to 5ha and combined potential for heat networks should be evaluated together and implement where feasible.

4. CARBON DIOXIDE EMISSIONS TRAJECTORIES

4.1 WORK PACKAGE AIM

The aim of this work package was to address objectives 1 and 2 as described in Section 1. The overarching aim of these objectives are to project what Greenhouse Gas (GHG) emissions will be in the GESP area over the plan period and to establish the component of emissions that would result from new development. This would then enable the impact of implementing carbon reduction policy for new development to be quantified within the context of overall emissions.

4.2 GENERAL APPROACH

GHG emission projections for GESP start from a baseline GHG inventory for the area. This is an inventory of emissions that arise within its geographic boundary i.e. they are accounted for on a *production* basis. For example, whilst emissions arise from the Industrial sector in producing goods that are traded beyond the GESP area, the emissions from all of the production are allocated to the GESP area. Similarly, any goods that are imported into the GESP area will result in emissions in manufacture that occur elsewhere and that are not counted in the GESP area footprint. It is estimated by the Committee on Climate Change[27] in its 2018 Progress Report to Parliament that in the UK the average GHG emissions are 8 tCO_2e/person if measured on a *production* basis or 13 tCO_2e/person if measured on a *consumption* basis.

Initial analysis (see 4.3.1) provides historic GHG emissions from 2008 to 2016 broken down by sector and greenhouse gas, together with total emissions expressed in tonnes of carbon dioxide equivalent (tCO_2e).

In order to project emissions from 2016 forward to 2050, two key documents from the Committee on Climate Change[27] (CCC) were utilised:

- 2018 Progress Report to Parliament (referred to as the Progress Report)[28]
- Net Zero: The UK's contribution to stopping global warming (referred to as the Net Zero report)[29].

Both of these documents assess and project GHG emissions by sector in the UK. The Progress Report is the latest in an annual series of reports that charts progress in each sector over recent years, and analyses the potential of existing and required policy to meet the requirements of future carbon budget periods[30]. The 2018 Progress Report runs to 2032, the end of the fifth carbon budget. The Net Zero report considers what policies and action is necessary by 2050 in order to achieve Net Zero GHG emissions.

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[27] The CCC is a statutory body set up under the 2008 Climate Change Act whose purpose is to advise the UK Government and Devolved Administrations on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change

[28] The CCC's 2019 Report to Parliament was released on 10 July 2019. The format of the 2019 report does not provide the sectorial analysis included in the 2018 report so the 2018 report has been used in this analysis.

[29] The CCC's "Net Zero, The UK's contribution to stopping global warming" was published in May 2019 together with the Net Zero Technical report which is used extensively in these projections.

[30] Carbon budget periods are periods of 5 years that commenced in 2008 when the UK Climate Change Act came into force.

In this work national emissions reduction projections from the two documents have been apportioned to the equivalent sectors in the GESP area. For example, if it were assumed nationally that by a certain year transport emissions would halve due to a series of government policies, then it was assumed transport emissions in the GESP area would also halve. Exceptions to this approach occurred in some areas, for example in the Industry sector much of the decarbonisation is associated with certain types of heavy industry that are not found in the GESP area, so the trajectory for the Industry sector in the GESP area discounted savings from those sectors. In other areas however, no specific considerations for the GESP area were made.

This is therefore a simplified approach, and differs from one where a series of known policies are individually modelled for the GESP area. Whilst this might be possible on a policy-by-policy basis, the approach taken has the advantage of being based on the latest assessment of government policies and calculated costs and savings. Many of the required decarbonisation measures are only really feasible when tackled at a national scale. A full "bottom-up" calculation of the impact of individual policies would require in depth detail on the uptake, impact and costs of each policy, which were not available. However, while much of the policy in the CCC reports is national, in many cases there will be a strong requirement for local actors to effectively engage at the delivery stage e.g. home insulation programmes, electric vehicle infrastructure, diet change etc.

In general, the sectors in the GESP area's GHG inventory, the Progress Report and the Net Zero report align well. The exceptions are the transport sector and the agriculture and land use sectors.

In the case of transport the Progress Report combines all transport modes (including aviation and shipping) into one sector, whereas for the other two, aviation and shipping are segregated. As the savings associated with each policy in the Progress Report could not be isolated it was necessary to consider transport as a single sector, inclusive of aviation and shipping.

The agriculture and land use change sectors were often combined, so for the calculations undertaken here they were also combined.

The Progress Report projects GHG emissions across the UK economy based on existing policies that are in place to deliver GHG reduction to 2032. For each of these policies, the CCC used three criteria to assess those policies:

- Design and implementation: Whether the policy tackles the right barriers, has the right track record of delivery, and avoids risks associated with a lack of coherence or political support.
- Incentives: Whether there are the right monetary or regulatory incentives in place to deliver the policy.
- Funding: Whether there is sufficient funding now and in the future to deliver the policy.

If all three criteria are met, then the policy is deemed to be low risk. Where any one of the criteria is failed then the policy is deemed to be medium risk. At a national level, two-thirds of potential emission reduction in 2032 is at this risk of under-delivery. Proposals which are not specified in sufficient detail to be classified as policies are labelled as high risk intentions. At a national level, a quarter of potential emission reduction in 2032 is at this high level of risk. In addition, in order to meet the CCC's least-cost path for decarbonisation, additional potential policies have been identified to bridge any gap between policies in place or intended and the CCC's least cost pathway. Delivering this "policy gap" will be required both to provide contingency for meeting carbon budgets, and to decarbonise further than the original Climate Change Act's 80% reduction requirement (i.e. to Net

Zero). These policies from both CCC reports were assigned to each sector within GESP to enable GHG trajectories within each of these sectors to be developed to 2032 (with policy risks) and then 2050.

The Net Zero report is used for projections from 2032 to 2050. The Net Zero Core Scenario addresses the 80% GHG reduction required by 2050 under the original 2008 Climate Change Act. The Further Ambition Scenario considers more challenging more expensive options which nationally archive 96% emission reduction by 2050. Achieving the remaining 4% to deliver Net Zero requires further Speculative Options which have high costs, technology challenges or low levels of public acceptability. Projections from the two CCC reports are combined and apportioned to GESP.

In order to assess the impact of potential policies to reduce GHG emissions a calculation process was undertaken to determine emissions from alternative policies to the envisaged business as usual pathway.

The calculation process for new dwellings was based on the following approach, assumptions and data sources:

- Various specifications and associated costs for four different dwelling typologies (detached, semi-detached, 1 bed flat and 2 bed flat [ground, mid and top floor for each of the flat scenarios]) were published in a report by Currie and Brown[31] (the C&B report) and the Impact Assessment of the Future Home Standard consultation[32]. These were used to determine the baseline specifications for a Part L 2013 compliant dwelling and the subsequent incremental cost uplift of improving performance of the fabric and services.
- The typical housing mix within the GESP area has been estimated previously by examining typical layouts of developments in East Devon's West End (taken to be 40% detached, 53% semi-detached, and 7% apartments). Calculations were undertaken for each dwelling architype but area weighted to give a GESP "typical" dwelling with an internal floor area of 88 m^2.
- The C&B report was used to establish the heat loss (in W/K) of each of the principle fabric elements (based on the reported element areas and U-values) and air exchange paths (ventilation based on a fixed natural ventilation rate of 0.5 air changes per hour as stated in SAP 10 and an air permeability rate of 5 m^3/h/m^2 @ 50 Pa. These were used to apportion the reported delivered energy consumption (kWh/m^2) for space heating. Delivered energy consumption for domestic hot water (DHW) was reported by C&B whilst delivered energy consumption for auxiliary energy (pumps), lighting, cooking and electrical appliances were calculated using methods stated in SAP 10.
- The delivered energy consumption for each element and end use was converted to both primary energy and carbon emissions using the conversion factors in Table 12 of SAP 10. In the case of primary energy, for energy generated using PV it was assumed that 50% would be used on-site (and therefore avoids importing an equivalent amount from the grid), with the remaining 50% exported to the grid. Therefore a primary energy factor was calculated for PV generation as an average of the import and export primary energy factors (the potential effects of battery storage was not considered).
- It was assumed that the Government's preferred specification for Part L 2020 from their consultation was chosen ("Part L 2020 Option 2"). This corresponds to a 30% carbon

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[31] Currie and Brown 2019, A report for the Committee on Climate Change The costs and benefits of tighter standards for new buildings Final report

[32] The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings, October 2019

reduction on a Part L 2013 dwelling and is achieved via moderate improvements in roof and window U-value, and 6.5 m^2 of connected PV facing SE/SW. The exact specification of the Future Home Standard proposed for 2025 is not known at this stage, though it is stated that it will achieve a 75 – 80% carbon reduction over a Part L 2013 dwelling and that there is an intent to not connect to the gas grid. Modelling undertaken here has found that the "Part L 2020 Option 2" specification without any PV though with an air source heat pump (ASHP) meets the FHS carbon reduction level, and so this was taken to be the specification for Part L 2025.

- The potential energy savings and financial costs of specifying better levels of performance (e.g. improved U-values, air tightness, mechanical ventilation with heat recovery [MVHR]) were calculated and two additional scenarios were created. Scenario A assumed floor, wall, roof and window U-values of 0.11, 0.13, 0.11 and 1.2 W/m2.K respectively, an air permeability rate of 3 $m^3/h/m^2$ @ 50 Pa, improved thermal bridging, and MVHR. Scenario B was the same as scenario A but with a window U-value of 0.8 W/m2.K and an air permeability rate of 1 $m^3/h/m^2$ @ 50 Pa (i.e. similar to the *Passivhaus* specification).
- The total potential PV generation on each of the dwelling architypes was calculated by estimating the available roof area and assuming that roof faced SE/SW with minimal shading. This was then used to determine the maximum potential amount of primary energy or carbon that could be offset from the different dwelling specifications.
- The calculated gas and electricity consumption for each potential dwelling specification (Part L 2013, Part L 2020, Part L 2025 [FHS], and two potential standards to test which were either net zero carbon or net zero primary energy (regulated energy only) were established. These were the theoretical outputs that would be obtained from SAP as opposed to in-use performance which is likely to be higher due to the "performance gap". It was assumed that Parts L 2020 and 2050 would be phased in over 5 years following the phase-in assumption in the Part L 2020 Impact Assessment, and that any GESP policy would be implemented in its entirety from 2023 onwards. These were used in combination with housing projections for the GESP period to estimate the BAU trajectory and the potential additional carbon reduction that might arise if a net zero carbon or net zero primary energy standard were to be set.

PLACEHOLDER AWAITING:

- Government consultation on non-domestic buildings
- Government proposals on measure to address the performance gap
- Consideration of embodied emissions

4.3 WORK PACKAGE OUTPUTS

4.3.1 HISTORIC AND CURRENT CARBON DIOXIDE EMISSIONS

Analysis of local GHG emission data shows that across the GESP area in 2016 total emissions were approximately 3.6 $MtCO_2e$. Transport emissions are dominant (31%) followed by Buildings (23%), Agriculture (17%) and the Power sector (16%). Minor contributors (13% total) include Waste, F-gasses and Industry. Total emissions were higher in Mid Devon and East Devon (29% and 28% respectively) and marginally less in Teignbridge (26%) when compared to lower emission in urban Exeter (16%).

Table 1: Total emissions in 2016 for each of the four districts and the combined value in ktCO$_2$e with % of the combined total in brackets

	East Devon		Exeter		Mid Devon		Teignbridge		Total	
Power	147	(14%)	166	(29%)	100	(10%)	143	(15%)	**557**	**(16%)**
Buildings	230	(23%)	192	(33%)	150	(14%)	259	(28%)	**831**	**(23%)**
Industry	0	(0%)	10	(2%)	6	(1%)	0	(0%)	**15**	**(0%)**
Transport	336	(33%)	107	(19%)	276	(26%)	393	(42%)	**1,113**	**(31%)**
Agriculture & LULUCF	240	(24%)	-3	(-1%)	306	(29%)	77	(8%)	**620**	**(17%)**
Waste	18	(2%)	36	(6%)	184	(17%)	23	(2%)	**261**	**(7%)**
F-gases	41	(4%)	69	(12%)	33	(3%)	43	(5%)	**186**	**(5%)**
Total	**1,012**	**(28%)**	**575**	**(16%)**	**1,054**	**(29%)**	**938**	**(26%)**	**3,582**	

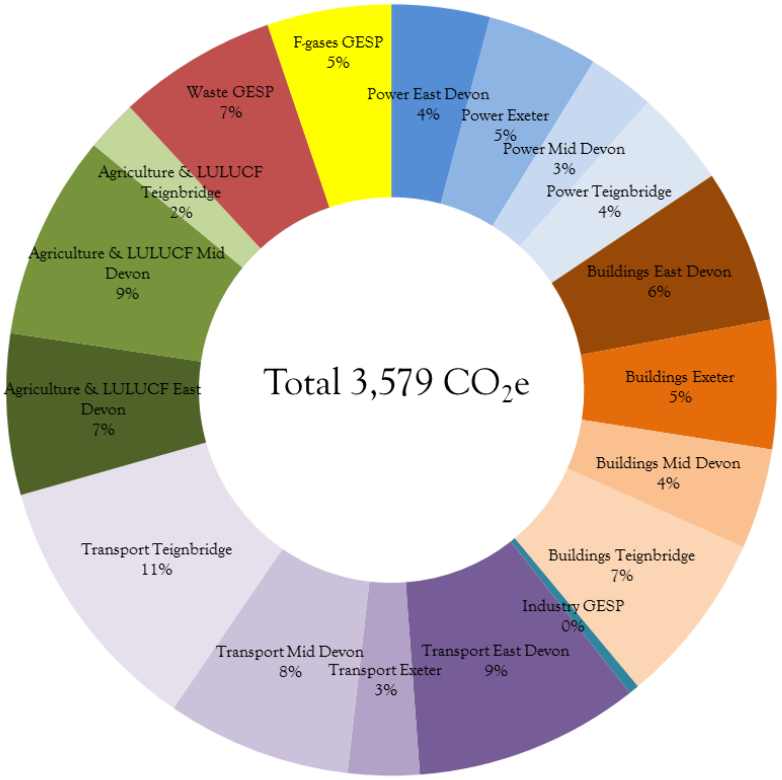

Figure 6: Split of GHG emissions in 2016 across the GESP area

Emissions have generally fallen in absolute terms (Figure 7) and per capita (Figure 8). The CCC's Industry sector includes only direct emissions from processes which are typically found in heavy industry (i.e. it excludes non-residential emissions from buildings). As there are few heavy industry facilities in the GESP area, per capita emissions are very much lower than in other parts of the country.

Whilst total emissions are highest in Mid Devon and East Devon, per capita emissions are significantly highest in Mid Devon due to its agricultural and transport emissions and being divided over a smaller population (Mid Devon's population is much smaller than the other three GESP authority areas). Exeter consistently has the lowest total and per capita emissions primarily driven by lower transport (due to shorter distances to travel and more sustainable options) and no agricultural emissions.

Despite the change in emission mix the per capita trend in carbon reduction in the GESP area compared to the UK has been similar by and large due to emissions from agriculture in GESP making up for those from industry UK wide.

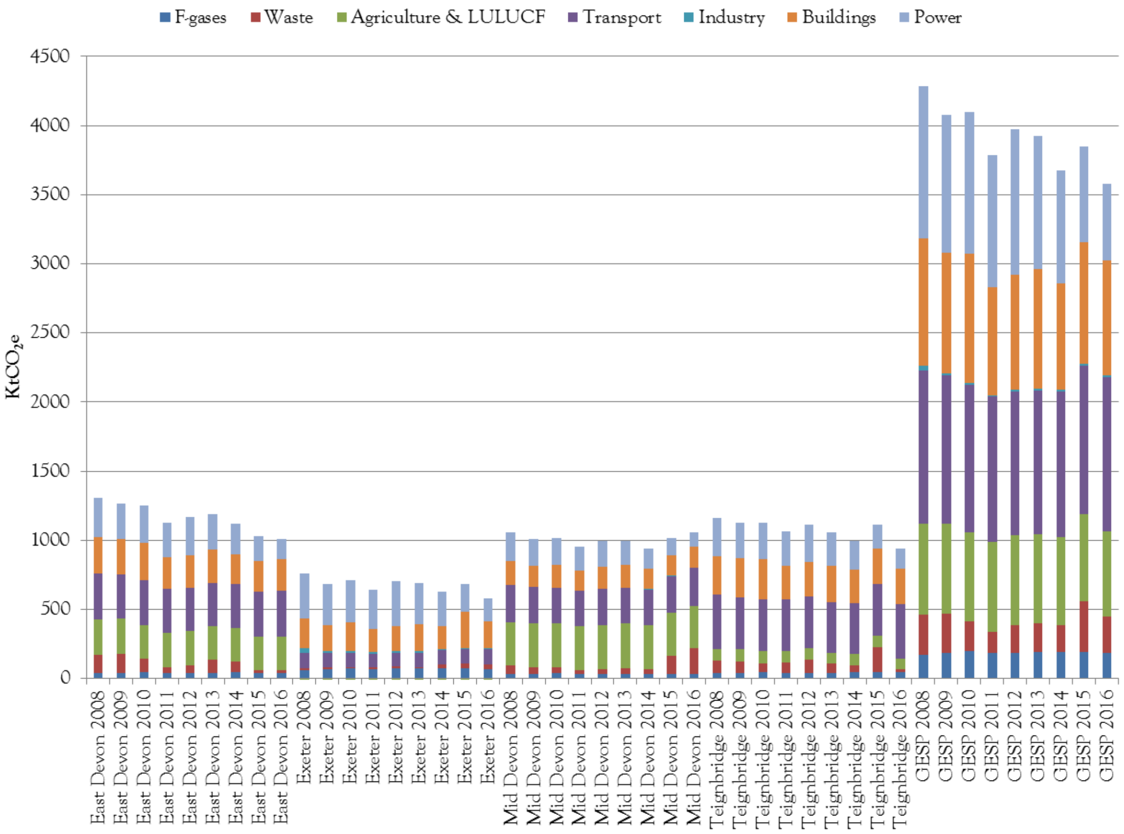

Figure 7: Absolute GHG emissions across the GESP area for each sector from 2008 to 2016

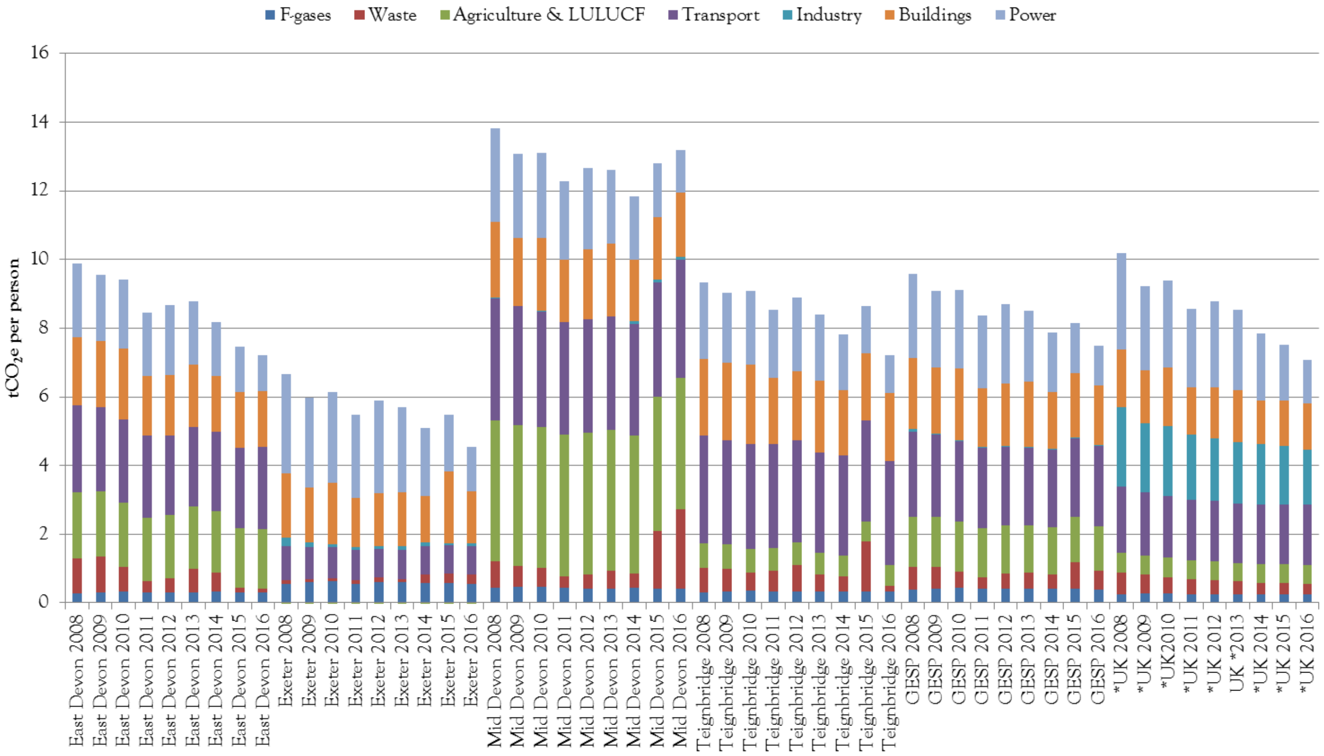

Figure 8: GHG emissions per capita across the GESP area for each sector from 2008 to 2016

**UK emissions exclude aviation and shipping sectors*


Power

Buildings

Industry

Surface transport

Agriculture and LULUCF

Waste

F-gases

Figure 9: Indexed GHG emissions across the sectors for the GESP area and the UK. The difference in the relative contributions of the Industrial sector is due to reductions in heavy industry in Devon. Changes in waste emissions are a reflection in the annual variation of the NAEI point source emission data

4.3.2 Projected Carbon Dioxide Emissions

Current and projected GHG emissions in GESP are shown in Figure 10 (values for 2016, 2032 and 2050 are provided in Appendix C). Emissions in 2016 were 3,579 ktCO_2e and, in the absence of any carbon reduction policy, these would rise to 4,157 ktCO_2e in 2050 including an allowance for population growth[33]. Low, medium and high risk policies to the end of the 5th Carbon Budget in 2032 would see emissions fall to 2,348 ktCO_2e (or 1,961 ktCO_2e if policy to meet the “policy gap” to and achieve the CCC’s least-cost decarbonisation path was to be identified) compared to the 3,678 ktCO_2e under business as usual. Of this carbon reduction, 12% is from “low risk” policy, 38% from “medium risk” policy and 23% from “high risk” policy. The final 23% is the current policy gap. Projecting to 2050, the CCC’s Core scenario would see emissions drop to 1,380 ktCO_2e, and delivering the measures in the Further Ambition scenario would see a further fall to 793 ktCO_2e. The inclusion of GHG removal technologies and offsetting would be required to achieve net zero emissions.

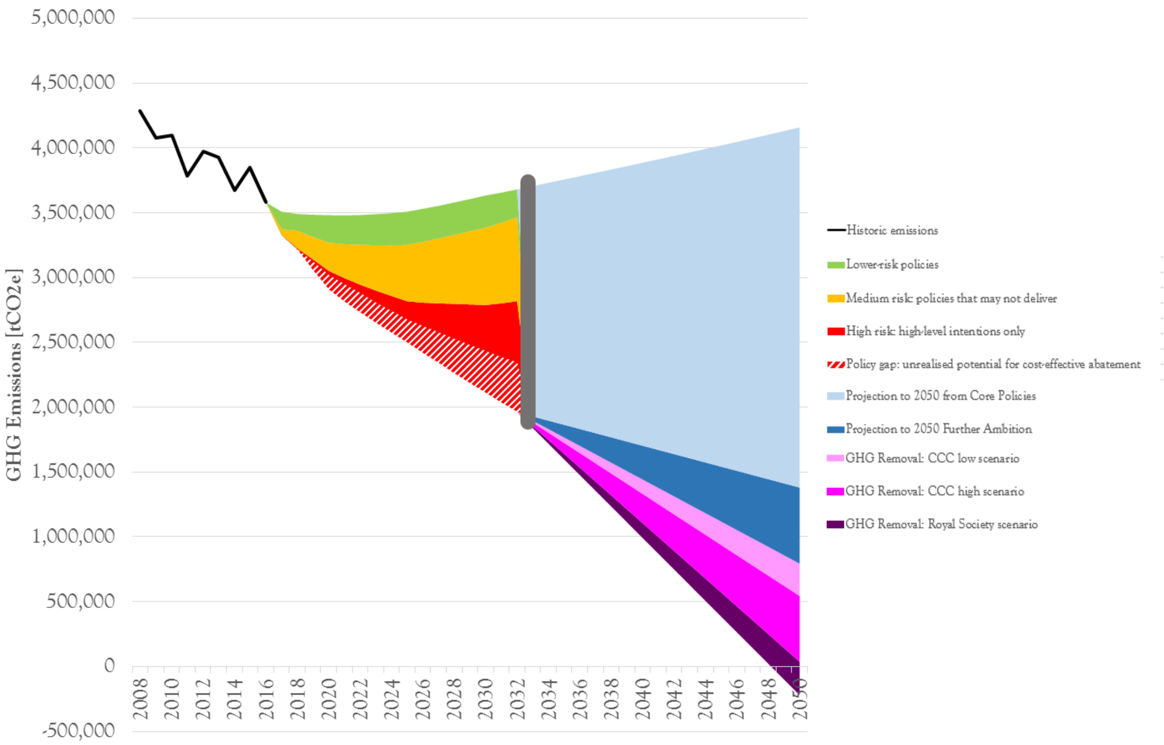

Figure 10: Projected GHG emissions in Devon including policies and their risk levels to 2032, and the CCC Net Zero scenarios to 2050, including GHG removal (purple shades)

Projected emissions broken down by sector are shown in Figure 11. This shows the scale and proportions of carbon reduction from business as usual that are associated with measures in each sector from Core scenario policies (dark shades) and the additional savings associated with the Further Ambition scenario (light shades). At a national level, the Core scenario results in 77% emission reduction, and the Further Ambition scenario a 96% reduction. The largest reductions in

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[33] The projected BAU carbon emissions are based on nationally projected changes to emissions which include the impacts of population change (growth). Analysis of population projections show that by 2030 the UK population is set to increase at a slightly faster rate than the Devon population (the ratio of the two populations in 2030 indexed to 2019 is 98%) and so the nationally projected BAU carbon emissions were taken forward as being reasonable in the context of the uncertainties within the approach adopted for this study.

emissions are planned to come from the Power, Buildings and Transport sectors, with a significant amount of further abatement required from GHG removal technologies.

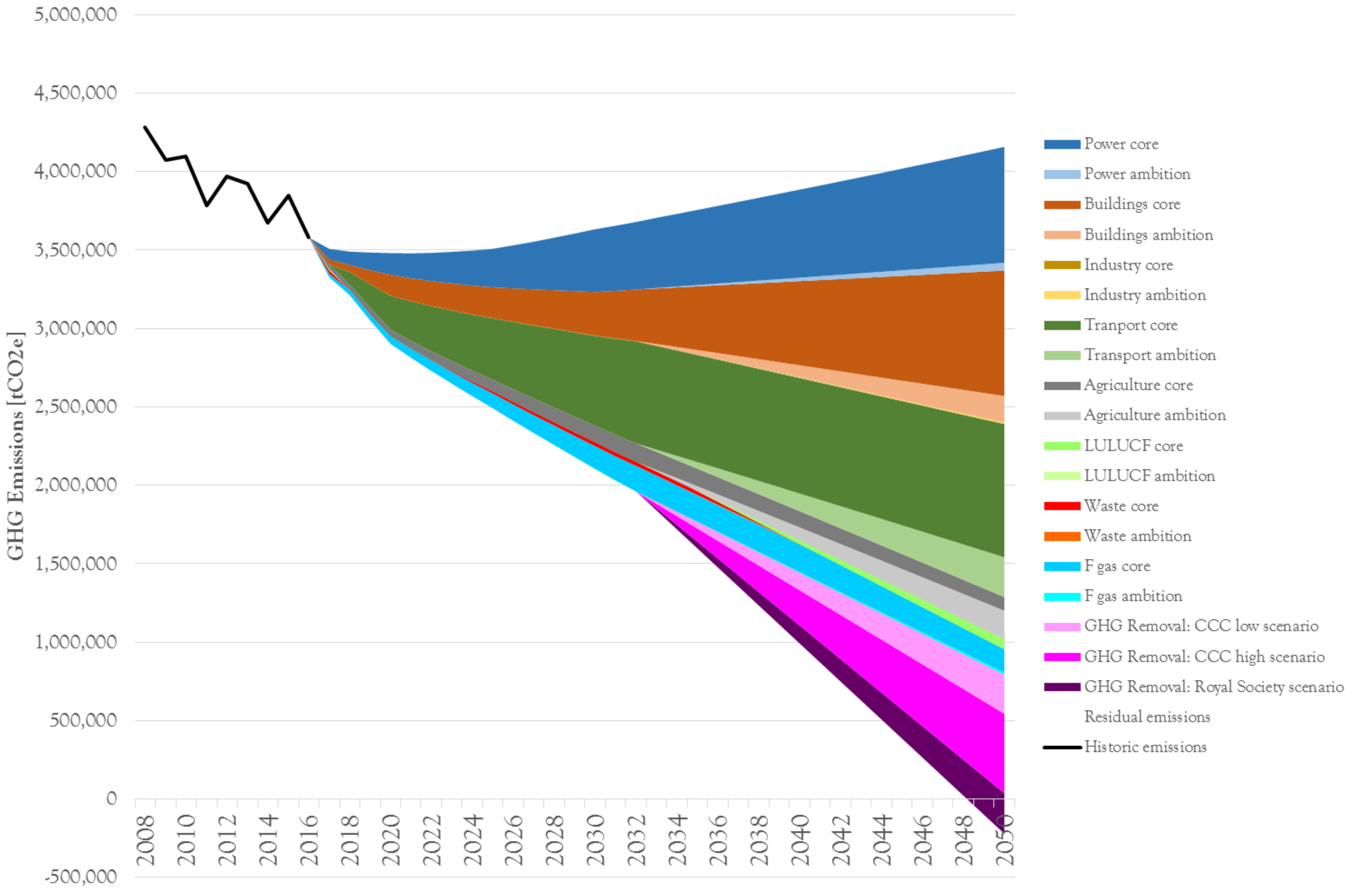

Figure 11: GHG trajectories in GESP to 2050 arranged by sector with each sector split into the Core (dark shades) and Further Ambition (light shades) scenarios.

4.3.3 EMISSIONS ASSOCIATED WITH NEW DWELLINGS

The results from the analysis of dwellings are shown in Table 2 to Table 4. For each of the proposed net zero primary energy and carbon standards these tables show the maximum potential reduction in either primary energy or carbon for either regulated or total (regulated plus unregulated) energy use, which is determined by the energy consumption, and the potential of roof mounted PV to offset this. A value of less than 100% implies that it is not possible to meet the standard. The accompanying costs (both per m2 of floor area or per dwelling) are given to either achieve the standard, or to get as close to it as possible (i.e. where it is not possible to meet the standard). These results highlight the following:

- The lowest cost way to achieve net zero carbon emissions from regulated uses would be to add PV to the Part L 2020 Option 2 with an ASHP. This would cost on average an additional £3,017 per dwelling over and above the envisaged building regulations of the day (i.e. of the Future Home Standard).
- A net zero primary energy target from regulated uses is harder/more expensive to achieve than a zero carbon target. This is because electricity generated by PV has a primary energy factor of approximately 0.5 compared to 1.5 for imported electricity, whereas the carbon intensity value of imported and generated electricity is the same. In addition, it is only possible to meet a zero net primary energy standard by uplifting the fabric and ventilation of the dwelling to the highest specification modelled (Option B). This would cost £6,714 per dwelling, and may in fact not be deliverable for certain configurations of flats.
- In none of the cases was it possible to meet standards that achieved net zero carbon or primary energy for regulated and unregulated combined.

Table 2: The potential to meet net zero primary energy and carbon standards together with cost uplifts per unit of floor area or per dwelling, for the range of dwelling architypes, for the Part L Option 2 specification

Part L 2020 Option 2	Detached	Semi-Detached	1 bed flat – ground	1 bed flat – mid	1 bed flat – top	2 bed flat – ground	2 bed flat – mid	2 bed flat – top	Average Weighted House
Primary Energy									
Max possible reduction regulated	89%	82%	58%	58%	58%	114%	114%	114%	85%
Max possible reduction regulated + unregulated	38%	34%	24%	24%	24%	45%	45%	45%	36%
Zero primary energy regulated £/m^2	£38	£44	£58	£58	£58	£46	£46	£46	£42
Zero primary energy unregulated (or maximum possible) £/m^2	£50	£57	£70	£70	£70	£58	£58	£58	£55
Zero primary energy regulated £/dwelling	£4,441	£3,720	£2,887	£2,885	£2,879	£3,213	£3,209	£3,201	£3,962
Zero primary energy unregulated (or maximum possible) £/dwelling	£5,902	£4,772	£3,511	£3,508	£3,502	£4,088	£4,084	£4,075	£5,157
Carbon Emissions									
Max possible reduction regulated	134%	123%	71%	71%	72%	171%	171%	172%	127%
Max possible reduction regulated + unregulated	57%	51%	34%	34%	34%	68%	68%	68%	54%
Zero carbon regulated £/m^2	£28	£34	£51	£51	£51	£36	£36	£36	£32
Zero carbon unregulated (or maximum possible) £/m^2	£54	£63	£83	£83	£83	£66	£66	£66	£60
Zero carbon regulated £/dwelling	£3,328	£2,847	£2,545	£2,543	£2,538	£2,509	£2,507	£2,501	£3,017
Zero carbon unregulated (or maximum possible) £/dwelling	£6,354	£5,278	£4,162	£4,160	£4,155	£4,632	£4,629	£4,623	£5,648

Table 3: The potential to meet net zero primary energy and carbon standards together with cost uplifts per unit of floor area or per dwelling, for the range of dwelling architypes, for the Option A

Option A	Detached	Semi-Detached	1 bed flat – ground	1 bed flat – mid	1 bed flat – top	2 bed flat – ground	2 bed flat – mid	2 bed flat – top	Average Weighted House
Primary Energy									
Max possible reduction regulated	100%	90%	61%	62%	61%	121%	123%	121%	94%
Max possible reduction regulated + unregulated	40%	36%	25%	25%	25%	47%	47%	47%	37%
Zero primary energy regulated £/m^2	£53	£63	£87	£82	£84	£65	£60	£62	£60
Zero primary energy unregulated (or maximum possible) £/m^2	£92	£106	£136	£130	£133	£111	£105	£107	£101
Zero primary energy regulated £/dwelling	£6,184	£5,328	£4,353	£4,082	£4,203	£4,567	£4,185	£4,356	£5,599
Zero primary energy unregulated (or maximum possible) £/dwelling	£10,721	£8,972	£6,778	£6,507	£6,628	£7,749	£7,367	£7,539	£9,543
Carbon Emissions									
Max possible reduction regulated	149%	135%	76%	77%	76%	182%	185%	182%	140%
Max possible reduction regulated + unregulated	59%	53%	35%	35%	35%	70%	70%	70%	56%
Zero carbon regulated £/m^2	£44	£54	£81	£75	£78	£56	£50	£53	£51
Zero carbon unregulated (or maximum possible) £/m^2	£70	£83	£113	£108	£110	£86	£81	£83	£79
Zero carbon regulated £/dwelling	£5,184	£4,532	£4,028	£3,760	£3,878	£3,907	£3,536	£3,697	£4,743
Zero carbon unregulated (or maximum possible) £/dwelling	£8,209	£6,963	£5,645	£5,377	£5,495	£6,029	£5,658	£5,819	£7,373

Table 4: The potential to meet net zero primary energy and carbon standards together with cost uplifts per unit of floor area or per dwelling, for the range of dwelling architypes, for the Option B specification

Option B	Detached	Semi-Detached	1 bed flat – ground	1 bed flat – mid	1 bed flat – top	2 bed flat – ground	2 bed flat – mid	2 bed flat – top	Average Weighted House
Primary Energy									
Max possible reduction regulated	116%	101%	66%	67%	66%	132%	136%	132%	107%
Max possible reduction regulated + unregulated	42%	37%	26%	26%	26%	48%	49%	48%	39%
Zero primary energy regulated £/m^2	£66	£73	£99	£94	£96	£78	£72	£75	£71
Zero primary energy unregulated (or maximum possible) £/m^2	£104	£117	£148	£142	£145	£123	£117	£120	£113
Zero primary energy regulated £/dwelling	£7,690	£6,195	£4,972	£4,681	£4,822	£5,448	£5,035	£5,238	£6,714
Zero primary energy unregulated (or maximum possible) £/dwelling	£12,227	£9,840	£7,397	£7,106	£7,247	£8,630	£8,218	£8,420	£10,658
Carbon Emissions									
Max possible reduction regulated	173%	152%	82%	84%	82%	198%	205%	198%	160%
Max possible reduction regulated + unregulated	63%	56%	36%	36%	36%	72%	73%	72%	59%
Zero carbon regulated £/m^2	£85	£65`	£93	£88	£90	£69	£63	£66	£63
Zero carbon unregulated (or maximum possible) £/m^2	£84	£94	£126	£120	£123	£99	£94	£96	£91
Zero carbon regulated £/dwelling	£6,829	£5,487	£4,666	£4,382	£4,516	£4,841	£4,449	£4,630	£5,962
Zero carbon unregulated (or maximum possible) £/dwelling	£9,855	£7,918	£6,283	£5,999	£6,133	£6,963	£6,571	£6,753	£8,592

The impact of setting a zero carbon or zero primary energy standard for new dwellings in the GESP is shown in Figure 12. This shows in shades of red this additional reduction. Whilst a zero primary energy standard would save more carbon by virtue of having more PV, the actual impact is small as over time the value of the carbon saved diminishes due to the reducing carbon intensity of the national electricity grid (in fact, the impact of a net zero primary energy standard is not visible to the human eye on the graph). Cumulative GHG savings from a zero carbon standard to 2050 are approximately 68,300 tCO_2e whilst a net zero primary energy standard would save a further 1,300 tCO_2e. As stated, the former would result in a cost uplift of approximately £3,000 per dwelling, whilst the latter would result in a £6,700 uplift. This means that for the dwellings that would be impacted by a policy in the GESP, the effective abatement cost would be approximately £2,500/tCO_2e for a net zero carbon standard, or £5,500/tCO_2e in the case of a net primary energy standard. These costs are high compared to – for example – the short-term traded carbon values[34], which in 2030 are approximately £80/tCO_2e under a medium scenario. The main reason for this is that over time as the electricity grid decarbonises, the carbon benefits of energy efficiency measures such as improved insulation or MVHR diminish, whilst the initial cost remains the same. The actual lifetime cost of carbon will be lower as the appraisal here has only considered the costs and benefits to 2050, though as the grid is taken to be almost decarbonised by this point and all energy use is electric, then this will not reduce the cost by much.

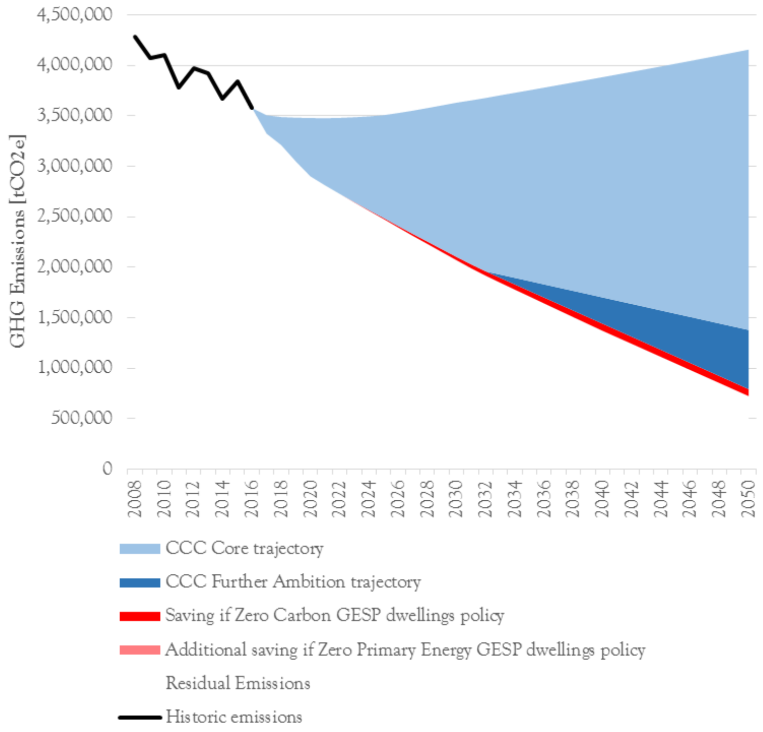

Figure 12: The additional carbon reduction in the GESP area resulting from potentially setting net zero carbon and primary energy standards.

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[34] BEIS 2019, Updated Short-Term Traded Carbon Values: Used for UK Policy Appraisal.

4.3.4 EMISSIONS ASSOCIATED WITH NEW NON-RESIDENTIAL BUILDINGS

PLACEHOLDER AWAITING:

- Government consultation on non-domestic building
- Input from viability work

4.3.5 CONCLUSIONS

Analysis of local GHG emission data shows that across the GESP area in 2016 total emissions were approximately 3.6 $MtCO_2e$. Emissions have generally fallen in absolute terms over time in a broadly similar manner to how they have fallen nationally. However this decline is due to the reduction in the power sector elsewhere in the UK and, if power is excluded, emissions in the GESP area have not noticeably changed Estimates of projected GHG emissions have shown that in the absence of any carbon reduction policy emissions would rise to approximately 4.2 $MtCO_2e$ in 2050 including an allowance for population growth. Low, medium and high risk policies to the end of the 5th Carbon Budget in 2032 would see emissions fall to 2.3 $MtCO_2e$. Projecting to 2050, the CCC's Core scenario would see emissions drop to 1.4 $MtCO_2e$, and delivering the measures in the Further Ambition scenario would see a further fall to 0.8 $MtCO_2e$. The inclusion of GHG removal technologies and offsetting would be required to achieve net zero emissions. The largest reductions in emissions are planned to come from the Power, Buildings and Transport sectors, with a significant amount of further abatement required from GHG removal technologies.

An analysis of new residential development has shown that if a standard of net zero carbon for regulated emissions were to be set in the GESP area, then the additional cost would be approximately £3,000 per dwelling. This would be achieved by adding PV to a FHS compliant home, which has been taken to have the same specification as the proposed Part L 2020 Option 2, but with an ASHP in place of a gas boiler. Setting a net zero primary energy target for regulated emissions is more challenging, and calculations have shown that to achieve this would require Passivhaus levels of energy reduction, in order to offset the balance of energy demand with the potential of PV generated electricity within available roof areas. This option costs £6,714 per dwelling, and may in fact not be deliverable for certain configurations of flats. In none of the cases was it possible to meet standards that achieved net zero carbon or primary energy for regulated and unregulated combined. When the magnitude of implementing such policies are viewed in the context of total GHG emissions in the GESP area, the cumulative GHG savings from a zero carbon standard to 2050 are approximately 68,300 tCO_2e whilst a net zero primary energy standard would save a further 1,300 tCO_2e. The effective abatement cost would be approximately £2,500/tCO_2e saved for a net zero carbon standard, or £5,500/tCO_2e in the case of a net primary energy standard.

An analysis of new non-domestic development is awaiting the Government's forthcoming consultation on non-domestic building standards.

5. LOW CARBON ENERGY SUPPLY

5.1 WORK PACKAGE AIM

The aim of this work package was to address objective 7 as described in Section 1; mapping the potential opportunity areas for different low carbon and renewable energy (RE) technologies, both integral to new developments allocations and as standalone developments and evidence the contribution that such schemes could make to low carbon development.

5.2 GENERAL APPROACH

Relevant current national and local policy and other relevant literature was reviewed and highlighted where appropriate. Policy approaches were developed for a long list of low carbon and renewable energy technologies. Technologies which required specific planning evidence were identified and the necessary mapping work undertaken.

5.3 WORK PACKAGE OUTPUTS

5.3.1 PLANNING POLICY CONTEXT

Part of the core planning principles in the NPPF (paragraph 17) is to *"encourage the use of renewable resources (for example, by the development of renewable energy)"*. Paragraph 97 states that to *"help increase the use and supply of renewable and low carbon energy"* local authorities should:

- *"have a positive strategy to promote energy from renewable and low carbon sources;*
- *design their policies to maximise renewable and low carbon energy development while ensuring that adverse impacts are addressed satisfactorily, including cumulative landscape and visual impacts;*
- *consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure the development of such sources*[35]*;*
- *support community-led initiatives for renewable and low carbon energy, including developments outside such areas being taken forward through neighbourhood planning; and*
- *identify opportunities where development can draw its energy supply from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers"*

In addition Government now requires local planning authorities to specifically allocate land suitable for wind turbines in order for them to come forward.

5.3.2 PRINCIPALS FOR RENEWABLE ENERGY PLANNING – "SUPPLY PUSH" AND "DEMAND PULL" TECHNOLOGIES

Renewable energy technologies where the resource requires solely the use of land at the site of the resource are wind, solar PV and hydro. These technologies are referred to as "supply push". Other technologies either require the siting of a corresponding heat load (solar thermal) or are those where a renewable fuel can be transported from the site where it originated to the point of use (AD, biomass, heat pumps). These technologies are referred to as "demand pull" technologies.

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[35] *In assessing the likely impacts of potential wind energy development when identifying suitable areas, and in determining planning applications for such development, planning authorities should follow the approach set out in the National Policy Statement for Renewable Energy Infrastructure (read with the relevant sections of the Overarching National Policy Statement for Energy Infrastructure, including that on aviation impacts). Where plans identify areas as suitable for renewable and low-carbon energy development, they should make clear what criteria have determined their selection, including for what size of development the areas are considered suitable.*

These fundamental differences in characteristics require a different approach to planning for the technologies. The "supply push" technologies are perhaps the most straight forward as, if the resource is to be developed, sites have to be located where there is available resource and are therefore driven by the resource assessment (see below). As these technologies produce electricity they also require either adjacent electricity loads, electricity storage or an electricity grid connection.

Efficient "demand pull" technologies need heat loads to serve. These either supply heat alone or, combined heat and power (CHP), and need to be located where appropriate heat loads are to be developed or currently exist or both. CHP schemes need both heat and electricity offtake arrangements. Further optimisation can be planned where heat networks can be deployed as existing local heat generation and offtake can also be included giving the opportunity to use new energy infrastructure to increase the efficiency of existing heat generators and users. A review of existing heat loads in the GESP area is shown in Appendix B.

5.3.3 OTHER TECHNOLOGIES

Other technologies include nuclear electricity generation, carbon capture and storage, deep geothermal and offshore renewable energy. Table 8 summaries the reasons why these technologies are not included further for the GESP area.

Table 5: Reasons for not including other technologies for the GESP area

Technology	Site selection dictated by existing sites and/or national policy	Geology in GESP area unsuited	Resource lies outside GESP area
Nuclear electricity generation	x		
Carbon capture and storage	x	x	
Deep geothermal		x	
Offshore renewables			x

5.3.4 REGIONAL RESOURCE ASSESSMENT DATA FOR "SUPPLY PUSH" TECHNOLOGIES

Extensive regional renewable energy resource assessments have been undertaken over the past 15 years. Initial work in 2004/05 [36,37,38] was followed by work using the SQW methodology in 2010. This work was summarised and consolidated for Devon in 2011[39]. More recently relevant resource assessments have been published as part of assessment of regional electricity grid capacity limitations[40] and as part of aspirations for local energy independence[41].

Table 9 summarises the resource assessment for each "supply push" technologies for which it is necessary to *"identify suitable areas for renewable and low carbon energy sources" (NPPF).*

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[36] "REvision 2010", CSE, Peter Capener et al for GOSW, 2004

[37] "REvision 2020", CSE, Peter Capener et al for GOSW, 2005

[38] "South West Renewable Energy Atlas DVD", Wardell Armstrong, 2005

[39] "A review of renewable energy resource assessments and targets for Devon", University of Exeter, 2011

[40] "Distributed generation and demand study – technology growth scenarios to 2030", Western Power Distribution & Regen SW, 2016

[41] "Energy independence 2025" City Science, 2017

Table 6: Summary of the renewable energy resource assessments in the GESP area

Technology	2010 resource assessment GWh (Ref REvision 2010)	2017 resource assessment GWh (Ref Energy Independence)
Large wind	1,179	1,242
PV ground mounted	-	1,934
PV roof mounted	231	599
Run of river hydro	21	21

Wind and hydro resource assessment have changed little. However, the falling cost of PV panels and the contemporaneous advent of the ground mounted solar PV industry have led to significant increases in the assessed quantity of PV resource.

5.3.5 LONG LIST TECHNOLOGY REVIEW

Table 10 lists electricity, electricity and heat and heat only generation technologies and summarises the planning approach adopted for each.

Table 7: Long list of low carbon and renewable energy generation technologies

Technology	Comments	Planning implications	Planning approach recommended
Electricity			
Onshore wind	Highest unconstrained RE resource (13,085 TWh ref 17) but highly constrained	Government requires allocation in local / neighbourhood plans	Map resource and consider allocating zones
Photovoltaic (PV)	The South West has the best solar resource in the UK. Ground mounted PV is the highest constrained RE resource (Table 9)	Planning support helpful – take same approach as wind	Map resource and consider allocating zones
Run of river hydro	Small scale. Negligible resource. Abstraction licences a constraint. Economics difficult without existing civils infrastructure in place	Typically small schemes make planning constraints less likely	No specific work – encourage in general small scale policy wording
Electricity & Heat			
Biomass energy	Resource not directly linked to location of technology which, to maximise efficiency, needs to be heat led	Tie in with heat demand of development and adjacent existing heat loads where applicable. Planning issues likely to be localised to proposed sites. Transport often a concern	Consider heat led site allocation (see Appendix C) and site specific policy development
EfW energy	Resource not directly linked to location of technology which, to maximise efficiency, needs to be heat led	Tie in with heat demand of development and adjacent existing heat loads where applicable. Planning issues likely to be localised to proposed sites. Transport often a concern	Consider heat led site allocation (see Appendix C) and site specific policy development. Integrate with Devon Waste Plan and avoid overlap
Anaerobic Digestion (AD)	Resource not directly linked to location of technology. Biogas export is the preferred technical solution to electricity generation (only). CHP requires an adjacent heat load	Planning issues likely to be localised to proposed sites. Low energy density of AD feedstock intensifies transport concerns. Permitting differences between on-farm and waste feedstocks are significant for planning. On farm sites are less likely to have heat loads	Non-waste site allocation unlikely to be appropriate. Consider specific AD policy wording to encourage biogas export. Where waste is a potential feedstock integrate with Devon Waste Plan and avoid overlap
Heat			
Heat networks	Heat demand led	Exeter / EDDC type policies required with additional incentives for more efficient low temperature heat networks and compatible heating systems in buildings	Determine by development scale and mapping of existing heat demand and generation (Section 3 and Appendix C). Heat led site allocation and site specific policy development
Solar thermal	The South West has the best solar resource in the UK. Large scale solar thermal arrays will play increasing role where there are heat networks as evidenced in Denmark and elsewhere in continental Europe	Provide land allocation adjacent to heat network energy centres	Consider allocation as part of site specific policy on developments suitable for heat networks. PV mapping contributes to the identification of suitable array sites
Heat pumps	Large scale HP important in FAB Link type waste heat recovery opportunities. Potential for increasing standalone role as electricity grid decarbonises subject to electricity prices and grid constraints	Access to waste heat a particular concern (FAB Link example)	Wording to provide requirement to deliver waste heat to heat users/networks and provide access and land where planning proposals have waste heat available

5.3.6 MAPPING AND ASSESSMENT OF ONSHORE WIND RESOURCE

The potential onshore wind resource in the GESP area has been estimated by applying appropriate spatial constraints in MAPINFO geographical information system (GIS) software[42], applying a density factor to account for acceptable landscape impact, then estimating the installed capacity and annual energy output based on the spatial requirements of wind turbines and a typical capacity factor. The constraints and electricity generation parameters were taken from similar previous assessments [43, 44].

Table 8 lists the spatial constraints applied to determine the onshore wind resource. The percentage of the GESP area excluded by applying each constraint is shown. The constraints will overlap, and so cannot simply be summed to determine the total available area. The figures do, however, indicate which constraints have the greatest effect in limiting the available area for wind turbines. The parameters found to individually exclude 10% or more of the GESP area are:

1. residential buildings within 400 m (82%),
2. wind speed < 6.5 m s^{-1} @ 80 m elevation (20%),
3. roads within 150 m (58%),
4. proximity to the Western Power Distribution (WPD) 33 kV or 132 kV grid > 2 km (48%),
5. primary surveillance radar (PSR) within line of site at tip height of 120 m (47%),
6. listed building within 400 m (43%),
7. overhead powerline (33 kV or 132 kV) within 100 m (38%),
8. areas of outstanding natural beauty (21%),
9. microwave links (19%),
10. secondary surveillance radar (SSR) or Height Monitoring Unit (HMU) within 15 nautical miles (27.8 km) (13%),
11. woodland (12%), and
12. national parks (10%).

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[42] Mapinfo Professional Version 16.0.1 (64 bit).

[43] "Resource assessment for wind and solar in North Somerset and opportunities to support the wider sustainable energy sector", Regen SW, 2014.

[44] "Technical paper E2. An assessment of the renewable energy resource potential in Cornwall", Cornwall Council, 2013.

Table 8: Spatial constraints applied to determine the onshore wind resource in the GESP area

Parameter	Constraint	Source of Data	% of GESP Area removed
Transport & Communications			
Airfield	> 3 km or > 5 km	DCC GIS	5.0% or 11.3%
Microwave Link	Exclude	DCC GIS	19.1%
NATS Parameters[45]			
Air-Ground-Air communication site	> 10 km	NATS	0.6%
En route navigation aid site	> 10 km	NATS	None
Primary Surveillance Radar zone	Exclude	NATS	47.4%[46]
SSR or HMU site	> 15 NM	NATS	13.0%
Overhead Power Line (33, 132 kV)	> 100 m	National Grid, WPD	38.2%
Railway Line	> 150 m	Ordnance Survey OpenMap	2.4%
Road	> 150 m	Ordnance Survey OpenMap	58.1%
Built Environment & Heritage			
Building	> 25 m	Ordnance Survey OpenMap	9.5%
Greenspace[47]	Exclude	Ordnance Survey Greenspace	1.1%
Landfill Site	> 1 km from centroid[48]	Google Earth	0.2%
Listed Building	> 400 m from centroid	Historic England	42.9%
MOD Danger Area	Exclude	DCC GIS	None
Quarry	Exclude	Google Earth	0.4%
Registered Park or Garden	Exclude	Historic England	0.9%
Residential Building	> 400 m from centroid[49]	District authority GIS	81.6%
Scheduled Monument	Exclude	Historic England	0.4%
Natural Features			
Area of Outstanding Natural Beauty	Exclude	Natural England	21.5%
Heritage Coast	Exclude	Natural England	1.4%
Local Nature Reserve	Exclude	Natural England	0.2%
Marshland	Exclude	Ordnance Survey Landcover	0.04%
National Nature Reserve	Exclude	Natural England	0.4%
National Park	Exclude	Natural England	10.5%
RAMSAR Site	Exclude	Natural England	0.6%
Site of Special Scientific Interest	Exclude	Natural England	3.4%
Special Area of Conservation	Exclude	Natural England	1.8%
Special Protection Area	Exclude	Natural England	1.1%
Tidal Water	Exclude	Ordnance Survey OpenMap	0.7%
Water	Exclude	Ordnance Survey OpenMap	0.6%
Woodland	Exclude	Ordnance Survey OpenMap	12.4%
World Heritage Site	Exclude	Historic England	0.3%
Technical Constraints			
Wind Speed	> 6.5 m s^{-1} @ 80 m	NOABL	20.4%
WPD Grid connection (33, 132 kV)	< 2 km	WPD	48.0%

The wind speed criterion has been revised from the previous assessment [1] to be more realistic for typical turbines with a hub height of about 80 m. The criterion previously applied was a minimum wind speed of 5.5 m s^{-1} at 10 m elevation. This was adopted from the Cornwall study [44]. The revised criterion is a minimum wind speed of 6.5 m s^{-1} at an elevation of 80 m, wind speeds being estimated

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[45] Formerly National Air Traffic Services.

[46] For a 120 m tip height.

[47] Includes allotments, bowling greens, cemeteries, churchyards, golf courses, play areas, public parks and sports fields.

[48] Only point data (centroids) were identified for this feature, the applied buffer should encompass the feature itself.

[49] Council Tax centroids.

at this elevation by applying the wind profile power law under neutral atmospheric stability conditions[50]. This is a less onerous constraint than that previously applied, removing about 20% of the land area compared to 60% previously. The difference is lessened when the other constraints are also applied.

A number of alternative scenarios were considered with some constraints relaxed.

1. The NATS self-assessment constraints for wind developments[51] pertain to national air traffic control infrastructure, and "*are an aid to developers in understanding where interference with NERL*[52] *infrastructure is likely. They do not represent an exhaustive list of the areas where there is a potential impact to NERL's infrastructure nor do they represent no-go areas where NERL will automatically object to proposed wind turbines. For* AGA [Air-Ground-Air communication], *Navigational Aids and* SSR [Secondary Surveillance Radar], *upon receiving a turbine planning application the plots are the ranges within which NERL would carry out an in-depth assessment for equipment of these types. For* PSR [Primary Surveillance Radar], *the plots are based on a line-of-sight method and indicate whether a further more detailed assessment needs to be carried out in relation to primary surveillance radars*". A number of existing wind farms in Devon (including Fullabrook and Den Brook) lie within the constraint areas (Figure 13). It was therefore decided to evaluate alternative constraints based on reducing the diameter of the constraints by 25%, 50% and 75%.

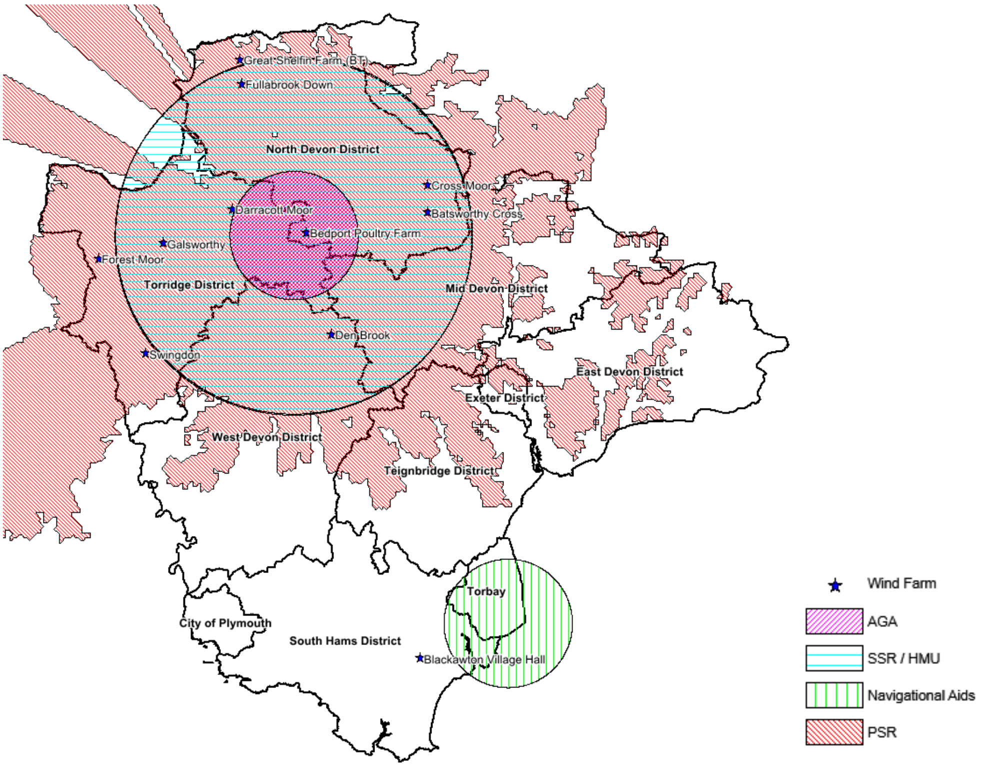

Figure 13: Existing wind farms in Devon compared to the NATS wind farm development self-assessment constraint areas

2. The minimum distance from airfields was reduced from 5 km to 3 km.

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[50] SWEEG, 2019, Internal Document 971 "Implications of Wind Speed on Wind Resource in the Greater Exeter Area"

[51] NATS self-assessment maps. https://www.nats.aero/services/information/wind-farms/self-assessment-maps/, accessed 8/8/2017.

[52] NATS[45] En Route plc, licenced to provide en-route air traffic services in the UK.

3. The maximum distance from a 33 kV or 132 kV grid connection of 2 km was removed. Large scale wind developments are more likely to sustain a longer connection distance and future technological developments including battery storage, smart grids and electric vehicles may increase the feasibility of installing wind turbines further downstream on the grid or autonomously

This resulted in 16 scenarios in total. Two of the scenarios were taken forward to the final assessment:

1. no constraint on maximum distance from the WPD electricity distribution grid, 3 km minimum distance from airfields and NATS constraints reduced to 25% of the default diameter, and
2. similarly, but with a 2 km minimum distance from the WPD electricity distribution grid.

5.3.6.1 MAPPING

The data for each of the constraints was converted to GIS format where necessary and distance buffers applied. Any overlaps were eliminated and the objects subtracted from the total GESP area to form layers with objects representing areas available for wind development. The area of each object was determined and objects smaller than a minimum size threshold of 250 m^2 [44] were eliminated. The resulting maps for the two scenarios are presented in Figure 14 and Figure 15.

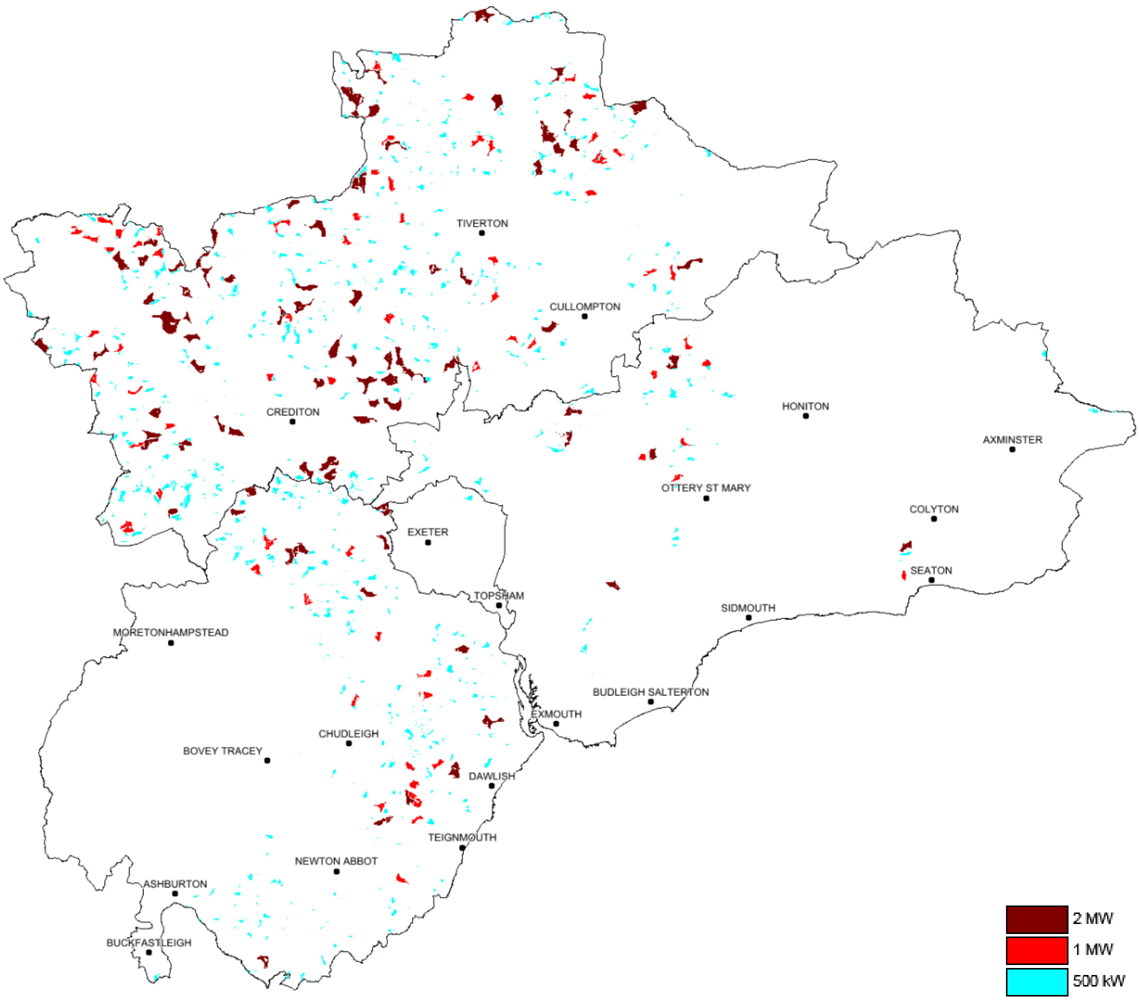

Figure 14: Scenario 1: Areas identified for onshore wind development with no constraint on the maximum distance from the WPD electricity distribution grid (the shading refers to the turbine sizes identified in the resource assessment)

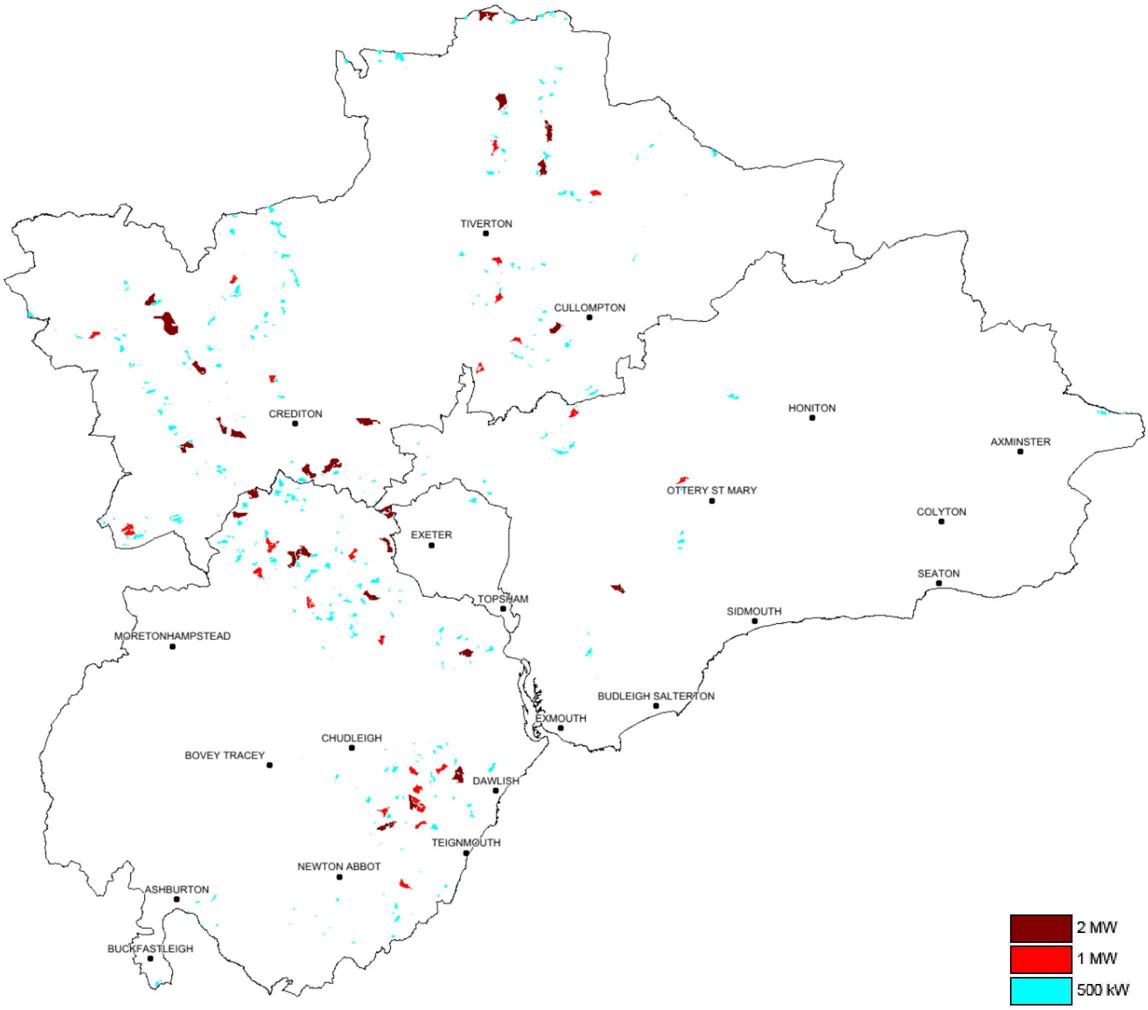

Figure 15: Scenario 2: Areas identified for onshore wind development with a 2 km constraint on the maximum distance from the WPD electricity distribution grid (the shading refers to the turbine sizes identified in the resource assessment)

5.3.6.2 RESOURCE ASSESSMENT

The identified areas were used to estimate the potential installed capacity and annual output from onshore wind turbines, adopting the methodology of previous reports [43,44]. In line with other studies[43], available parcels of land (sites) have been categorised by area. That study adopts a minimum site size of 250 m^2 and states an installed capacity of 9 MW per square kilometre for 2 MW turbines or larger, or 8 MW per square kilometre for 1 MW turbines. This equates to an area requirement of 0.222 km^2 per 2 MW (or larger) turbine, or 0.125 km^2 for a 1 MW turbine. Smaller sites (meeting the minimum threshold) are each assumed to support a single 500 kW turbine. The sites have been assessed in two separate scenarios: one using 500 kW and 1 MW turbines, and another using 500 kW and 2 MW turbines.

Taking the identified areas presented above forward to estimate the total resource, a density factor has been applied to restrict development and limit landscape impact. The factors applied were taken from similar studies[43]. A density factor of 50% has been applied to the single 500 kW turbines (i.e. only half of the sites will be utilised); developments using larger turbines (which could take the form of a cluster or wind farm) have a density factor of 80% applied.

A capacity factor of 28% was applied to account for the intermittency of wind when calculating the annual energy output. This is a typical figure used in other studies [38, 43, 44]. These factors have been applied to arrive at the predicted resource figures below, but are not included in the GIS mapping presented above.

The scenario using 1 MW turbines resulted in greater installed capacity and output owing to more sites being eligible for a large turbine as against a 500 kW turbine. The increase was 46% for the scenario with a 2 km maximum distance from the grid, and 51% for the scenario without this constraint. The 2 MW scenario has been taken forward, larger turbines offering economies of scale.

The resulting numbers of sites, installed capacities and annual electrical output are listed in Table 9 and Table 10 (the numbers of sites and turbines resulting from the application of the density factor have been rounded to the nearest whole number).

Table 9: Estimated onshore wind resource in the GESP area with no constraint on the maximum distance from the WPD electricity distribution grid

Local authority	Number of sites (or turbines) (500 kW)	Number of sites (2 MW)	Number of 2 MW turbines	Total capacity (MW)	Annual Output (GW h)
East Devon	50	5	5	35.0	85.8
Exeter	1	0	0	0.5	1.2
Mid Devon	386	48	66	325.0	797.2
Teignbridge	191	10	10	115.5	283.3
Total	**628**	**63**	**81**	**476.0**	**1167.5**

Table 10: Estimated onshore wind resource in the GESP area with a 2 km constraint on the maximum distance from the WPD electricity distribution grid

Local authority	Number of sites (or turbines) (500 kW)	Number of sites (2 MW)	Number of 2 MW turbines	Total capacity (MW)	Annual Output (GW h)
East Devon	23	1	1	13.5	33.1
Exeter	1	0	0	0.5	1.2
Mid Devon	140	11	15	100.0	245.3
Teignbridge	126	9	9	81.0	198.7
Total	**290**	**21**	**25**	**195.0**	**478.3**

In reality the resource is likely to lie somewhere between the values in Table 9 and Table 10 since proximity to the grid is not an absolute constraint (for example, a greater distance might not be a constraint for a larger wind farm, and the development of local grids and battery storage may also reduce the importance of grid proximity in the future).

5.3.6.3 CURRENT RESOURCE USE AND REMAINING RESOURCE

Table 11 summarises 2016 wind development in the GESP area by local authority[53].

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[53] "Renewable electricity by local authority" BEIS, September 2017, https://www.gov.uk/government/statistics/regional-renewable-statistics

Table 11: Current wind development in the GESP area (source BEIS)

Local authority	Number of sites	Capacity (MW)	Annual Output (GW h)
East Devon	13	0.2	0.435
Exeter	0	0	0
Mid Devon	34	0.5	1.027
Teignbridge	7	0.1	0.126
Total	**54**	**0.8**	**1.587**

Current wind generation within the GESP area represents 0.4% of the grid-constrained resource or 0.2% without the grid proximity constraint. Table 12 shows the yet to be developed wind resource in the GESP area, again indicating large unexploited potential in terms of capacity and output. The number of existing sites is a significant proportion of the total identified sites, indicating the average installed turbine size is small compared to that assumed in the resource assessment. This may be symptomatic of the installation of small turbines by landowners as against large, high capital cost installations, and an increase in commercial turbine size with time.

Table 12: Unexploited wind potential within the GESP area

Local authority	Number of sites	Capacity (MW)	Annual Output (GW h)
Without grid constraint			
East Devon	42	34.8	85.4
Exeter	1	0.5	1.2
Mid Devon	400	324.5	796.1
Teignbridge	194	115.4	283.2
Total	**637**	**475.2**	**1165.9**
With grid constraint			
East Devon	11	13.3	32.7
Exeter	1	0.5	1.2
Mid Devon	117	99.5	244.3
Teignbridge	128	80.9	198.6
Total	**257**	**194.2**	**476.7**

5.3.7 MAPPING AND ASSESSMENT OF PV RESOURCE

The potential large scale PV resource in the GESP area has been estimated using a process similar to that for onshore wind: by applying appropriate spatial constraints, applying a density factor to account for acceptable landscape impact, then estimating the installed capacity and annual energy output based on a typical installed capacity per unit area and a typical capacity factor. The constraints and electricity generation parameters were taken from similar previous assessments [43, 44].

Table 13 lists the spatial constraints applied to determine the PV resource. The percentage of the GESP area excluded by applying each constraint is shown. These figures indicate which constraints have the greatest effect in limiting the available area for PV. The parameters that individually exclude 10% or more of the GESP area are:

1. proximity to the Western Power Distribution (WPD) 33 kV or 132 kV grid > 2 km (48%),
2. areas of outstanding natural beauty (21%),
3. roads within 25 m (14%),
4. woodland (12%),
5. agricultural land grade 1 or 2 (13%)
6. national parks (10%), and
7. buildings within 25 m (10%).

Table 13: Spatial constraints applied to determine the PV resource in the GESP area

Parameter	Constraint	Source of Data	% of GESP Area removed
Transport & Communications			
Airfield[54]	Exclude	DCC GIS	0.1%
Railway Line	> 25 m	Ordnance Survey OpenMap	0.4%
Road	> 25 m	Ordnance Survey OpenMap	13.9%
Built Environment & Heritage			
Building	> 25 m	Ordnance Survey OpenMap	9.5%
Greenspace[47]	Exclude	Ordnance Survey Greenspace	1.1%
Landfill Site	> 1 km from centroid[48]	Google Earth	0.2%
MOD Danger Area	Exclude	DCC GIS	None
Quarry	Exclude	Google Earth	0.4%
Registered Park or Garden	Exclude	Historic England	0.9%
Scheduled Monument	Exclude	Historic England	0.4%
Natural Features			
Agricultural Land Classification	Exclude 1, 2[55]	Natural England	13.1%
Area of Outstanding Natural Beauty	Exclude	Natural England	21.5%
Heritage Coast	Exclude	Natural England	1.4%
Local Nature Reserve	Exclude	Natural England	0.2%
Marshland	Exclude	Ordnance Survey Landcover	0.04%
National Nature Reserve	Exclude	Natural England	0.4%
National Park	Exclude	Natural England	10.5%
RAMSAR Site	Exclude	Natural England	0.6%
Sand Dunes	Exclude	Ordnance Survey Landcover	0.03%
Site of Special Scientific Interest	Exclude	Natural England	3.4%
Slope	Exclude > 20° facing between east and west via north	Ordnance Survey OpenMap	0.5%
Special Area of Conservation	Exclude	Natural England	1.8%
Special Protection Area	Exclude	Natural England	1.1%
Tidal Water	Exclude	Ordnance Survey OpenMap	0.7%
Water	Exclude	Ordnance Survey OpenMap	0.6%
Woodland	Exclude	Ordnance Survey OpenMap	12.4%
World Heritage Site	Exclude	Historic England	0.3%
Technical Constraints			
WPD Grid connection (33, 132 kV)	< 2 km	WPD	48.0%

Alternative scenarios were considered with or without the requirement for a 33 kV or 132 kV grid connection within 2 km. Future technological developments including battery storage, smart grids and electric vehicles may increase the feasibility of installing PV further downstream on the grid or autonomously.

5.3.7.1 MAPPING

The data for each of the constraints was converted to GIS format where necessary and distance buffers applied. Any overlaps were eliminated and the objects subtracted from the total GESP area to form layers with objects representing areas available for PV development. The area of each object

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[54] No constraint has been applied outside of the airfield boundary; there are existing PV installations in close proximity to both Exeter and Newquay airports so it does not appear reasonable to have a blanket constraint within a certain proximity of the airfield boundary.

[55] Ideally grade 3a would also be excluded, but grades 3a and 3b have only been distinguished in post-1988 mapping. Where grade 3a and 3b data are available, approximately half is grade 3a and half is grade 3b, and this has been considered later in the analysis.

was determined and objects smaller than a minimum size threshold of 1 ha [44] were eliminated. The resulting maps for the two scenarios are presented in Figure 16 and Figure 17. Ideally grade 3a agricultural land would be excluded, but the sub-classification of grade 3 is only available for very limited areas (those surveyed since 1988). The maps therefore indicate grade 3 agricultural land that has not been excluded by other constraints; only about one-half of this is likely to be grade 3b and therefore suitable for PV development.

Development within an area of outstanding natural beauty (AONB) may be possible if there is a proven need, public interest, inability to accommodate the use outside of the designated area, and the impacts upon the environment, landscape and recreational opportunities can be moderated. In particular, minimising landscape impact and commitment to return the land to its former state when the installation is removed would be necessary in terms of solar development within an AONB. AONBs account for a significant area of East and Mid Devon districts. The maps illustrate the areas within the AONB that would meet the other constraints.

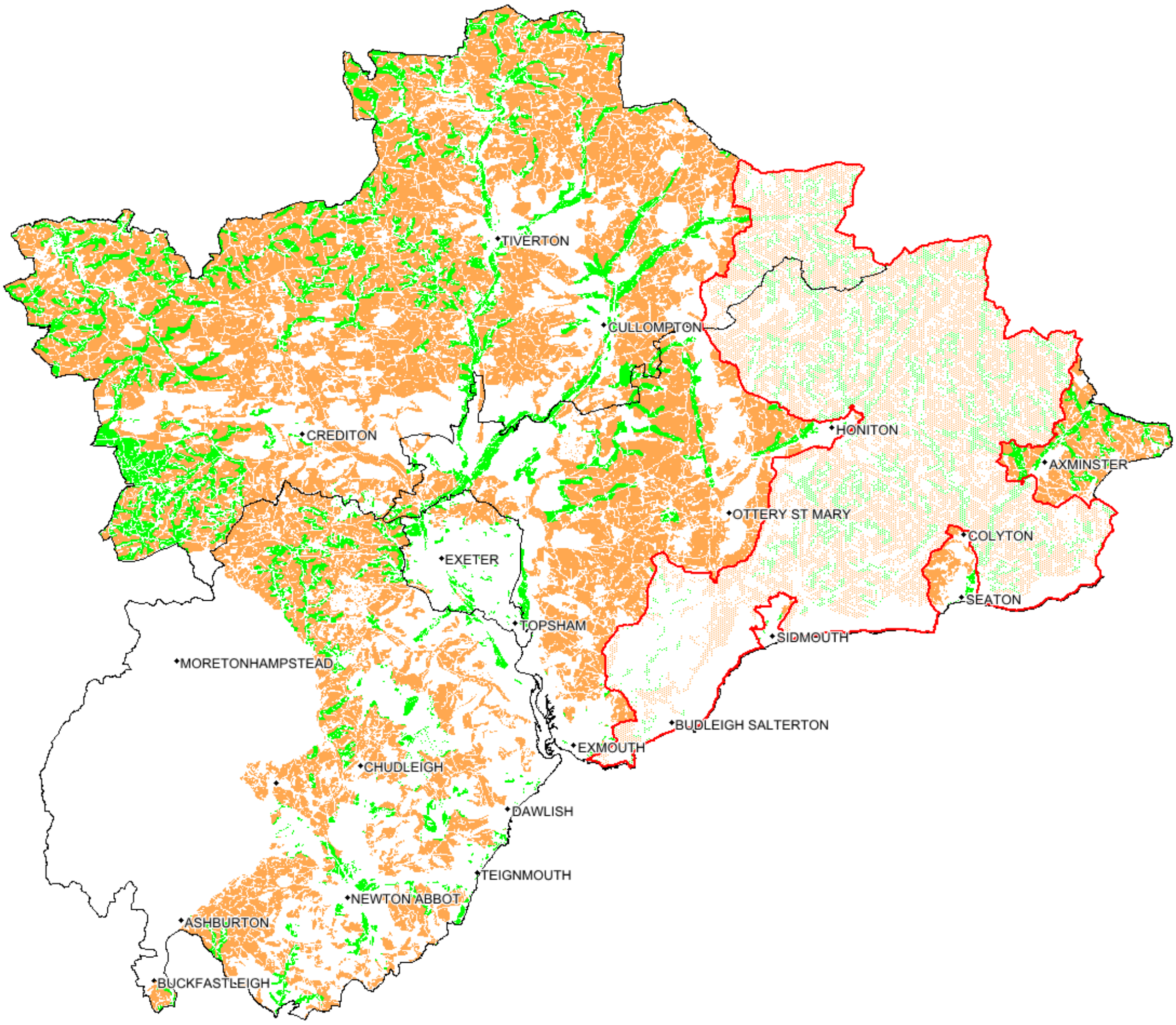

Figure 16: Areas identified for PV development with no constraint on the maximum distance from the WPD electricity distribution grid. Areas in green are agricultural land grade 4 or 5. Areas in orange are agricultural land grade 3. The AONB boundary is shown in red, and possible development within the AONB as hatched areas.

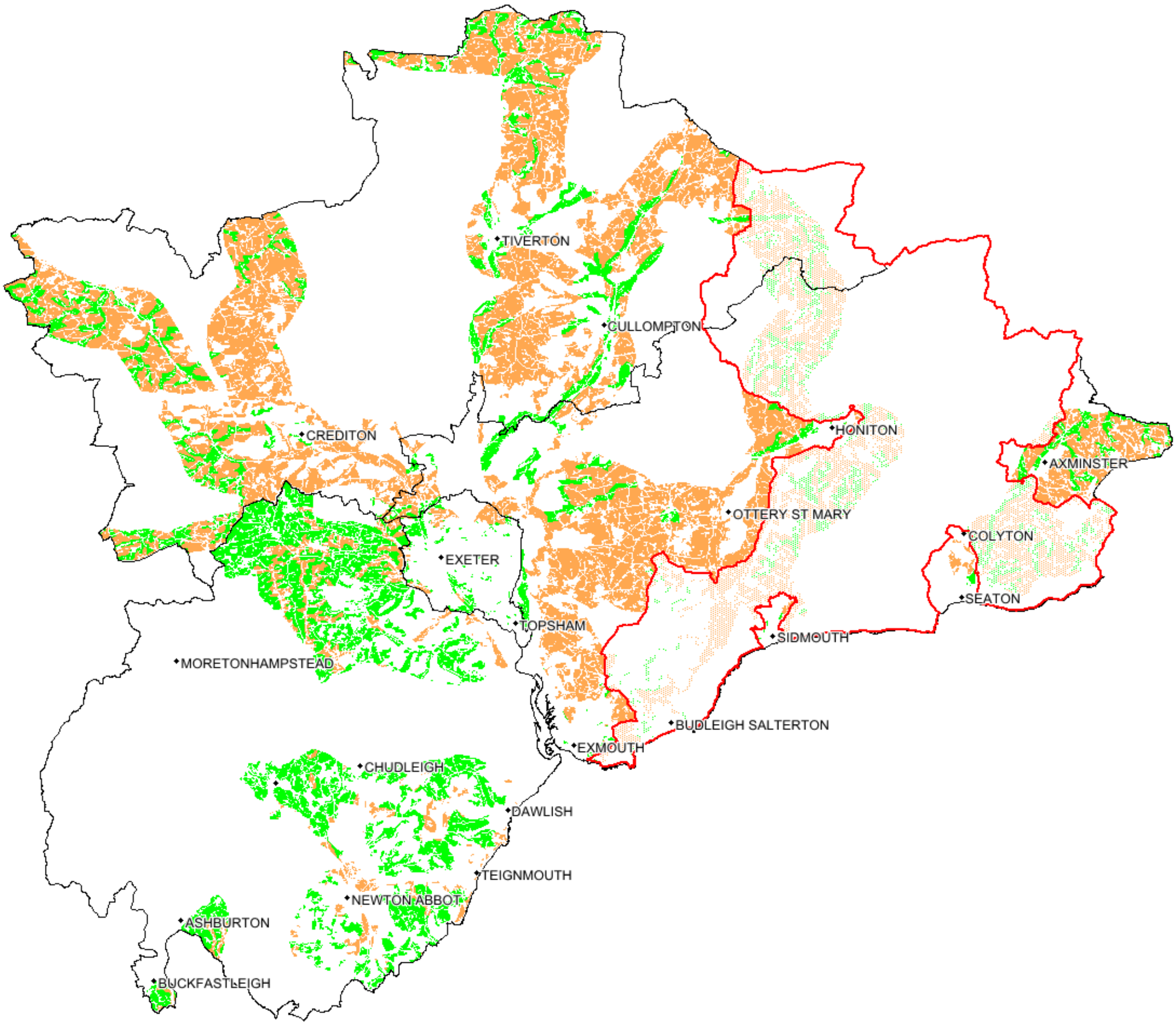

Figure 17: Areas identified for PV development with a 2 km constraint on the maximum distance from the WPD electricity distribution grid. Areas in green are agricultural land grade 4 or 5. Areas in orange are agricultural land grade 3. The AONB boundary is shown in red, and possible development within the AONB as hatched areas.

5.3.7.2 RESOURCE ASSESSMENT

The identified areas were used to estimate the potential installed capacity and annual output from PV, adopting the methodology of previous reports [43,44]. In line with other studies[43], an installed capacity of 0.13 MW per acre (32.1 MW per square kilometre) has been assumed.

A density factor of 25% has been applied to restrict development from that outlined above to limit landscape impact. This is taken from the Cornwall study [44] (other studies[43] referenced this value, but used a higher figure of 35% to account for PV being highly constrained by other factors such as green belt and flood risk; the GESP area is broadly more similar in character to Cornwall). A capacity factor of 11%[56] was applied to account for the intermittency of solar insolation when calculating the annual energy output. A similar figure was used in other studies[43, 57]. These factors

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[56] "BEIS electricity generation costs (November 2016)". https://www.gov.uk/government/publications/beis-electricity-generation-costs-november-2016, accessed 3/10/2017.

[57] The REGEN North Somerset study applied a capacity factor but the value is not stated; back-calculation from the rounded capacity and output figures in the report gives a value of about 10%.

have been applied to arrive at the predicted resource figures below, but are not included in the GIS mapping presented above.

The resulting numbers of sites, areas, installed capacities and annual electrical output are listed in Table 14 and Table 15 (note: the number of sites resulting from the application of the density factor have been rounded to the nearest whole number). Clearly, there is a significant difference between the estimated outputs when constraints of distance to the WPD electricity distribution grid are applied. Therefore, to achieve outputs higher than those identified in Table 18, it will be necessary for sites remote from the grid to be developed in tandem with effective battery storage or direct supply opportunities.

Table 14: Estimated PV resource in the GESP area with no constraint on the maximum distance from the WPD electricity distribution grid

Local authority	Number of sites	Area (km^2)	Total capacity (MW)	Annual Output (GW h)
East Devon	172	44.1	1418.0	1366.3
Exeter	24	2.0	63.7	61.4
Mid Devon	312	130.4	4189.1	4036.6
Teignbridge	208	43.1	1384.5	1334.1
Total	**716**	**219.6**	**7055.3**	**6798.5**

Table 15: Estimated PV resource in the GESP area with a 2 km constraint on the maximum distance from the WPD electricity distribution grid

Local authority	Number of sites	Area (km^2)	Total capacity (MW)	Annual Output (GW h)
East Devon	134	30.2	971.4	936.1
Exeter	23	1.6	50.2	48.3
Mid Devon	194	62.5	2007.1	1934.1
Teignbridge	146	29.5	947.7	913.2
Total	**496**	**123.8**	**3976.4**	**3831.7**

The figures above exclude any development within the AONB. Were development permitted within the AONB, the area available would increase by 78 km^2 without the grid constraint, or 30 km^2 with the grid constraint applied. Capacity and output would increase commensurately, by 40% and 63% respectively.

Table 16 and Table 17 incorporate an adjustment to estimate the amount of Grade 3a agricultural land in each local authority (shown in Table 16) and exclude it from the available area. This is based on the percentage split between grades 3a and 3b where this survey data exists. Despite the estimation, these results are thought to represent a more realistic constrained resource and have been taken forward into Section 7: Economic Impact of Building and Standards and Renewables .

Table 16: Estimated PV resource in the GESP area with no constraint on the maximum distance from the WPD electricity distribution grid: results adjusted to exclude Grade 3a agricultural land

Local authority	Estimated percentage of Grade 3 land that is Grade 3a	Number of sites	Area (km^2)	Total capacity (MW)	Annual Output (GW h)
East Devon	52%	95	24.8	795.5	766.5
Exeter	55%	16	1.4	46.1	44.4
Mid Devon	60%	161	67.7	2175.1	2095.9
Teignbridge	44%	129	27.3	875.5	843.7
Total	**53%**	**401**	**121.2**	**3892.2**	**3750.5**

Table 17: Estimated PV resource in the GESP area with a 2 km constraint on the maximum distance from the WPD electricity distribution grid: results adjusted to exclude Grade 3a agricultural land

Local authority	Number of sites	Area (km^2)	Total capacity (MW)	Annual Output (GW h)
East Devon	73	16.8	538.7	519.1
Exeter	16	1.2	38.9	37.4
Mid Devon	99	32.1	1032.2	994.6
Teignbridge	92	18.9	606.4	584.3
Total	**280**	**69.0**	**2216.1**	**2135.4**

5.3.7.3 CURRENT RESOURCE USE AND REMAINING RESOURCE

Table 18 summarises 2016 PV development in the GESP area by local authority [53].

Table 18: Current (2016) PV development in the GESP area (source BEIS)

Local authority	Number of sites	Capacity (MW)	Annual Output (GW h)
East Devon	3,707	85.5	76.2
Exeter	1,997	8.1	7.1
Mid Devon	3,650	37.7	35.2
Teignbridge	3,314	32.1	30.0
Total	**12,668**	**163.2**	**148.5**

Current total ground mounted and roof mounted PV generation in the GESP area represents 4.1% of the grid-constrained resource (to agricultural land grades 3 and above) or 2.3% without the grid proximity constraint. These figures increase to 7.4% and 4.2% respectively if the resource is constrained to grades 3b and above. Table 19 and Table 20 show the yet to be developed PV resource in the GESP area and indicates a large unexploited potential. The data installations numbers includes all sizes (i.e. roof-mounted panels). The total potential number of sites (of 1 ha or greater) and the number of existing sites (of any size) should therefore not be compared.

Table 19: Unexploited PV potential within the GESP area (constrained to agricultural land grades 3 and above)

Local authority	Capacity (MW)	Annual Output (GW h)
Without grid constraint		
East Devon	1332	1290
Exeter	56	54
Mid Devon	4151	4001
Teignbridge	1352	1304
Total	**6892**	**6650**
With grid constraint		
East Devon	886	860
Exeter	42	41
Mid Devon	1969	1899
Teignbridge	916	883
Total	**3813**	**3683**

Table 20: Unexploited PV potential within the GESP area (constrained to agricultural land grades 3b and above)

Local authority	Capacity (MW)	Annual Output (GW h)
Without grid constraint		
East Devon	710	690
Exeter	38	37
Mid Devon	2,137	2,061
Teignbridge	843	814
Total	**3,729**	**3,602**
With grid constraint		
East Devon	453	443
Exeter	31	30
Mid Devon	994	959
Teignbridge	574	554
Total	**2,053**	**1,987**

5.3.8 POLICY FOR EACH LARGE SCALE TECHNOLOGY

The GESP has the potential to deal with strategically significant low carbon energy supply. Table 24 provides guidance on the scale of development which is considered strategically significant:

Table 21: Definitions of "large scale" strategically significant low carbon technologies

Technology type	Development capacity	Notes
Onshore wind turbines	Single turbines or a cluster of turbines which exceed 1.5 MW peak capacity	Feed in Tariff (FiT) breakpoint and proximal regional study definition (1.3MW in Revision 2010 and 2020)
PV	PV arrays or clusters of arrays which exceed 1 MW peak capacity	FiT breakpoint. 1MW peak occupies about 2ha
Run of river hydro	n/a	Not a large scale technology
Biomass / EfW energy	Installations with the capacity to generate 1 MWe or 2MWth and above	Break point for the Government's Renewables Obligation (RO) policy
Anaerobic digestion	Installations with the capacity to generate 500 kW of biogas and above	FiT breakpoint
Heat networks	Heat networks serving: • more than 1,200 homes • more than 10 ha of standalone employment/industrial/commercial facilities • more than 5 ha of employment/industrial/commercial facilities adjacent to housing developments over 1,200 homes • heat suppliers of more than 1MWth	No of homes from heat network calculator (see section 3.3.1) Based on evidence from employment sites with heat network conditions in the GESP area (see section 3.3.1) RHI break point
Solar thermal	7 MWth peak capacity [58]	2 ha array as per PV. Allocate sites next to existing or planned heat networks
Heat pumps	Over 250kW peak electrical demand	Based on a 1MW load and a coefficient of performance (COP) of 4

Policy recommendations for each technology are as follows:

Large scale onshore wind

Mapping has identified potential areas for the development of wind resource in the GESP area. Policy should encourage applications for large scale onshore wind turbine sites in the areas identified provided such applications meet the policy set out in the NPPF and the relevant local and neighbourhood plans.

Large scale ground mounted PV

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[58] 2ha array gives 7 MWth peak (based on Cranbrook Project Sunshine array of 1.354 MWth peak from a1,814m^2 array on 3,992m^2 of ground)

Mapping has identified potential areas for the development of the solar electric resource in the GESP area. Policy should encourage applications for PV in the areas identified provided such applications meet the policy set out in the NPPF and the relevant local and neighbourhood plans.

Biomass/EfW energy

Large biomass and EfW energy facilities should be developed only where the facility can be demonstrated to utilise CHP to enhance overall efficiency (useful energy output divided by fuel energy input) by more than 50% over the electricity only efficiency (i.e. if the electricity only efficiency is 20% achieve an overall efficiency of at least 30%) through the provision of useful heat (useful heat excludes unnecessary heat loads such as accelerated drying) or to provide efficient useful heat only.

Anaerobic digestion

Anaerobic digestion facilities should only be developed where they can either export biogas to the gas grid or use CHP to enhance overall efficiency (useful energy output divided by fuel energy input) by more than 50% over the electricity only efficiency (i.e. if the electricity only efficiency is 40% achieve an overall efficiency of at least 60%) through the provision of useful heat (useful heat excludes unnecessary heat loads such as accelerated drying) or to provide efficient useful heat only.

Heat networks

Where heat networks exist or are proposed policy should encourage heat networks to be developed and brought forward to supply heat in new development. Accepted thresholds are development with a floor space of at least 1,000m^2 (either new build or conversion) or those that comprising ten or more dwellings. These should be required, where viable, to connect to any existing, or proposed, heat network in the locality to bring forward low and zero carbon energy supply and distribution.

Where there is no existing or proposed heat network in the locality, proposals for residential / mixed use developments with a standalone or combined total of 1,200 houses or more should evaluate the potential for such systems and implement them where they are viable over the life of the developments in the locality.

Stand-alone commercial/employment sites of 10ha or more should evaluate the potential for heat networks and implement them where they are viable over the life of the developments in the locality. However, where commercial/employment sites are in the vicinity of residential / mixed use developments with a standalone or combined total of over 1,200 homes this threshold is reduced to 5ha and the combined potential for heat networks on the commercial/employment and residential / mixed use sites should be evaluated together.

Developments which produce more than 1MWth of heat that is not usefully used should, where viable, connect to any existing, or proposed, heat network in the locality to bring forward low and zero carbon energy supply and distribution. If no heat network is currently in existence or proposed, then such developments should be constructed so as to not preclude the future connection to and development of such a network.

Low temperature heat networks, where flow temperature is reduced from 80-90 °C to 50-60 °C, reduce heat losses and enable lower temperature heat sources such as waste heat and solar thermal to contribute more effectively and should therefore be required for new heat networks. In developments where low temperature heat networks are economic all buildings should be required to have suitable heat transfer surfaces to facilitate the correct return temperatures (typically through the use of underfloor heating, radiators with a larger surface area or space heating using warm air circulation).

Large scale solar thermal

Denmark has over 1 million square meters of solar thermal collectors which provide heat to 85 heat networks. "Large-scale solar thermal plants can compete today with all forms of fossil fuels. The sector reaches heat prices from 3 to 5 euro cents/kWh, provided that the plant is large enough."[59] The Silkeborg solar thermal array in Denmark is 156,000m^2 with capacity of 110MWth (see Figure 18).

Figure 18: An aerial view of the Silkeborg solar thermal array in Denmark

Graz in Austria is planning a 450,000m^2 array covering 100ha which is anticipated to supply the local heat network with 20% of its annual heat demand.

Policy should allocate sites for large scale solar thermal arrays up to 100 hectares on suitable land (identified by the PV mapping) adjacent to existing or planned heat networks.

Large scale heat pumps

Large scale heat pumps have a particularly important role in upgrading heat which otherwise could not be useful.

Developments that have a cooling load (i.e. waste heat) of more than 1MWth which is not usefully used should have land allocated adjacent the waste heat source for the installation of a heat pump which could then upgrade the waste heat to serve a heat network.

Smaller scale renewables including run of river hydro

Smaller scale renewable energy including run of river hydro should be encouraged subject to policy in national, local and neighbourhood plans.

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[59] See http://solar-district-heating.eu/NewsEvents/News/tabid/68/ArticleId/477/1-Million-Square-Meters-Solar-Thermal-Collectors-in-Danish-District-Heating-Plants.aspx accessed 8th March 2018

6. CLIMATE CHANGE ADAPTATION

6.1 WORK PACKAGE AIM

The aim of this work package was to address objective 8 as described in Section 1. That is, to develop built environment (buildings and infrastructure) climate change adaptation evidence and policy guidance for adapting to climate change. The aim is to consider elements to be included within any policy on climate change resilience including an explanation of impact upon the viability of development.

6.2 GENERAL APPROACH

The first step undertaken was to consult the UK Climate Projections most recent projections (UKCP09)[60] to establish the potential changes to the climate across the GESP area. The impact on the built environment was then assessed using the Innovate UK (IUK, formerly Technology Strategy Board [TSB]) Design for Future Climate document[61]. Potential ways of adapting to that climate change were then considered by consulting technical guides produced by professional bodies (e.g. Environment Agency and CIBSE), existing plan policies for other LPAs, and the outputs from IUK's Design for Future Climate (D4FC) work stream. The D4FC project looked at Climate Change in the design of £4.2 billion of construction and building refurbishment in the UK. It ran over two phases between 2010 and 2014 and granted £5 million to 45 projects.

6.3 WORK PACKAGE OUTPUTS

6.3.1 CLIMATE CHANGE PROJECTIONS FOR THE GESP AREA

The 2009 UK Climate Projections (UKCP09) provide projections of climate change for the UK, giving greater spatial and temporal detail, and more information on uncertainty than previous UK climate scenarios. The data is also probabilistic allowing the entire range of possible climate change to be estimated for different emissions scenarios.

Over land, UKCP09 gives projections of changes for a number of climate variables, averaged over seven overlapping 30-year time periods, at a 25 km resolution. Similar projections are also given for a smaller number of variables averaged over marine regions around the UK. UKCP09 is the first set of UKCIP projections to attach probabilities to different levels of future climate change. The probabilities given in UKCP09 represent the relative degree to which each climate outcome is supported by the evidence currently available, taking into account our understanding of climate science and observations. The Met Office Hadley Centre has designed a methodology to provide probabilistic projections for UKCP09, based on ensembles of climate model projections consisting of multiple variants of the Met Office climate model, as well as climate models from other centres around the world. These ensembles sample the major known uncertainties in the climate system. For a given emissions scenario, the UKCP09 probabilistic projections account for uncertainties arising from the representation of different climate processes, and the effects of natural internal variability of the climate system. Changes to external factors such as solar activity and volcanic eruptions cannot be predicted, and are not considered.

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[60] http://ukclimateprojections.metoffice.gov.uk/22530

[61] Technology Strategy Board 2010, Design for Future Climate: Opportunities for adaptation in the built environment

UKCP09 gives projections for each of three of the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (SRES) scenarios (A1FI [called "High" in UKCP09], A1B [Medium] and B1 [Low]) to show how different emissions pathways affect future climate. Each of the emissions scenarios suggests a different pathway of economic and social change over the course of the 21st Century; it is not possible to assign probabilities to each scenario. The current global emissions trajectory indicates that the "High" emissions scenario (A1FI) best represents the current status quo. The UKCP09 methodology uses the Met Office regional climate model (RCM) to downscale global climate projections to a 25 km scale; uncertainties in this downscaling are also included in the probabilistic projections. It has not been possible to produce probabilistic projections of changes in wind speed or snowfall rate[62]. The current observed strength of the Urban Heat Island effect is included in the projections of future climate, but possible changes in the strength of the Urban Heat Island in the future cannot yet be included. It is unlikely that an abrupt change in the Atlantic Ocean Circulation will occur this century. The effects of a gradual weakening of the circulation over time are included in the UKCP09 climate projections.

Uncertainty in UKCP09 is dealt with by presenting projections, which are **probabilistic** in nature. This sort of presentation is more informative than the single projection (for a given emissions scenario) as in UKCIP02 (Figure 19 and Figure 20), or even a range of different projections from different climate models, but is also necessarily more complex. It gives the user the relative probability of different outcomes, based on the strength of evidence, and more openly reflects the state of the science. This is why probabilistic projections were adopted by IPCC for the first time in their most recent science assessment. The UKCP09 Projections respond to demands from a wide range of users for this level of detail. Uncertainty in climate change projections is a major problem for those planning to adapt to a changing climate. Adapting to a smaller change (or one in the wrong direction) than that which actually occurs could result in costly impacts and endanger lives, yet adapting to too large a change (or, again, one in the wrong direction), could waste money.

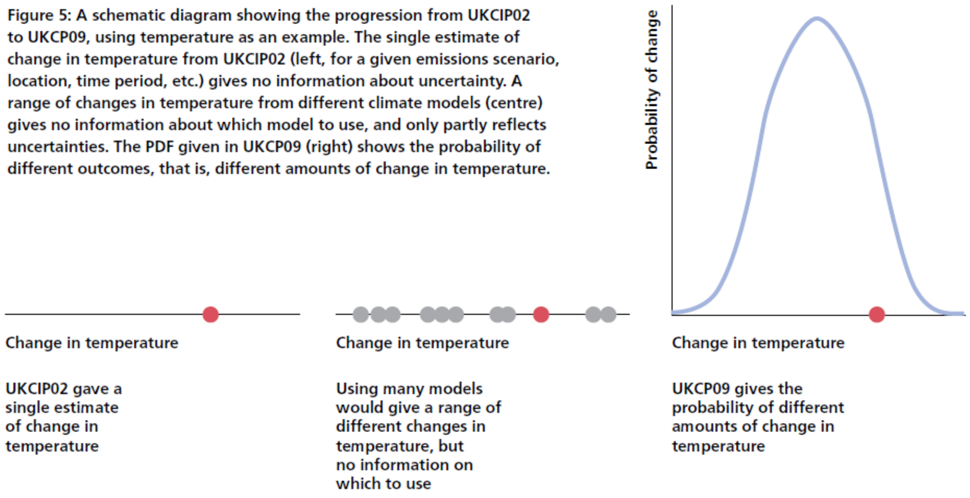

Figure 5: A schematic diagram showing the progression from UKCIP02 to UKCP09, using temperature as an example. The single estimate of change in temperature from UKCIP02 (left, for a given emissions scenario, location, time period, etc.) gives no information about uncertainty. A range of changes in temperature from different climate models (centre) gives no information about which model to use, and only partly reflects uncertainties. The PDF given in UKCP09 (right) shows the probability of different outcomes, that is, different amounts of change in temperature.

UKCIP02 gave a single estimate of change in temperature

Using many models would give a range of different changes in temperature, but no information on which to use

UKCP09 gives the probability of different amounts of change in temperature

Figure 19: Excerpt from UKCP09 report. Illustration of how probabilistic projections are obtained and the difference between UKCP09 and the previous climate projections UKCIP02.

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[62] Users are recommended to take these from the 11-member RCM ensemble

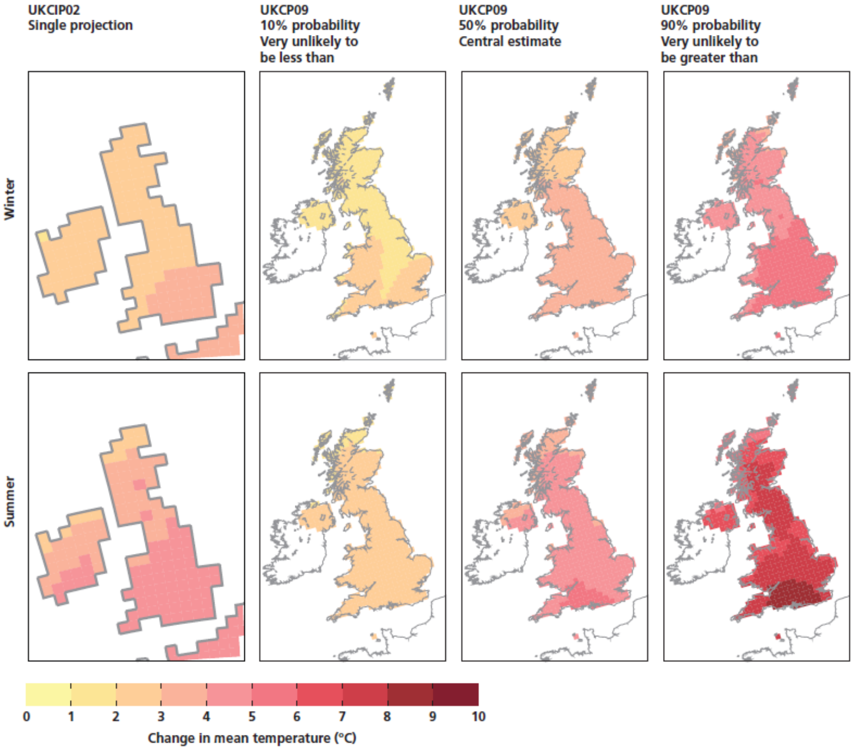

Figure 20: Indicative outputs from UKCP09 and how they differ from UKCIP02.

The changes to key environmental parameters under the "High" emissions scenario for a range of probabilities are shown in Table 22. These are shown mapped for projected changes to summer temperature, winter and summer precipitation, water stress, and soil shrinkage in Figure 21 to Figure 25.

Table 22: Projected climate change under the High emissions projections for the 2050s and 2080s under 10%, 50% and 90% probabilities.

Parameter	Sub-Parameter	Year	Very unlikely to be less than... (10% scenario)	Central Estimate (50%)	Very unlikely to be greater than... (90% scenario)
Change in Summer Temperatures	Mean Minimum	2050s	0 to 1°C	2 to 3°C	3 to 4°C
		2080s	1 to 2°C	2 to 3°C	4 to 5°C
	Mean	2050s	0 to 1°C	2 to 3°C	2 to 3°C
		2080s	1 to 2°C	2 to 3°C	3 to 4°C
	Mean Maximum	2050s	1 to 2°C	3 to 4°C	6 to 7°C
		2080s	2 to 3°C	5 to 6°C	9 to 10°C
	Warmest Day	2050s	-2 to 0°C	2 to 4°C	8 to 10°C
		2080s	-2 to 0°C	4 to 6°C	10 to 12°C
Change in Winter Temperatures	Mean Minimum	2050s	1 to 2°C	2 to 3°C	4 to 5°C
		2080s	1 to 2°C	3 to 4°C	5 to 6°C
	Mean	2050s	1 to 2°C	2 to 3°C	3 to 4°C
		2080s	1 to 2°C	3 to 4°C	5 to 6°C
	Mean Maximum	2050s	0 to 1°C	2 to 3°C	3 to 4°C
		2080s	1 to 2°C	2 to 3°C	5 to 6°C
% Change in Precipitation	Annual Mean	2050s	-10 to 0%	-10 to 0%	0 to 10%
		2080s	-10 to 0%	0 to 10%	0 to 10%
	Winter Mean	2050s	-10 to 0%	10 to 20%	30 to 40%
		2080s	-10 to 0%	10 to 20%	60 to 70%
	Summer Mean	2050s	-40 to -50%	-20 to -30%	0 to 10%
		2080s	-60 to -70%	-30 to -40%	0 to 10%
	Wettest winter day	2050s	-10 to 0%	10 to 20%	20 to 30%
		2080s	0 to 10%	10 to 20%	40 to 50%
	Wettest summer day	2050s	-10 to -20%	0 to 10%	10 to 20%
		2080s	-20 to -30%	0 to 10%	30 to 40%
% Change in Relative Humidity	Winter mean RH	2050s	-5 to 0%	0 to 5%	0 to 5%
		2080s	0 to 5%	0 to 5%	0 to 5%
	Summer mean RH	2050s	-5 to -10%	-5 to 0%	0 to 5%
		2080s	-5 to -10%	-5 to 0%	0 to 5%
% Change in Cloud Cover	Winter cloud	2050s	-10 to 0%	0 to 10%	0 to 10%
		2080s	-10 to 0%	-10 to 0%	0 to 10%
	Summer Cloud	2050s	-20 to -30%	-10 to -20%	0 to 10%
		2080s	-30 to -40%	-10 to -20%	-10 to 0%

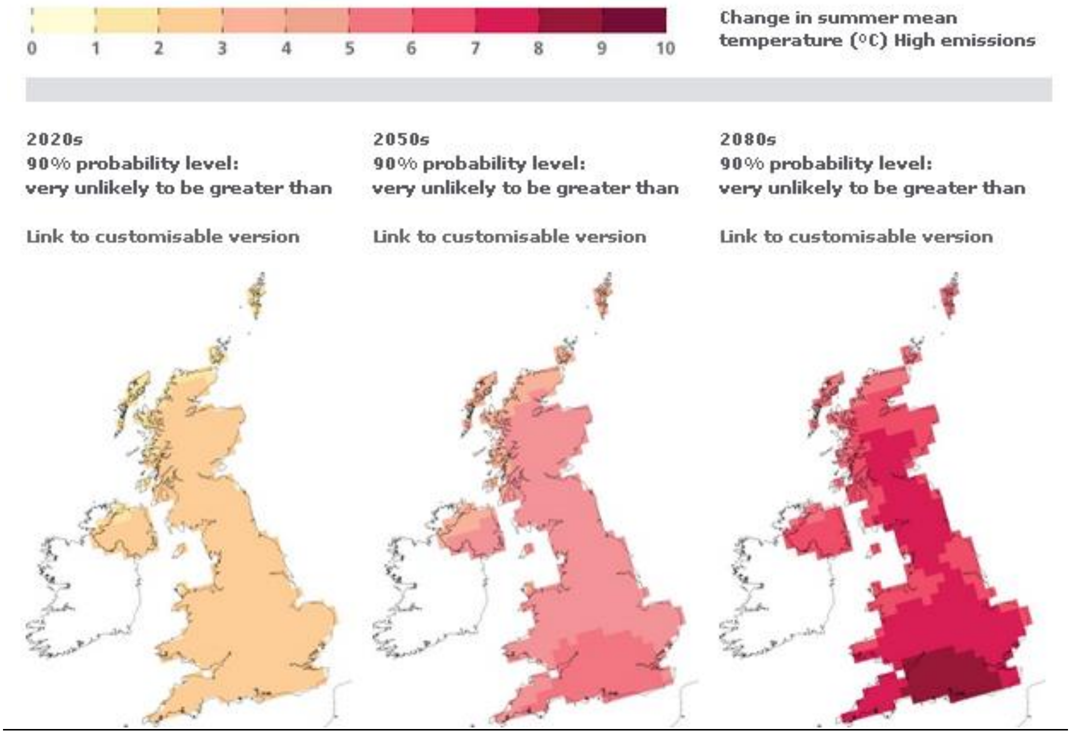

Figure 21: Changes in summer mean temperature under the High emissions scenario at the 90% probability level i.e. Very unlikely to be exceeded (Source: UKCP09)

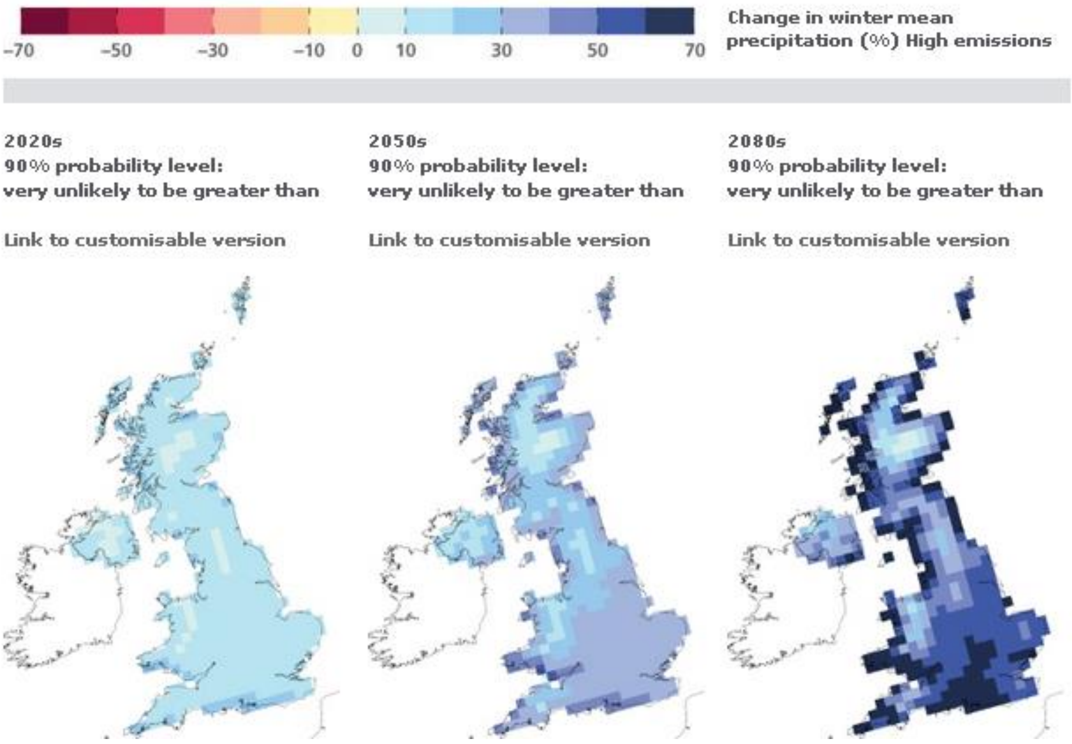

Figure 22: Changes in winter mean precipitation under the High emissions scenario at the 90% probability level i.e. Very unlikely to be exceeded (Source: UKCP09)

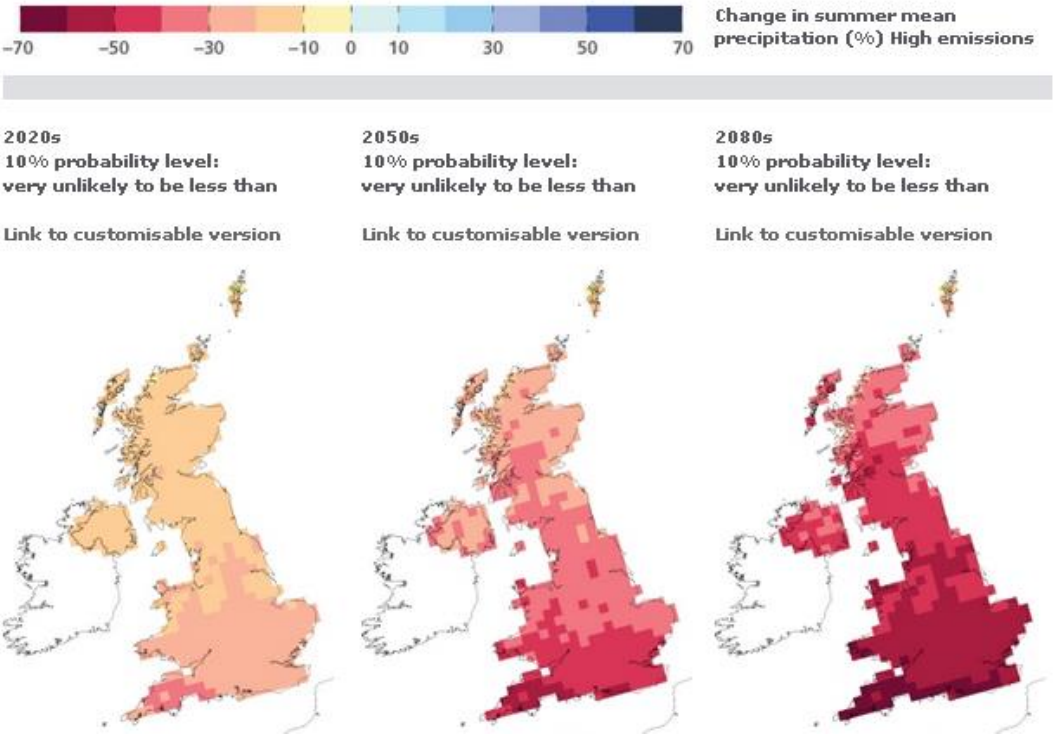

Figure 23: Changes in summer mean precipitation under the High emissions scenario at the 10% probability level i.e. Very unlikely to be less than (Source: UKCP09)

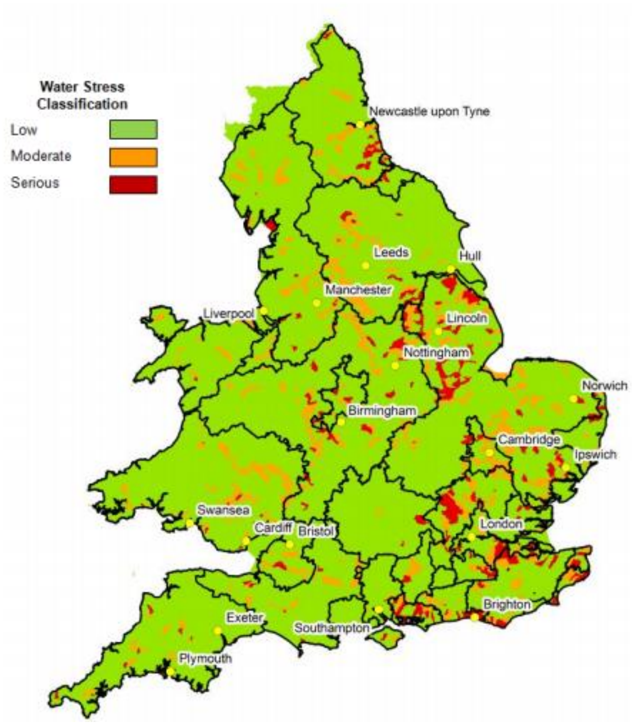

Figure 24: Areas of water stress in England and Wales at a water body scale (Source: Environment Agency[63])

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[63] Environment Agency 2013, Water stressed areas – final classification

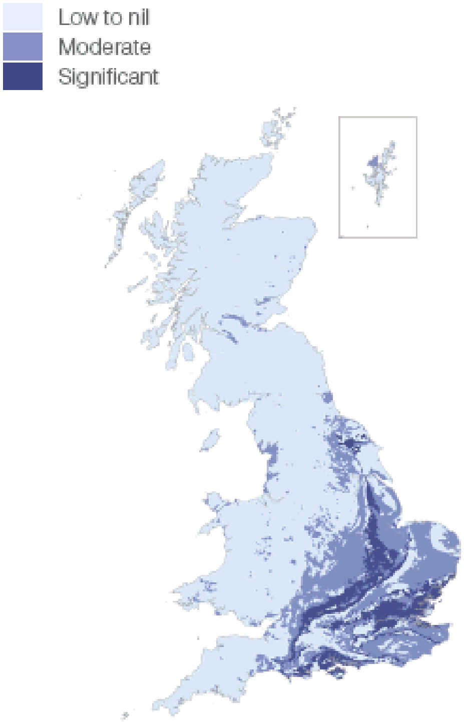

Figure 25: The risk of subsidence due to soil shrinkage (IUK[64])

6.3.2 IMPACTS OF CLIMATE CHANGE ON THE GESP AREA

The IUK report on designing for future climate change[61] identifies risks across three broad areas:

Designing for comfort:

- Keeping cool – building design: Of all the projected climate change impacts, hotter summers will affect the design of buildings the most. For the GESP area to the end of the plan period, central estimates are that mean summer temperatures may be 2 to 3°C higher, and the hottest summer day could be up to 4°C warmer. Buildings constructed within the GESP period would be expected to remain in use for decades more. By the end of the century, temperatures could be higher still. The increase in temperatures will increase the risk of overheating which gives rise to both discomfort and for the hottest periods, potentially heat stress. In some cases this may be addressed by retrofitting comfort cooling, which has associated cost and environmental issues. New construction can be designed to be more resilient to higher summer temperatures by careful consideration of orientation, façade design, thermal mass and ventilation strategy.
- Keeping cool – outside spaces: The projected increases in summer temperature that pose a risk to occupants within buildings also result in potential impacts outside of buildings. To address this, designers can consider additional shading on-site, incorporating trees and plants to assist with both shading and cooling from transpiration, and provision of green and blue spaces within larger developments.
- Keeping warm: As temperatures across the year are projected to increase, less energy will be required to heat buildings. However, as they must be able to provide adequate warmth under the current climate there is no material impact on how buildings need to be designed

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[64] IUK after UK shrink swell map, reproduced with the permission of the British Geological Survey, copyright NERC. All rights reserved)

in this regard. Insulation standards should not be reduced to offset a general increase in temperature.

Construction:

- Structural stability – below ground: Changes to rainfall patterns may increase the risk of soil shrinkage which may impact on building foundations. However, the risk of subsidence across the vast majority of the GESP area due to soil shrinkage is low (see Figure 25) and so no additional provision needs to be made with respect to adapting to climate change in those areas. For those areas where there is a risk, there may be a need to consider designing building foundations and retaining wall structures with this in mind.
- Structural stability – above ground: Design wind loads on buildings are dependent on geographical location – whether a site is particularly sheltered (for example, in a city) or exposed (as on the coast) – and also on the shape and size of the building itself. The UKCP09 has not modelled projected changes to wind speed resulting from climate change, but the IUK report states that older buildings constructed prior to the introduction and subsequent strengthening of building codes (i.e. from prior to the 1940s) are at greater risk. It is therefore difficult to propose adaptive measures to reduce the risk of stability of a building's structure as a result of climate change with any certainty.
- Weatherproofing, detailing and materials: Under projected climate change, winter driving rain may increase, though this has not been quantified by UKCP09. The GESP area is already predominantly in a "severe" exposure zone (the second highest classification of exposure) with areas of Teignbridge and Mid Devon in the "very severe" exposure zone. Given the uncertainty of the data, the IUK document suggests that adapting the building to climate change with respect to weatherproofing and detailing, that construction methods are specified at one exposure rating higher, which in the case of the GESP would be "very severe" (there is no guidance in the case of areas that are already in the "very severe" zone). This may include consideration of recessed window and door reveals, projecting sills with drips, render finishes, extended eaves, greater laps and fixings to roof and cladding fixings, and avoidance of fully filled cavities

Managing water:

- Water conservation: This shift in seasonal rainfall patterns together with increasing intensity and frequency of extreme events is likely to result in flooding on the one hand and scarcity of water on the other. The Environment Agency classifies[64] the GESP area (South West Water) as being under "Moderate" water stress, both now and under a range of future scenarios with the final stress rating stated as being "Not Serious". Changes to Part G of the Building Regulations have introduced an Optional Requirement for new dwellings to be designed to consume not more than 110 litres/person/day of water, as opposed to the general limit of 125 litres/person/day. As the area is not under "Serious" stress, meeting the general limit of the Building Regulations would be appropriate.
- Drainage: At the end of the GESP plan period winter rainfall may be 10 – 20% higher both on average, and for the wettest day. This may mean that gutters, downpipes and drainage systems will require larger capacities.
- Flooding: The increase in precipitation both on average and at peak times will increase the risk of flooding. This is one of the key potential risks associated with climate change, though the extent of this risk is highly site specific. Adapting to this climate impact will require consideration of Sustainable Urban Drainage Systems (SUDS), consideration of flash flooding, and potential changes to ground water levels. The Environment Agency guidance with regard to adapting to climate change will need to be considered.

6.3.3 POTENTIAL MEASURES AND STANDARDS TO ADAPT TO CLIMATE CHANGE

The IUK report contains matrices of adaptation measures for each of the comfort, construction and managing water impacts (Figure 26 to Figure 28).

Designing for comfort

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.[†]

Key

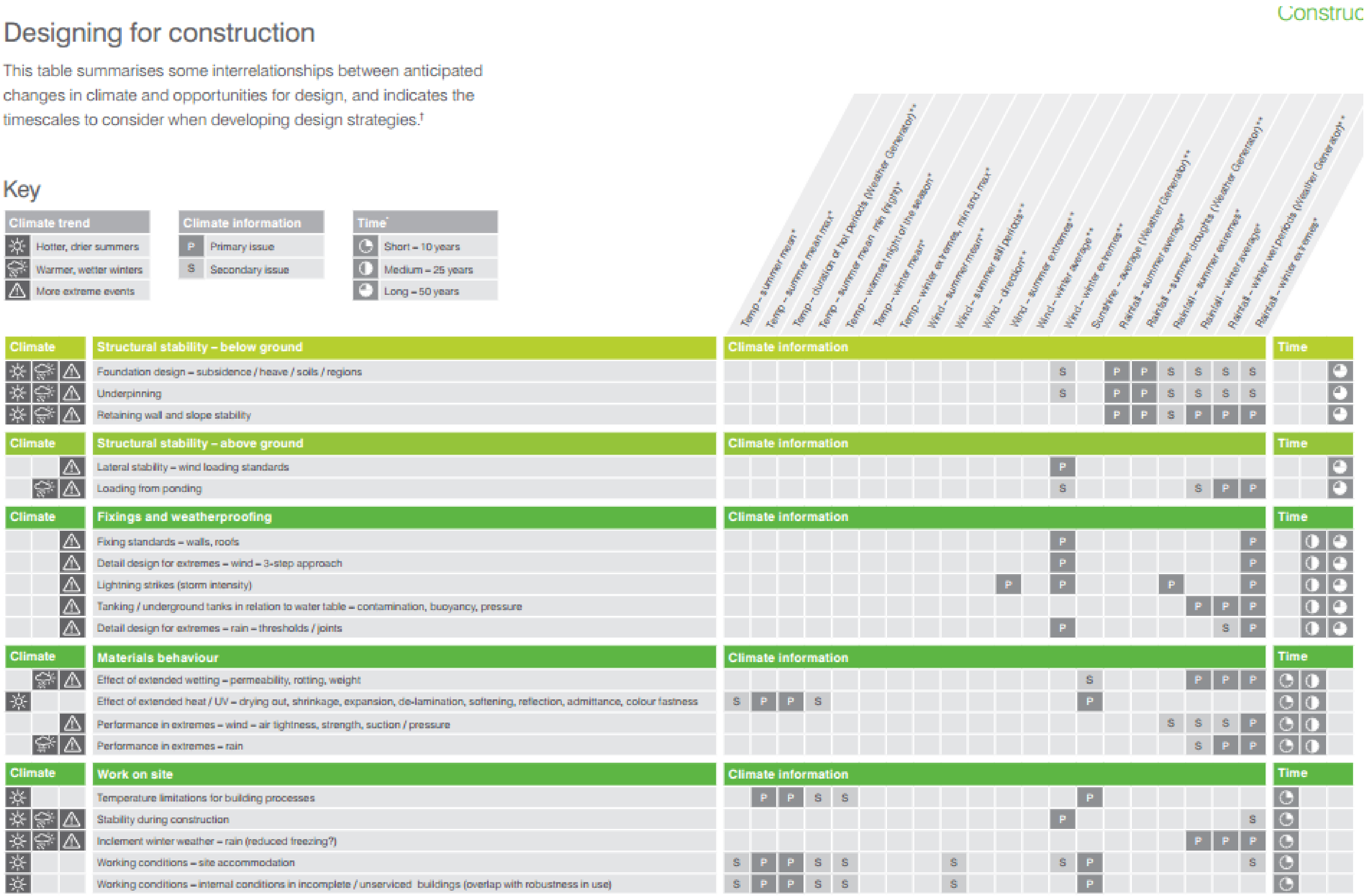
Climate trend	
☼	Hotter, drier summers
🌧	Warmer, wetter winters
⚠	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time*	
◔	Short – 10 years
◑	Medium – 25 years
◕	Long – 50 years

Climate				Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*	Time		
Climate			Design opportunities: Keeping cool – building design	Climate information																				Time		
☼			Shading – manufactured	P	P	S	S	S				P	S	S		S	P		S					◔	◑	
☼			Shading – building form	P	P	S	S	S				P	S	S		S	P		S							◕
☼			Glass technologies	P	P	S	S	S				P	S	S			P		S						◑	
☼			Film technologies	P	P	S	S	S				P	S	S			P		S					◔		
☼			Green roofs / transpiration cooling	P	P	S	S	S				P	S	S			P		S						◑	◕
☼			Shading – planting	P	P	S	S	S				P	S	S			P		S					◔	◑	◕
☼			Reflective materials	P	P	S	S	S				P	S	S			P		S					◔	◑	
☼			Conflict between maximising daylight and overheating (mitigation vs adaptation)	P	P	S	S	S				P	S	S			P		S					◔	◑	◕
☼			Secure and bug-free night ventilation	P	P	P	P	P				P	S	S			P		S					◔	◑	
☼			Interrelationship with noise and air pollution	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Interrelationship with ceiling height	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Role of thermal mass in significantly warmer climate	P	P	P	P	P				P	S	S			P		S							◕
☼			Enhancing thermal mass in lightweight construction	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Energy efficient / renewable powered cooling systems	P	P	P	P	P				P	S	S			P		S						◑	
☼			Groundwater cooling	P	P	S	S	S				P	S	S			P	S	S		P				◑	
☼			Enhanced control systems – peak lopping	P	P	S	S	S				P	S	S			P		S					◔	◑	
☼			Maximum temperature legislation	P	P	P	P	P				P	S	S			P		S						◑	◕
Climate			Design opportunities: Keeping cool – external spaces	Climate information																				Time		
☼			Built form – building to building shading	P	P	S	S	S				P	S	S			P		P							◕
☼			Access to external space – overheating relief	P	P	S	S	S				P	S	S			P		P							◕
☼			Shade from planting	P	P	S	S	S				P	S	S			P		P					◔	◑	◕
☼			Manufactured shading	P	P	S	S	S				P	S	S		S	P		P					◔	◑	
☼			Interrelationship with renewables	P	P	S	S	S				P	S	S			P		P						◑	
☼			Shading parking / transport infrastructure	P	P	S	S	S				P	S	S			P		P					◔	◑	
☼			Role of water – landscape / swimming pools	P	P	S	S	S				P	S	S			P		P				S		◑	◕
Climate			Design issue and opportunities: Keeping warm	Climate information																				Time		
	🌧		Building fabric insulation standards						P	P					S	S	P								◑	◕
	🌧		Relevance of heat reclaim systems						P	P					S	S	P								◑	
	🌧		Heating appliance design for minimal heating – hot water load as design driver						P	P					S	S	P							◔	◑	

Figure 26: List of environmental parameters impacted by climate change, and design measures that apply with regard to designing a building to achieve comfort



Designing for construction

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.[†]

Key

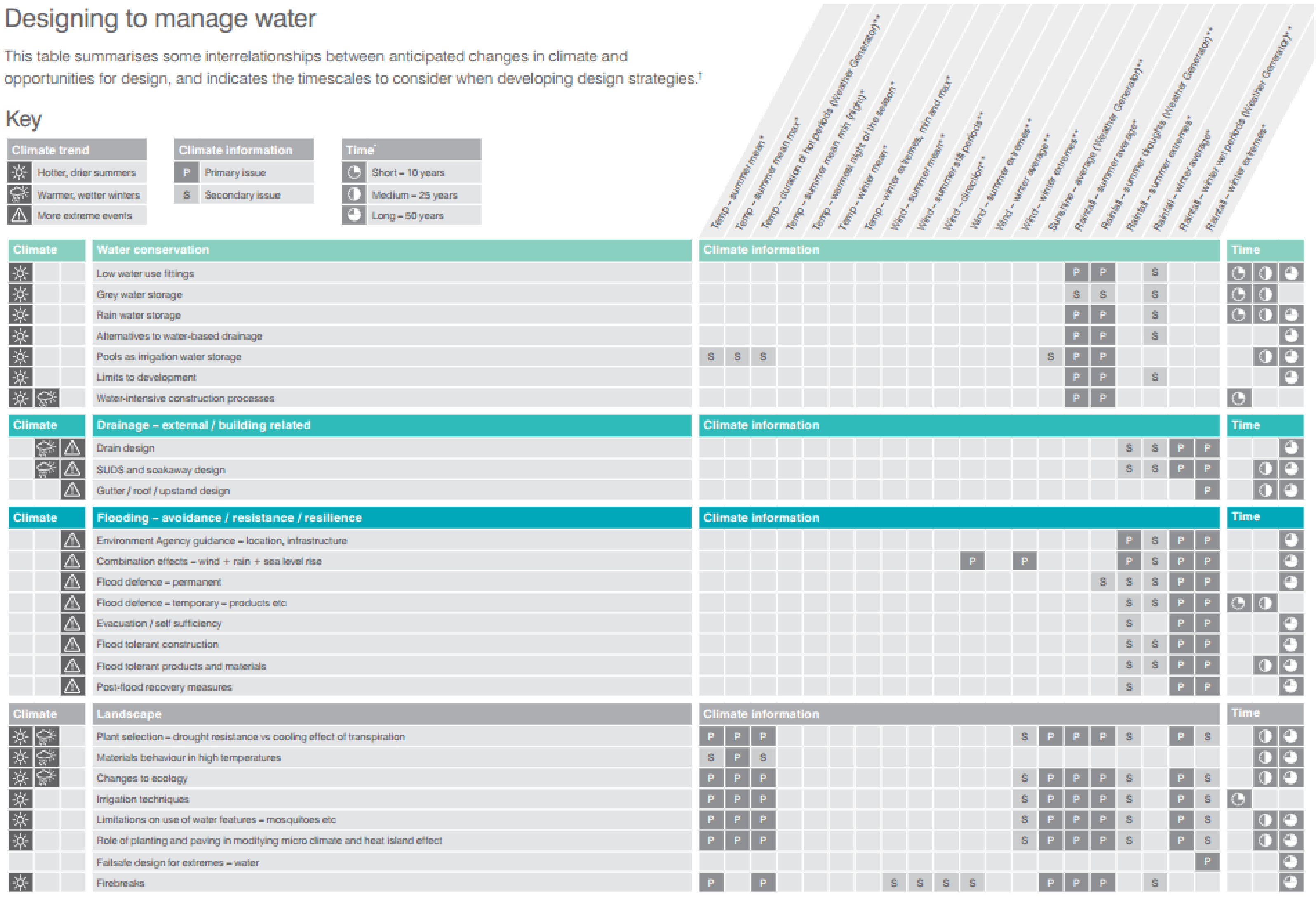
Climate trend	
☀	Hotter, drier summers
🌧	Warmer, wetter winters
⚠	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time*	
◔	Short – 10 years
◑	Medium – 25 years
◕	Long – 50 years

				Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*			
Climate			**Structural stability – below ground**	**Climate information**																				**Time**		
☀	🌧	⚠	Foundation design – subsidence / heave / soils / regions													S		P	P	S	S	S	S			◕
☀	🌧	⚠	Underpinning													S		P	P	S	S	S	S			◕
☀	🌧	⚠	Retaining wall and slope stability															P	P	S	P	P	P			◕
Climate			**Structural stability – above ground**	**Climate information**																				**Time**		
		⚠	Lateral stability – wind loading standards													P										◕
	🌧	⚠	Loading from ponding													S					S	P	P			◕
Climate			**Fixings and weatherproofing**	**Climate information**																				**Time**		
		⚠	Fixing standards – walls, roofs													P							P		◑	◕
		⚠	Detail design for extremes – wind – 3-step approach													P							P		◑	◕
		⚠	Lightning strikes (storm intensity)											P		P				P			P		◑	◕
		⚠	Tanking / underground tanks in relation to water table – contamination, buoyancy, pressure																		P	P	P		◑	◕
		⚠	Detail design for extremes – rain – thresholds / joints													P						S	P		◑	◕
Climate			**Materials behaviour**	**Climate information**																				**Time**		
	🌧	⚠	Effect of extended wetting – permeability, rotting, weight														S				P	P	P	◔	◑	
☀			Effect of extended heat / UV – drying out, shrinkage, expansion, de-lamination, softening, reflection, admittance, colour fastness	S	P	P	S										P							◔	◑	
		⚠	Performance in extremes – wind – air tightness, strength, suction / pressure																	S	S	S	P	◔	◑	
	🌧	⚠	Performance in extremes – rain																		S	P	P	◔	◑	
Climate			**Work on site**	**Climate information**																				**Time**		
☀			Temperature limitations for building processes		P	P	S	S									P							◔		
☀	🌧	⚠	Stability during construction													P							S	◔		
☀	🌧	⚠	Inclement winter weather – rain (reduced freezing?)																		P	P	P	◔		
☀			Working conditions – site accommodation	S	P	P	S	S				S				S	P						S	◔		
☀			Working conditions – internal conditions in incomplete / unserviced buildings (overlap with robustness in use)	S	P	P	S	S				S					P							◔		

Figure 27: List of environmental parameters impacted by climate change, and design measures that apply with regard to the construction of the building



Designing to manage water

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.[†]

Key

Climate trend	
☀	Hotter, drier summers
🌧	Warmer, wetter winters
⚠	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time*	
◔	Short – 10 years
◑	Medium – 25 years
◕	Long – 50 years

				Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*			
Climate			**Water conservation**	**Climate information**																				**Time**		
☀			Low water use fittings															P	P		S			◔	◑	◕
☀			Grey water storage															S	S		S			◔	◑	
☀			Rain water storage															P	P		S			◔	◑	◕
☀			Alternatives to water-based drainage															P	P		S					◕
☀			Pools as irrigation water storage	S	S	S											S	P	P						◑	◕
☀			Limits to development															P	P		S					◕
☀	🌧		Water-intensive construction processes															P	P					◔		
Climate			**Drainage – external / building related**	**Climate information**																				**Time**		
	🌧	⚠	Drain design																	S	S	P	P			◕
	🌧	⚠	SUDS and soakaway design																	S	S	P	P		◑	◕
		⚠	Gutter / roof / upstand design																				P		◑	◕
Climate			**Flooding – avoidance / resistance / resilience**	**Climate information**																				**Time**		
		⚠	Environment Agency guidance – location, infrastructure																	P	S	P	P			◕
		⚠	Combination effects – wind + rain + sea level rise											P		P				P	S	P	P			◕
		⚠	Flood defence – permanent																S	S	S	P	P			◕
		⚠	Flood defence – temporary – products etc																	S	S	P	P	◔	◑	
		⚠	Evacuation / self sufficiency																	S		P	P			◕
		⚠	Flood tolerant construction																	S	S	P	P			◕
		⚠	Flood tolerant products and materials																	S	S	P	P		◑	◕
		⚠	Post-flood recovery measures																	S		P	P			◕
Climate			**Landscape**	**Climate information**																				**Time**		
☀	🌧		Plant selection – drought resistance vs cooling effect of transpiration	P	P	P										S	P	P	P	S		P	S		◑	◕
☀	🌧		Materials behaviour in high temperatures	S	P	S																			◑	◕
☀	🌧		Changes to ecology	P	P	P										S	P	P	P	S		P	S		◑	◕
☀			Irrigation techniques	P	P	P										S	P	P	P	S		P	S	◔		
☀			Limitations on use of water features – mosquitoes etc	P	P	P										S	P	P	P	S		P	S		◑	◕
☀			Role of planting and paving in modifying micro climate and heat island effect	P	P	P										S	P	P	P	S		P	S		◑	◕
			Failsafe design for extremes – water																				P			◕
☀			Firebreaks	P		P					S	S	S	S			P	P	P		S					◕

Figure 28: List of environmental parameters impacted by climate change, and design measures that apply with regard to designing a building to managing water

The most relevant standard for considering adapting dwellings to achieving thermal comfort in the summer under projected climate change is CIBSE TM59[65]. This document outlines a standardised method to model dwellings using dynamic thermal modelling software and to determine performance against the adaptive comfort criteria stipulated in CIBSE TM52[66]. The calculations are performed using future climate files. It is stated that the methodology is proposed for all residences and should especially be considered for:

- Large developments
- Developments in urban areas, particularly in Southern England
- Blocks of flats
- Dwellings with high levels of insulation and airtightness
- Single aspect flats.

It would be prudent to ensure that this approach is followed for development in the GESP area, in particular if there are blocks of flats within the proposed developments.

Whilst there is no equivalent standard for non-domestic buildings, it would still be possible to undertake equivalent modelling exercises using probabilistic future climate files (as described in CIBSE TM48[67]) and ensuring the adaptive comfort criteria stipulated in CIBSE TM52 are met.

The most relevant guidance and standards regarding adapting to flood risk are provided in the NPPF and associated government guidance[68]. In addition there is a statutory duty to consult with the Environment Agency for developments in areas at risk of flooding. The NPPF (paragraphs 100 to 108) outline the process that must be followed in order to direct development away from areas at highest risk, or where development is necessary, making it safe without increasing flood risk. This involves undertaking a Strategic Flood Risk Assessment, potentially followed by applying the Sequential Test and the Exception Test. The lifetime of the project for residential development should be considered for a minimum of 100 years, unless there is specific justification for considering a shorter period, and includes consideration of the impact of climate change. Specific additional advice is provided by the Environment Agency[69] for considering the impacts of climate change. This states that allowances should be made within flood risk assessments to incorporate the impacts of climate change. Allowances for a range of impacts and climate change scenarios are provided. For the GESP area (which is within the wider "South West river basin district") and for the latest time period (2080s, which is applicable given that residential development lifetimes should be considered for 100 years) the allowances are as follows:

- Peak river flow allowances: 30% at Central allowance (50th centile) category, 40% at Higher Central allowance (70th centile) category and 85% at Upper End allowance (90th centile) category. In other words, scientific evidence suggests that it is just as likely that the increase

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[65] CIBSE 2017, TM59: Design methodology for the assessment of overheating risk in homes

[66] CIBSE 2013, TM52: The limits of thermal comfort: avoiding overheating in European buildings

[67] CIBSE 2009, TM48: Use of climate change scenarios for building simulation: The CIBSE future weather years

[68] https://www.gov.uk/guidance/flood-risk-and-coastal-change

[69] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

in peak river flow will be more than 30% as less than 30%, and that there is a 10% chance that peak river flow will increase by 85%.

- Peak rainfall intensity allowance: 20% at Central allowance category and 40% at Upper End allowance category.
- For coastal development:
  - Sea level rise allowance: Cumulative rise of 1.14 m from 1990 to 2015.
  - Offshore wind speed and extreme wave height: +10% for each of offshore wind speed allowance and sensitivity test, and extreme wave height allowance and sensitivity test.

The Environment Agency states under which circumstance to apply each allowance category, based on the stated vulnerability of the development. For example, for development in Flood Zone 3a essential infrastructure should use the upper end allowance in flooding assessments (for river flows and rainfall), whereas water compatible development need only use the central allowance.

6.3.4 COSTS OF ADAPTING TO CLIMATE CHANGE

The cost of adapting development to climate change depends on a number of factors including the building type and site specific issues, and as such it is not possible to quantify the cost uplift. Some adaptation measures can be achieved for effectively no cost e.g. optimal orientation, or site organisation, whilst other measures will increase the capital cost of a project e.g. uprated construction details or drainage capacity. The Design for Future Climate (D4FC) competition[70] was a funded programme by IUK to build climate adaptation expertise within the UK building profession, and to provide evidence of the commercial advantages of considering future climate adaptation in both new build and refurbishment projects. IUK has published[71] the outputs of each of the 47 D4FC case study projects across England and Wales, which represent a range of building types and approaches. Each of the projects includes a cost-benefit analysis which includes site specific costs of incorporating a range of adaptation measures.

IUK has also published a summary report[72] from the programme, though tellingly this has not collated the costs from these projects as they have to be taken on a case-by-case basis. Chapter 2 of this report discusses the business case of adapting to climate change. It is stated that "*there are many kinds of client for building design services, distinguished by their fundamental purpose, the duration of their stake in the building, their attitude to risk, and a myriad of other increasingly subtle factors. However, despite these differences, almost all share one overriding concern – capital cost*". It is also observed that for a range of projects investigated, the overall cost over the lifetime of a building is reduced if the building is adapted to climate change. For example, by improving the building's resilience to overheating risk obviating the need for retrospective fitting of comfort cooling systems, with their associated capital and operating costs. However, it is recognised that in almost all cases such an approach would require additional capital investment at the construction stage. It is stated that a means of appraising the benefit of adapting a building to climate change would be to undertake a discounted cost-benefit analysis. When undertaking such an analysis, factors that impede investment include:

- High discount rates;
- Future losses being a long time ahead;

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[70] http://www.arcc-network.org.uk/design-for-future-climate/

[71] https://connect.innovateuk.org/web/design-for-future-climate/projects-outputs

[72] IUK 2015, The business case for adapting buildings to climate change: Niche or mainstream?

- Uncertainty and imperfect information e.g. of climate change effects, it's impact on people, and the effectiveness of resilience measures;
- Missing markets ("externalities") e.g. impacts not being measurable in financial terms;
- Misaligned markets e.g. investors not capturing benefits;
- Budget constraints.

Many if not all of these barriers were encountered on the D4FC projects where incorporating resilience measures would constitute improving on regulatory backstops e.g. the Building Regulations.

The outputs from the 47 projects were consulted and it was found that there were six residential schemes where there was sufficient cost information to reveal the cost uplift of adapting to climate change. These cost uplifts are shown in Table 23. The increased costs were associated with meeting all three broad areas, though the majority of the costs were in general associated with controlling overheating and managing water. In addition to each site having its own specific challenges (this is especially the case regarding flooding), the projects were research projects and as such each team adopted different approaches to meeting the challenge. It is therefore unsurprising to observe that the cost uplift varied drastically with some projects around the 1% mark, others nearer 10%, and one project as high as 68%. A key observation was that the approach that many teams took to adapting a building to climate change was to plan to implement measures at key trigger points e.g. 20 or 40 years after their initial construction. Whilst this approach would result in less (or even no) additional cost uplift at the initial point of build, there is no guarantee that in practice these adaptive measures would actually be implemented in the future, or that rather than passive adaptive measures air conditioning would not be retrospectively installed instead. An important lesson from the projects was to design in as much at the initial design as possible. This could include optimising orientation, or windows that open inwards to enable the fitting of external shutters in the future. It should also be reiterated that designing residential buildings to CIBSE TM59 using current climate files still represents a big improvement on the overheating check that is currently incorporated in SAP calculations as required for Part L of the building regulations, irrespective of whether calculations are also undertaken using future climate files.

Table 23: Notes on cost uplift of designing residential schemes to be adapted to climate change

Scheme	No. Homes in study	Notes on cost
Acton Gardens, London Climate Adaptation	2,600	Masterplan (site level) costs difficult to quantify as benefits and requirements tied in with other factors. Costs calculated as 30 year NPVs. No measures needed installing now, so costs presented either if measures installed now or retrofitted in 2050s. Ground floor flats £13,277 now, £6,419 2050s; Upper floor flats £7,008 now, £4,014 - £6,419 2050s; Ground floor in houses £35,641 now, £16,655 2050s; Upper floors in houses £9,825 now, £4,500 2050s. i.e. always lower overall cost to install when needed – in all likelihood due to future costs being discounted as part of the NPV analysis– so the important thing is to not design out the ability to do this e.g. have windows opening inwards to allow for external shutters later. This approach risks the adaptive measure later being air conditioning.
Oakham North, Rutland	135	Assumes a base build cost of £1000/m2. For a detached house minimum additional cost per dwelling is £16,365 (16% cost uplift) and a maximum of £73,500 (68% uplift) which includes £37,800 on basement box foundations.
Climate Adaptive Neighbourhoods (CAN) Project, Norwich	72 homes + 2,000 sq. ft. retail	Capital cost increase of 1.4%, mainly enhancing fabric from lightweight to heavyweight construction. Retrofitting cooling measures including labyrinth and stack ventilation resulted in a total overall cost increase of 3.1%.
Brighton New England Quarter	147 apartments, 98 bed hotel, 3,000 sq.m office, 240 sq.m retail	Extra over costs of 10.2% - 11.3% based on a package of mechanical and electrical (M&E) items plus novel "Cool Box Evaporative Coolers", solar glass, exposed thermal mass, external blinds and F rated brick cladding, most of which implemented at the outset (external blinds and solar control glazing potentially later).
Princes Park, Liverpool	100	The total additional expenditure accepted by the client totalled over £830,000 on a project value of approx. £10 million i.e. 8.3% extra over cost. Of this £666,746 was for thermal measures with the rest regarding managing water. An additional £40,950 was identified for future methods to control overheating i.e. solar control glass. In addition, it was stated that "The Cost Benefit or Lifecycle Analysis approach to evaluating costs was ruled out as almost all of the adaptations proposed offered a benefit to the end user (the tenant) and not to the client. The key criterion in the current funding regime is Capital Cost. Whilst tenants would enjoy the benefit of solar shading, good ventilation etc. the Client would be able to construct less houses and this would affect future funding provision. Therefore, 'near to market' options must compete effectively for limited funding, and be cost neutral or offer minimal cost for maximum benefit. "
NW Bicester Eco Development	400 homes in first phase	The development was being developed to exemplar standards and as such included a number of measures within the base cost of £1,469 per sq.m. In addition to this, a number of measures were proposed to be retrofitted in the 2030s and 2050s. The total cost of implementation at both of these periods amounted to an overall cost uplift of 1.2% of the original cost plan. Interestingly, it was identified that increasing thermal mass (i.e. increasing the capacity of the building structure to store heat, which together with consideration of ventilation is a passive cooling strategy to reduce peak internal temperatures) would be a proposed measure required by the 2080s, but it would not be possible to retrofit this and so if it were to be incorporated it would need to be done at the initial build phase.

6.3.5 CONCLUSIONS

It is estimated that over the GESP period temperatures may rise by 2 – 3°C and rainfall increase by 10 – 20%. Specific actions that should be considered for new development in the GESP area include; designing buildings using the approach set out in CIBSE TM59; especially for large developments and where there are flats, to consider designing constructions to meet the requirements for a "very severe" exposure zone; and to incorporate specific climate change uplift factors provided by the Environment Agency when undertaking flood risk assessments.

There is no standardised approach to adapting new development to climate change, and as such it has not been possible to ascertain the cost uplift to developers of achieving this. Interrogation of outputs from a large scale research programme where design teams were left to develop their own approaches to adapting their residential developments to climate change resulted in overall cost uplifts ranging from 1% to nearer 10%, with one project as high as 68%. This very wide range is indicative of both the different approaches adopted by design teams in the absence of an official approach, together with the site specific aspect of climate change adaptation; flooding can be a very localised issue. A key observation was that low/zero cost design measures can be undertaken now that enable (or at the least do not preclude) the retrofitting of adaptive measures at trigger points in the future e.g. when building services or fabric elements like windows are due to be replaced.

It should also be reiterated that designing residential buildings to CIBSE TM59 using current climate files still represents a big improvement on the overheating check that is currently incorporated in SAP calculations as required for Part L of the building regulations, irrespective of whether calculations are also undertaken using future climate files.

7. ECONOMIC IMPACT OF BUILDING AND STANDARDS AND RENEWABLES

7.1 WORK PACKAGE AIM

The aim of this work package was to address objective 9 as described in Section 1 which was to consider opportunities for improving viability and attractiveness of low carbon and renewable energy technology through the creation and encouragement of a local industry based around these technologies.

7.2 GENERAL APPROACH

The approach taken was to take a selection of the scenarios for construction standards and large scale renewable energy (wind turbines and ground mounted PV) described in chapters 0 and 5 and to establish the economic impacts of applying those standards across the GESP area. The underlying assumption was that the cost uplift associated with each scenario is equivalent to additional "turnover" within each of the energy efficiency and renewable energy sectors in the area. A report by RegenSW[73] was used to establish the number of jobs (measured in full time equivalents [FTE]) and gross value added (GVA) resulting from this assumed turnover. In addition, the RegenSW report quotes leakage factors (i.e. where economic value leaks from a region) and supply chain multipliers (i.e. where economic activity is reinforced by further activity along the supply chain), and these were used to obtain net values for each of the FTE and GVA outputs. This approach probably over-states the value of these multipliers as the RegenSW report looked at the entire SW region, and so when considering the GESP area leakage is likely to be much higher as the area is smaller. In addition, the turnover has been applied in the main to volume housebuilders and large scale energy suppliers, where again the likelihood is that economic benefit is more likely to leak from the GESP area. As such the results are likely to be optimistic.

The turnover associated with the building standards explored in chapter 0 was established by multiplying the cost uplift of each standard by the number of dwellings or area of non-domestic floor space projected to be developed in each year between 2020 and 2040. The turnover per FTE and GVA per FTE values reported by RegenSW for the energy efficiency sector were then applied to the "turnover" in each year to establish FTE and GVA and these in turn were multiplied by the leakage and supply chain multiplier factors to establish net values for these two outputs. As the build profile over the period was not uniform, the average FTE and GVA was taken as being representative of the impact of the standards on the GESP economy. No account was made for potential impacts on the economy associated with lower energy consumption and therefore household bills and disposable income. The NHS has quantified[74] the annual cost to their service of £1.36 billion in England. It has also previously been observed that improvements in energy efficiency can have other positive economic multipliers, for example it was found in a study[75] that for every £1 spent on reducing exposure to cold in homes 42 p was returned in quality of life gains. However, these studies focus on improvements to the existing building stock whereas setting standards for new dwellings would be against a reference case which in practice should already be sufficiently warm to avoid the dis-benefits that the study identified.

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[73] The Economic Contribution of the Renewable Energy and Energy Efficiency Sectors in the South West of England, DTZ for RegenSW 2010

[74] https://www.ageuk.org.uk/latest-news/archive/cold-homes-cost-nhs-1-point-36-billion/

[75] Liddell, C. 2008, Estimating the health impacts of Northern Ireland's Warm Home Scheme 2000–2008; University of Ulster, Londonderry

The turnover associated with the renewable energy resource explored in chapter 5 was taken to relate to the large scale wind and ground mounted PV technologies. In the case of wind turbines, the scenario with a 3 km airport buffer and 25% NATS buffer was taken and for both technologies, both being within 2 km of the 33 kVA electricity grid and being unconstrained to proximity to the electricity grid (e.g. for when storage technologies mature) were considered. Costs of the various technologies were based on stated construction and operation costs from a report by government[76]. From this, benchmark values in terms of £/MW were established for wind and PV and these were applied to the calculated resource for the four scenarios (two technologies both either grid constrained or not). Finally, the calculated FTE and GVA values were compared to projections of these economic indicators for the entire GESP period that was produced in parallel to this project[77].

7.3 WORK PACKAGE OUTPUTS

The impact of building standards and taking up the renewable energy resource is shown in Table 24. Constructing new dwellings to energy Code level 4 and requiring a 10% improvement on Part L for non-domestic buildings may result in 121 additional FTE jobs (0.05% of all jobs in the GESP area in 2040) and almost £4 million GVA. Improving the requirement to Code level 5 and 20% for non-domestic buildings and utilising allowable solutions to cover all "regulated" emissions could increase FTE to 788 (0.32%) and £26 million GVA. PV and wind development with no grid constraints could create 3,759 jobs (1.51% total GESP jobs), mainly in the PV sector, and add approximately £177 million GVA. Constraining renewable deployment to be within 2 km of the electricity grid could result in the creation of 1,995 jobs (0.80%) and £94 million GVA[78].

Table 24: Estimated impact on direct and net FTE and GVA arising from different construction standards and how this compares to the size of the GESP economy in 2040.

	Average annual contribution to GVA/FTE 2020 - 2040				*% of total GESP in 2040*			
Scenario	*FTE Direct*	*GVA Direct*	*FTE Net*	*GVA Net*	*FTE Direct*	*GVA Direct*	*FTE Net*	*GVA Net*
Energy Code 4 homes, 2013 Part L +10% non-residential	104	£3,431,058	121	£3,996,496	0.04%	0.02%	0.05%	0.03%
Energy Code 5 homes, 2013 Part L +20% non-residential with AS for both	677	£22,334,907	788	£26,015,700	0.27%	0.16%	0.32%	0.18%
Wind turbines and Ground mounted PV no grid constraint	3228	£151,694,073	3759	£176,693,256	1.29%	1.06%	1.51%	1.24%
Wind turbines and Ground mounted PV 2km grid constraint	1713	£80,501,015	1995	£93,767,582	0.69%	0.56%	0.80%	0.66%

7.4 CONCLUSIONS

A high level estimate of the impact of implementing various renewable energy and sustainable construction standards on the economy in the GESP area was undertaken. This showed that utilising the available renewable energy resource could add 1.5% to the GESP area's economic output whilst constructing new developments to more aspirational standards could add a further 0.3%.

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[76] BEIS 2016 Electricity Generation Costs, from Table 19.

[77] Greater Exeter Economic Development Needs Assessment, Hardisty Jones Associates 2017

[78] With PV development constrained to exclude agricultural land grades 1, 2 and 3a.

APPENDIX A: ABBREVIATIONS

AD	Anaerobic Digestion
AGA	Air-Ground-Air communication system for air traffic control
AONB	Area of Outstanding Natural Beauty
ATC	Air Traffic Control
BEIS	Department for Business, Energy & Industrial Strategy
BREEAM	Building Research Establishment Environmental Assessment Method
CCC	Committee on Climate Change
CCS	Carbon Capture & Storage
CEE	Centre for Energy and the Environment
CERT	Carbon Emissions Reduction Target
CHP	Combined Heat and Power
CIBSE	Chartered Institute of Building Services Engineers
CIL	Community Infrastructure Levy
CPI	Consumer Price Index
CSE	Centre for Sustainable Energy
CSH	Code for Sustainable Homes
CO_2	Carbon dioxide
D4FC	Design for Future Climate
DH	District Heating
ECO	Energy Company Obligation
EfW	Energy from Waste
ESOS	Energy Savings Opportunity Scheme
FiT	Feed-in Tariff
FTE	Full Time Equivalent
GESP	Greater Exeter Strategic Plan
GHG	Greenhouse Gas
GIS	Geographic Information System (computer-based mapping)
GOSW	Government Office of the South West
GVA	Gross Value Added
ha	Hectare
HMU	Height Monitoring Unit (radar receiver for air traffic control)
HP	Heat Pump
HSR	Housing Standards Review
I&C	Industrial and Commercial sector
IUK	Innovate UK
kV	Kilo-volts
kVA	Kilo-volt-amperes
kW	Kilowatt
kWh	Kilowatt-hour
LPA	Local Planning Authority
LSTF	Local Sustainable Transport Fund
LZC	Low and Zero Carbon technologies
MACC	Marginal Abatement Cost Curve
MOD	Ministry of Defence
$MtCO_2$	Mega-tonne Carbon Dioxide
MWth	Megawatts (thermal)
NATS	ATC Provider (formerly National Air Traffic Services)
NEF	National Energy Foundation
NERL	NATS[45] En Route plc, ATC Provider

NHS	National Health Service
NPPF	National Planning Policy Framework
NPV	Net Present Value
PSR	Primary Surveillance Radar (radar for air traffic control)
PV	Photovoltaic
RAMSAR site	Land protected under the Convention on Wetlands (Ramsar Convention)
RE	Renewable Energy
RHI	Renewable Heat Incentive
RO	Renewables Obligation
s106	Section 106
SAP	Standard Assessment Procedure
SBEM	Simplified Building Energy Model
SPG	Supplementary Planning Guide
SQW	SQW Limited, Energy and Land Use Consultants
SSR	Secondary Surveillance Radar (radar for air traffic control)
tCO_2	Tonne of carbon dioxide
TWh	Terawatt hour
UKCP09	UK Climate Projections 2009
VSC	Vertical Sky Component
WPD	Western Power Distribution
WMS	Written Ministerial Statement
WPSH	Winter Probable Sunlight Hours
ZCH	Zero Carbon Hub

APPENDIX B: HEAT NETWORK VIABILITY CALCULATOR

The heat network viability calculator is a simplified calculation tool which gives an indication of the viability of a heat network in a proposed development based on experience in the GESP area and the reference studies [18,19,20]. It is important to note that the calculator does not establish if heat a network is viable or not but a positive viability outcome from the calculator is a trigger for more detailed site specific assessment to be undertaken.

Input data

The input variables to the calculator are the number of homes in a development area and the start year of the development.

When considering the number of homes in a development, where there are multiple packages of land in a development within in reasonable proximity of each other (boundaries of individual packages less than 1km apart), as for example as at the Monkerton / Tithebarn / Pinhoe developments to the east of Exeter, the number of homes in each package should be added together.

Connection fee model

The heat network viability calculator assumes a total connection fee of £4,000 per home based on evidence from the Monkerton and South West Exeter heat network schemes.

It is important to note that this connection figure is the amount paid to the heat network developer and not the net cost to the housebuilder. The net cost to the housebuilder should deduct avoided costs (e.g. boiler, other gas equipment, gas network, etc.) and the value of the CO_2 benefits which the heat network provides and add any heat network costs borne by the housebuilder (e.g. civil works). Work for South West Exeter, which does not include any CO_2 benefits, shows a net deduction of £700/per home[79] giving a housebuilder cost of £3,250/home. Any tightening of CO_2 emissions requirements will decrease the net connection cost to the housebuilder or, alternatively, enable a higher connection fee to be paid to the network developer thereby enhancing the viability of the heat networks.

The calculator includes a connection cost table which enables different connection fees to be included for different development start years. This gives the flexibility to incorporate any changes in connection fees which may result from future announcements on the tightening of CO_2 emissions standards.

Capex model

The estimated capital costs of a heat network (total costs including heat pipe and energy centre/CHP engines) are based on studies of heat network solutions in large developments in the GESP area. Plotting these capex costs against the numbers of homes in the respective development enables a linear regression formula to be derived and this is used to estimate the capital costs for the number of homes input to the calculator.

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[79] "Comments on WWA review of district heating network costs at South West Exeter" CEE, July 2016

Non-fuel operating cost model

As with Capex costs non-fuel operating costs from heat network solutions in large developments in the GESP area are used to calculate non-fuel opex (total for heat pipe and energy centre/CHP engines).

Heat demand and energy revenue model

The calculator uses heat demand from studies of large developments in the GESP area to estimate heat demand for the number of homes input. Heat demand is then used in a simplified energy model to calculate net energy revenue in a heat network assuming a gas fired CHP energy solution with heat storage. Energy input and output volumes are calculated assuming:

Heat network losses	15%
CHP contribution of heat	75%
CHP heat efficiency	40%
CHP electrical	40%
Back up boiler efficiency	80%

Revenues are calculated assuming average real lifetime costs based on BEIS energy price forecasts. The 2018 version of the calculator uses the BEIS "Central" energy price forecasts published in March 2017 (see Annex M on https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016)

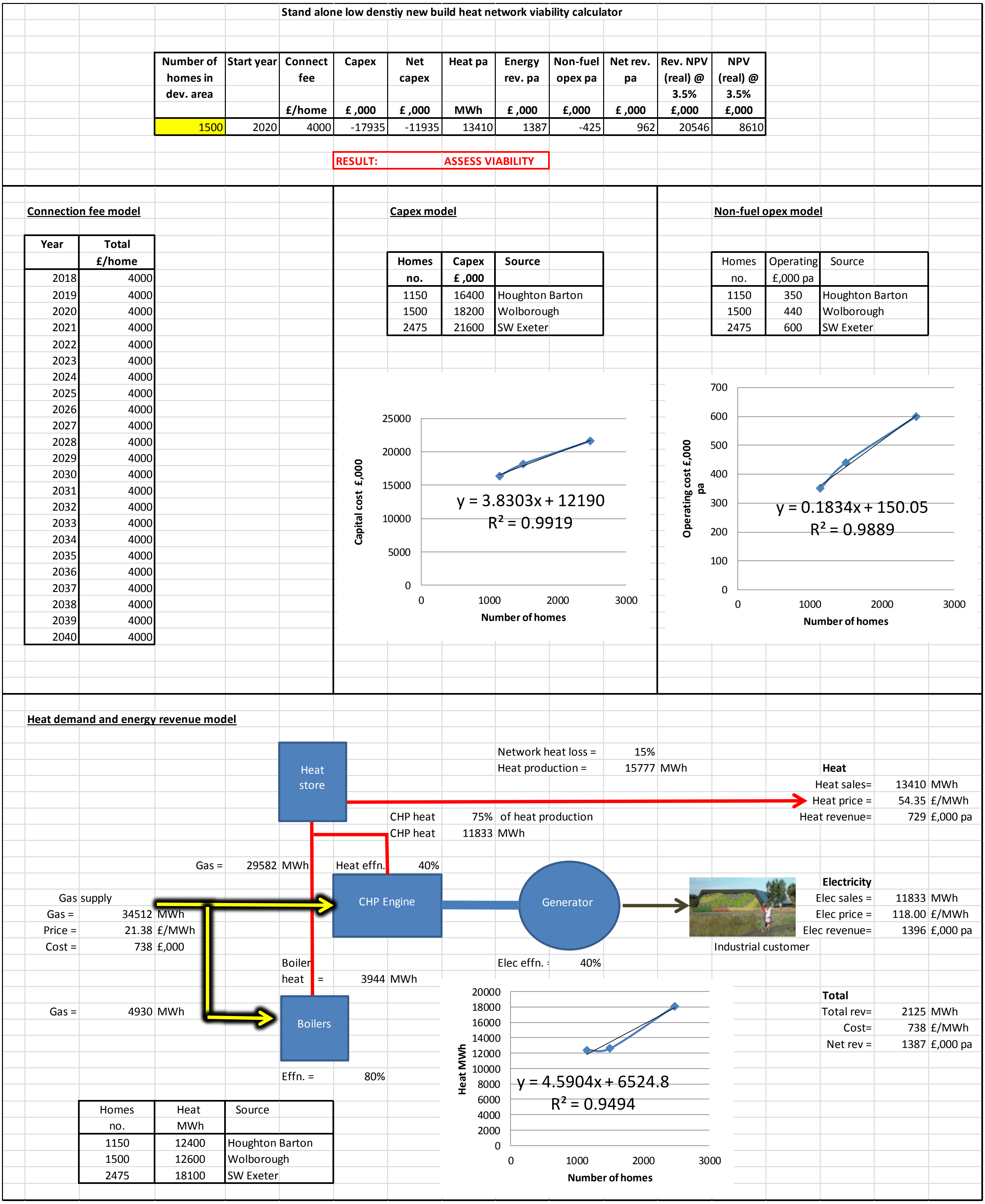
Calculation of viability

The calculator uses the number of homes input and the capex model to calculate the total capital cost of the heat network solution and from this deducts the total connection fee to provide net capex.

The heat demand and energy revenue model calculates the annual energy revenue. The non-fuel opex is deducted from the energy revenue to provide net annual revenue.

The net present value (NPV) of the annual revenue is calculated over 40 years. The choice of discount rate to be used will depend on how the scheme is likely to be financed. If a scheme is to be financed by the public sector the UK Treasury Green Book discount rate of 3.5% real could be adopted. A 10% real discount rate, which is more representative of discount rates adopted by the private sector, could be used if a scheme is to be privately financed. The net capex is deducted from the annual revenue NPV to give the estimated NPV of the heat network solution.

A positive NPV from the calculator indicates that the viability of a heat network solution should be specifically assessed for the proposed development. This site specific assessment will incorporate the data and assumptions appropriate for that scheme.



Stand alone low denstiy new build heat network viability calculator

Number of homes in dev. area	Start year	Connect fee £/home	Capex £ ,000	Net capex £ ,000	Heat pa MWh	Energy rev. pa £ ,000	Non-fuel opex pa £,000	Net rev. pa £ ,000	Rev. NPV (real) @ 3.5% £,000	NPV (real) @ 3.5% £,000
1500	2020	4000	-17935	-11935	13410	1387	-425	962	20546	8610

RESULT: ASSESS VIABILITY

Connection fee model

Year	Total £/home
2018	4000
2019	4000
2020	4000
2021	4000
2022	4000
2023	4000
2024	4000
2025	4000
2026	4000
2027	4000
2028	4000
2029	4000
2030	4000
2031	4000
2032	4000
2033	4000
2034	4000
2035	4000
2036	4000
2037	4000
2038	4000
2039	4000
2040	4000

Capex model

Homes no.	Capex £ ,000	Source
1150	16400	Houghton Barton
1500	18200	Wolborough
2475	21600	SW Exeter

Non-fuel opex model

Homes no.	Operating £,000 pa	Source
1150	350	Houghton Barton
1500	440	Wolborough
2475	600	SW Exeter

Heat demand and energy revenue model

Network heat loss = 15%
Heat production = 15777 MWh

Heat
Heat sales= 13410 MWh
Heat price = 54.35 £/MWh
Heat revenue= 729 £,000 pa

CHP heat 75% of heat production
CHP heat 11833 MWh

Gas = 29582 MWh
Heat effn. 40%

Gas supply
Gas = 34512 MWh
Price = 21.38 £/MWh
Cost = 738 £,000

Electricity
Elec sales = 11833 MWh
Elec price = 118.00 £/MWh
Elec revenue= 1396 £,000 pa

Elec effn. = 40%

Boiler heat = 3944 MWh

Gas = 4930 MWh

Effn. = 80%

Total
Total rev= 2125 MWh
Cost= 738 £/MWh
Net rev = 1387 £,000 pa

Homes no.	Heat MWh	Source
1150	12400	Houghton Barton
1500	12600	Wolborough
2475	18100	SW Exeter

The tool is shown overleaf.

APPENDIX C: DATA TABLES

This appendix contains the underlying data (tCO_2e) in years 2016, 2032 and 2050 for the trajectory graphs that are used for each sector within the report.

Power

	2016	2032	2050
BAU pathway	556,288	603,583	801,101
Savings from lower-risk policies	*0*	*113,000*	*0*
Savings from medium-risk policies	*0*	*144,535*	*0*
Savings from high risk high-level intentions	*0*	*103,344*	*0*
Savings from current policy gaps	*0*	*69,531*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*738,789*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*49,308*
Adopt all measures pathway	556,288	173,172	13,005

Buildings

	2016	2032	2050
BAU pathway	830,329	911,235	1,007,486
Savings from lower-risk policies	*0*	*46,361*	*0*
Savings from medium-risk policies	*0*	*46,253*	*0*
Savings from high risk high-level intentions	*0*	*148,609*	*0*
Savings from current policy gaps	*0*	*87,097*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*799,828*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*168,326*
Adopt all measures pathway	830,329	582,914	39,332

Industry

	2016	2032	2050
BAU pathway	15,193	13,303	12,245
Savings from lower-risk policies	*0*	*210*	*0*
Savings from medium-risk policies	*0*	*432*	*0*
Savings from high risk high-level intentions	*0*	*1,411*	*0*
Savings from current policy gaps	*0*	*524*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*1,355*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*9,008*
Adopt all measures pathway	15,193	10,726	1,881

Transport

	2016	2032	2050
BAU pathway	1,111,809	1,170,599	1,325,157
Savings from lower-risk policies	*0*	*54,913*	*0*
Savings from medium-risk policies	*0*	*241,953*	*0*
Savings from high risk high-level intentions	*0*	*195,944*	*0*
Savings from current policy gaps	*0*	*158,083*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*849,405*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*253,694*
Adopt all measures pathway	1,111,809	519,707	222,057

Agriculture and Land Use Change

	2016	2032	2050
BAU pathway	619,953	625,813	646,885
Savings from lower-risk policies	*0*	*0*	*0*
Savings from medium-risk policies	*0*	*47,662*	*0*
Savings from high risk high-level intentions	*0*	*8,851*	*0*
Savings from current policy gaps	*0*	*45,854*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*148,732*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*81,080*
Adopt all measures pathway	619,953	523,446	417,073

Waste

	2016	2032	2050
BAU pathway	260,262	161,773	133,866
Savings from lower-risk policies	*0*	*0*	*0*
Savings from medium-risk policies	*0*	*2,216*	*0*
Savings from high risk high-level intentions	*0*	*12,007*	*0*
Savings from current policy gaps	*0*	*25,938*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*47,239*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*12,322*
Adopt all measures pathway	260,262	121,612	74,305

F-gases

	2016	2032	2050
BAU pathway	324,376	336,738	403,684
Savings from lower-risk policies	*0*	*0*	*0*
Savings from medium-risk policies	*0*	*285,831*	*0*
Savings from high risk high-level intentions	*0*	*0*	*0*
Savings from current policy gaps	*0*	*0*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*335,881*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*23,011*
Adopt all measures pathway	324,376	50,907	44,792

Devon Total

	2016	2032	2050
BAU pathway	6,627,501	6,803,755	7,644,951
Savings from lower-risk policies	*0*	*367,769*	*0*
Savings from medium-risk policies	*0*	*1,146,333*	*0*
Savings from high risk high-level intentions	*0*	*804,175*	*0*
Savings from current policy gaps	*0*	*694,941*	*0*
Savings to 2050 from Core Policies	*0*	*0*	*4,874,415*
Savings to 2050 from Further Ambition Policies	*0*	*0*	*1,050,548*
Savings from GHG Removal: CCC low scenario	*0*	*0*	*392,781*
Additional savings from GHG Removal: CCC high scenario	*0*	*0*	*797,837*
Additional savings from GHG Removal: Royal Society scenario	*0*	*0*	*405,056*
Adopt all measures pathway	6,627,501	3,790,537	124,314

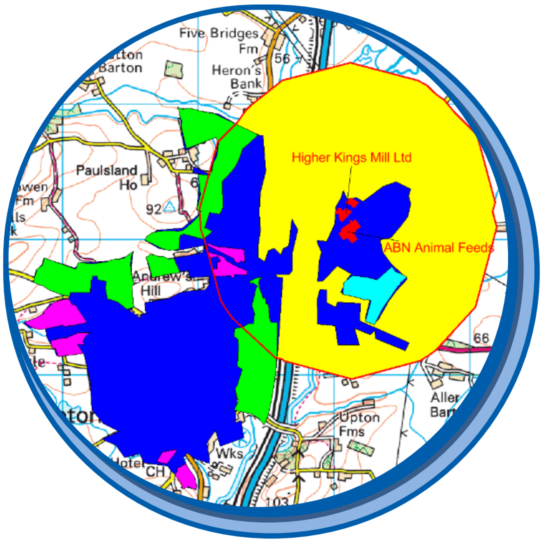
APPENDIX D: IDENTIFICATION OF HEAT LOADS FOR THE GREATER EXETER STRATEGIC PLAN

Identification of Heat Loads for the Greater Exeter Strategic Plan

CENTRE FOR ENERGY AND THE ENVIRONMENT

Internal Document 929 Version 4

April 2017



Report Name:	Identification of Heat Loads for the Greater Exeter Strategic Plan
Author(s):	T.A.Mitchell
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Ver. No.	*Comments*	*Approved By*	*Date*
1	Initial draft	-	-
2	Incorporated comments from Eleanor Ward	-	-
3	Incorporated comments from Howard Smith and review/addition of industrial sites	A. Norton	21/04/17
4	Extent of gas grid added		

Management Summary

This report considers the location of large users of electricity and heat, and planned new developments that would present opportunities for matching heat supply and demand, or otherwise incentivise the formation of a district heating network. A number of potential heat sources and electricity and heat loads have been identified from planning policy reports, publically available energy consumption data and local knowledge. It is recommended that the results form part of the GESP development location discussions, and that the potential which local energy demand and supply present are discussed and evaluated in progressive levels of detail as the GESP is developed. It is important that this initial data is not used without further analysis, evaluation and interpretation.

1.Introduction

This report considers the juxtaposition of large users of electricity and heat, and planned new developments that would present opportunities for matching heat supply and demand, or incentivise the formation of a district heating network through, for example, the direct supply of electricity from CHP. This energy perspective is important for the Greater Exeter Strategic Plan (GESP), which seeks to optimally locate new development. Localised opportunities are most likely to arise through heat networks which provide suitable loads for solar thermal, biomass, heat pump, combined heat and power technologies (using gas, biomass or waste) and waste heat.

2.Methodology

1. **Identify existing large electricity and heat users:**
   a. There is limited statistical information published on non-domestic energy consumptions. To avoid identifying individual users the statistics issued by the Department for Business, Energy and Industrial Strategy (BEIS) for non-domestic consumers are aggregated at middle layer super output area (MSOA). The population of each MSOA is at least 5000 and nationally averages 7200. For each MSOA, the total, mean and median consumption are provided along with the number of meters. Data are available for electricity[80] and mains gas[81]. The most recent data available are for 2015.
   b. The MSOA data can give a high level indication of areas of interest since if there are a small number of large consumers in an MSOA, this will disproportionately inflate the mean compared to the median. As a first step, the mean was divided by the median; a larger result suggests that consumption within the MSOA is dominated by a few large consumers, however this does not indicate the magnitude of consumption. As a refinement, the amount of energy consumed by large consumers was estimated from the formula $n \times (\bar{e} - \tilde{e})$, where n is the number of meters, $\bar{e}$ is the mean consumption per meter and $\tilde{e}$ is the median consumption per meter. This formulation is based on the assumption that the difference between the mean and median is attributable to large consumers, the number of which is very small compared to the total number of consumers. Particular note was made of results exceeding the thresholds of 0.5 $\mathrm{MW_e}$ and 2 $\mathrm{MW_{th}}$, which equate to annual consumption of 4.38 GW h for electricity and 17.52 GW h for gas.

---

[80] **Lower and Middle Super Output Areas electricity consumption.** BEIS, 2017. https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-electricity-consumption . Accessed 2/3/2017.

[81] **Sub-national gas consumption data.** BEIS, 2016. https://www.gov.uk/government/collections/sub-national-gas-consumption-data . Accessed 2/3/2017.

   c. The results of this analysis were plotted both as absolute values and rank orders of results, using the MAPINFO geographical information system (GIS) software.
   d. The Department of Energy and Climate Change (DECC)/Centre for Sustainable Energy (CSE) National Heat Map[82] was also examined. Some known locations of high heat demand were identified, but a large number of spurious sites were also indicated and given that the underlying data are about seven years old it was not used in the analysis.
   e. Further registers of industrial processes were examined: the Environment Agency Operational Risk Appraisal database[83], the National Atmospheric Emissions Inventory register of large point sources[84] and the EU Emissions Trading Scheme National Allocation Tables[85].
   f. MSOAs flagged at stage 1b as having potentially high consumption attributable to large heat users, and the significant industrial processes identified in stage 1e were examined more closely on Ordnance Survey and Google mapping. Confirmed sites were plotted along with 1 km radius buffer zones.

2. **Identify existing and planned heat networks and heat sources:**
   Recent and planned heat networks (e.g. those serving Cranbrook, Monkerton and Exeter City Centre) are well known. The FAB Link high voltage interconnector to France is a potential source of heat to the east of Exeter. Current and future waste disposal facilities with (or with potential for) energy recovery were identified from the DCC Waste Local Plan[86] Within the GESP area, these include the existing Exeter energy recovery facility, planned gasification and pyrolysis plants at Hill Barton adjacent to the A3052 to the east of Exeter, and potential sites in the Tiverton eastern extension and at Heathfield.
3. **Review local plans:**
   Current development sites in the GESP were mapped and co-plotted to identify synergies between the identified heat loads and sources and the heat demands and supply of potential new development.

3.Results

Figure 29 and Figure 30 indicate the mean non-domestic consumption of electricity and gas per meter within the GESP area. The method for estimating consumption due to large users described above yields Figure 31 and Figure 32. For electricity, the most significant areas are around Exeter (city centre, Alphington, Clyst Heath, and to the north) and the industrial and commercial area to the north of Newton Abbot. For gas, the significant areas are more evident and include Clyst Heath, Alphington, Tiverton, Cullompton, north of Newton Abbot and Crediton. Areas which are partially or wholly off gas grid are evident from the low or zero gas consumption. This is shown in greater detail based on postcode-level domestic gas consumption data[87] in Figure 33.

---

[82] **National Heat Map.** DECC, 2012. https://www.cse.org.uk/projects/view/1183. Accessed 21/3/2017.
[83] **OPRA.** Environment Agency, 2015. https://data.gov.uk/dataset/opra. Accessed 10/4/2017.
[84] **Emissions from NAEI large point sources.** National Atmospheric Emissions Inventory, 2014. http://naei.defra.gov.uk/data/map-large-source. Accessed 19/4/2017.
[85] **Participating in the EU ETS.** Department for Business, Energy & Industrial Strategy, 2016. https://www.gov.uk/guidance/participating-in-the-eu-ets. Accessed 4/4/2017.
[86] **Devon Waste Local Plan 2011 – 2031.** DCC, 2014. https://new.devon.gov.uk/planning/planning-policies/minerals-and-waste-policy/devon-waste-plan . Accessed 21/3/2017.
[87] **Postcode level gas estimates: 2015 (experimental).** BEIS, 2017. https://www.gov.uk/government/statistics/postcode-level-gas-estimates-2015-experimental. Accessed 24/4/2017.

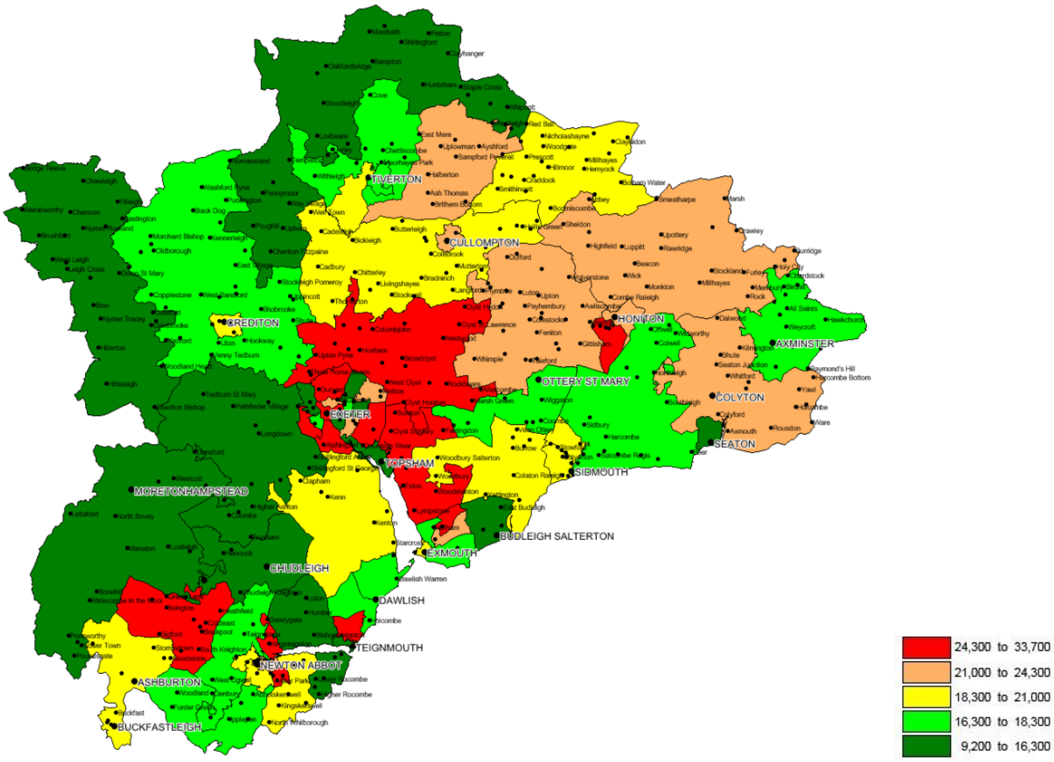

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Figure 29. Mean electricity consumption in each MSOA (in kW h per meter per annum).

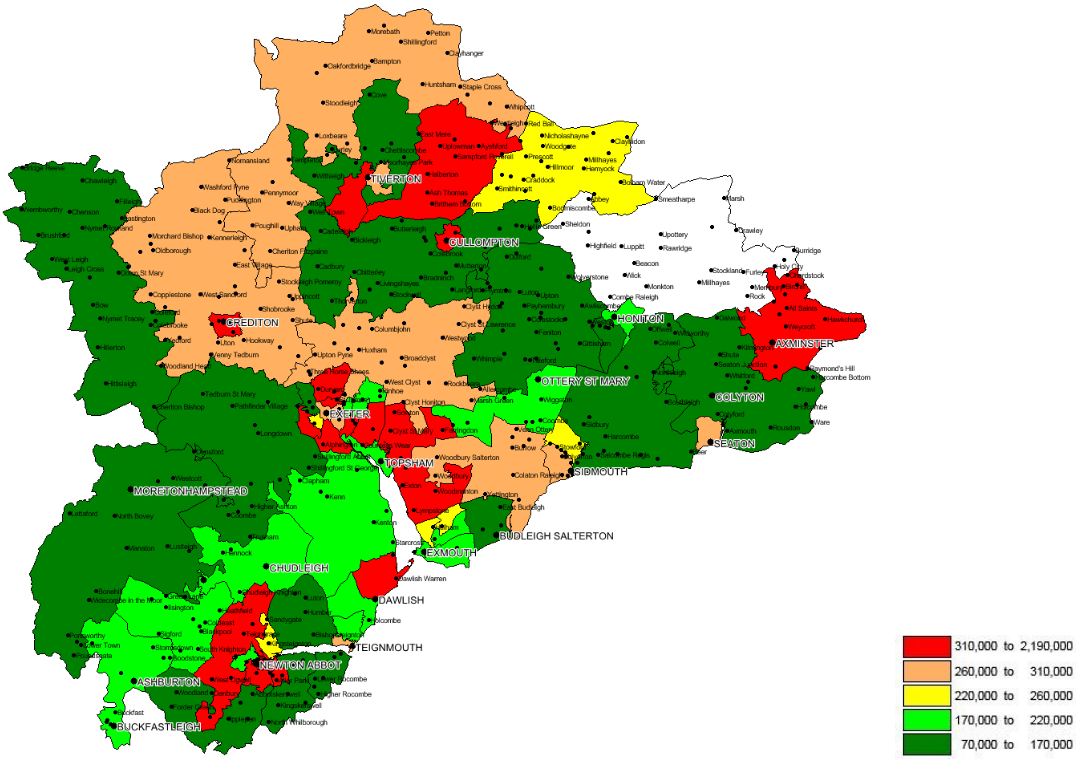

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Figure 30. Mean gas consumption in each MSOA (in kW h per meter per annum). No data are available for the MSOA centred on Rawridge; it is assumed that mains gas consumption is negligible in this rural area.

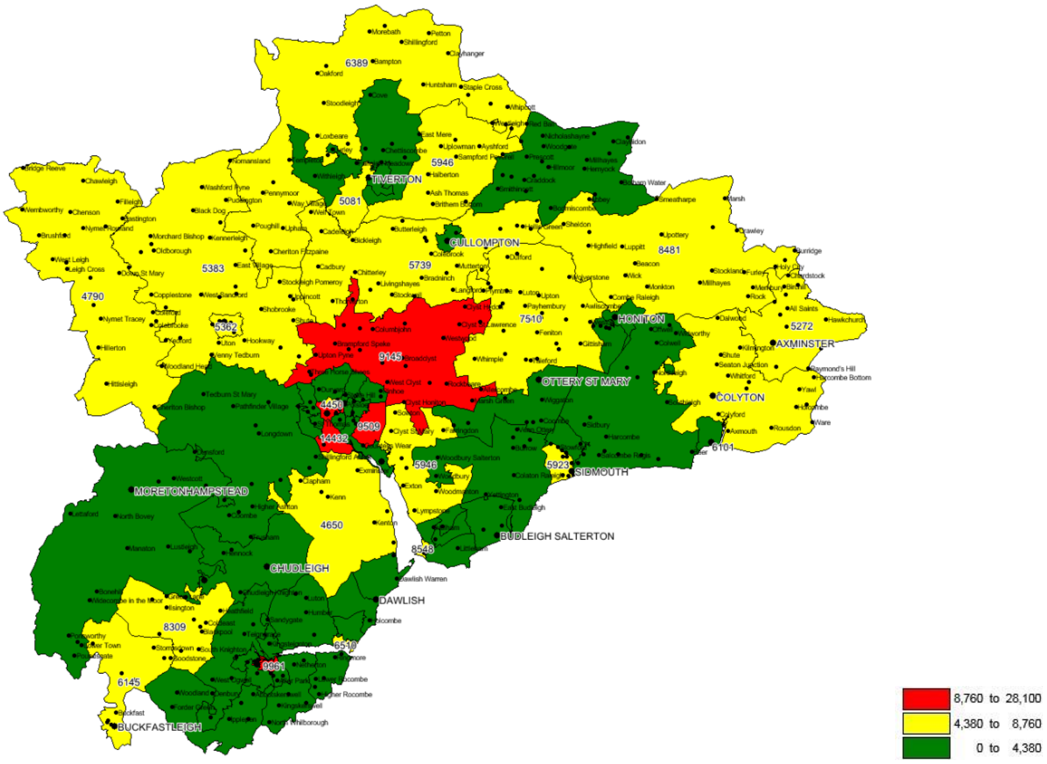

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Figure 31. Estimated electricity consumed by large consumers in each MSOA (in MW h per MSOA per annum). Consumption estimates are indicated numerically where they exceed the 4.38 GW h threshold.

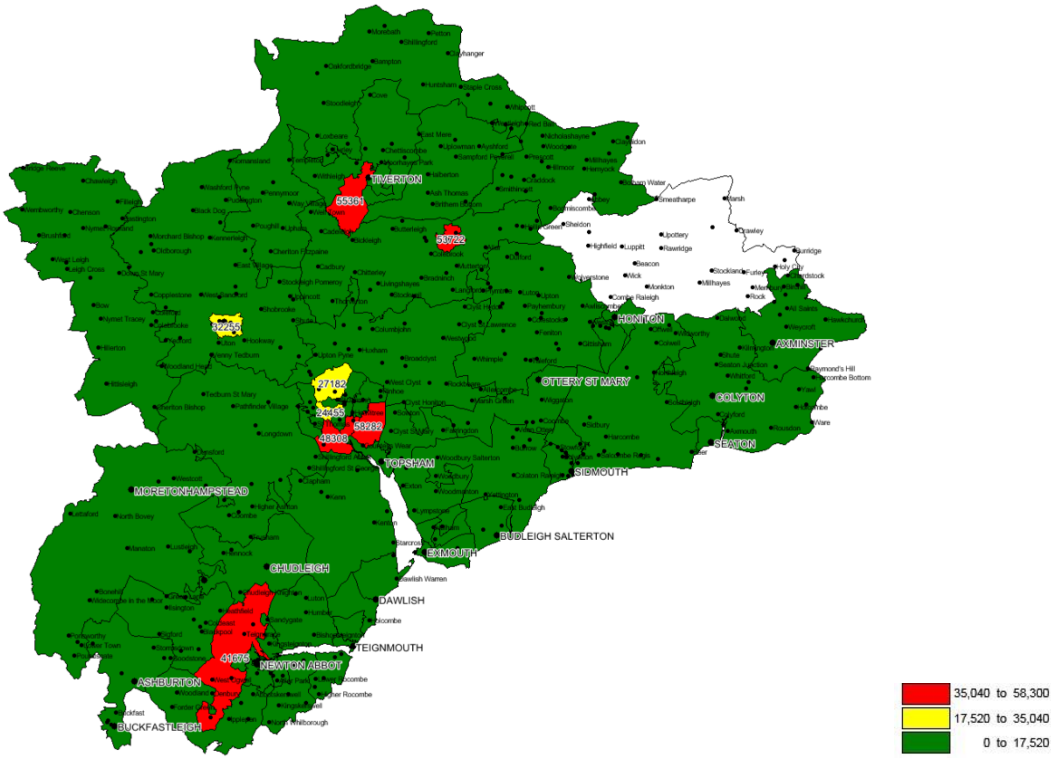

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Figure 32. Estimated gas consumed by large consumers in each MSOA (in MW h per MSOA per annum). Consumption estimates are indicated numerically where they exceed the 17.52 GW h threshold. No data are available for the MSOA centred on Rawridge; it is assumed that mains gas consumption is negligible in this rural area.

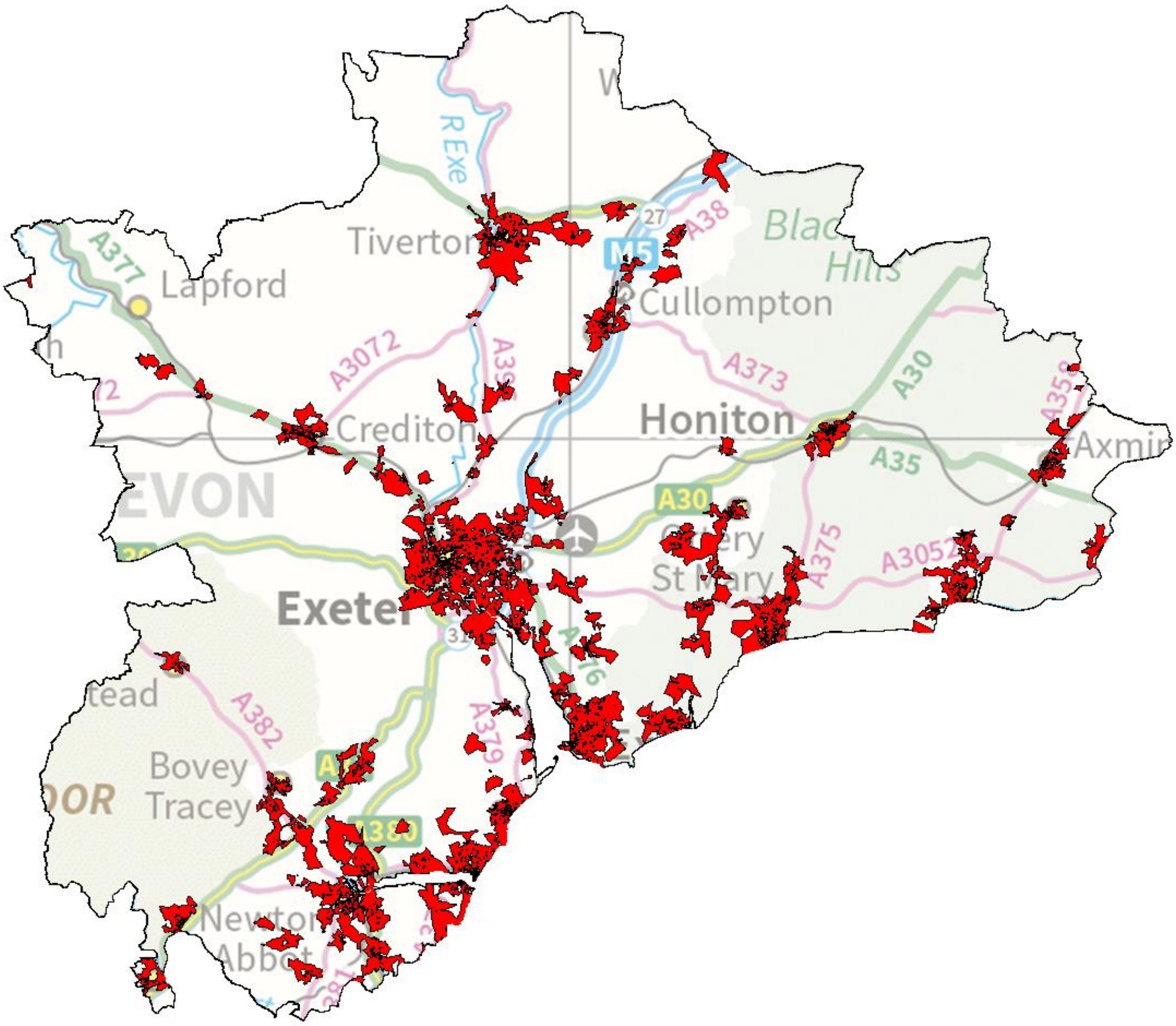


Figure 33. Extent of the mains gas network, based on postcodes containing at least one gas meter.

Examination of the areas indicating large consumers of electricity and gas has led to Table 25.

Table 25. List of identified large heat user Those in italics may not meet the minimum consumption criteria.

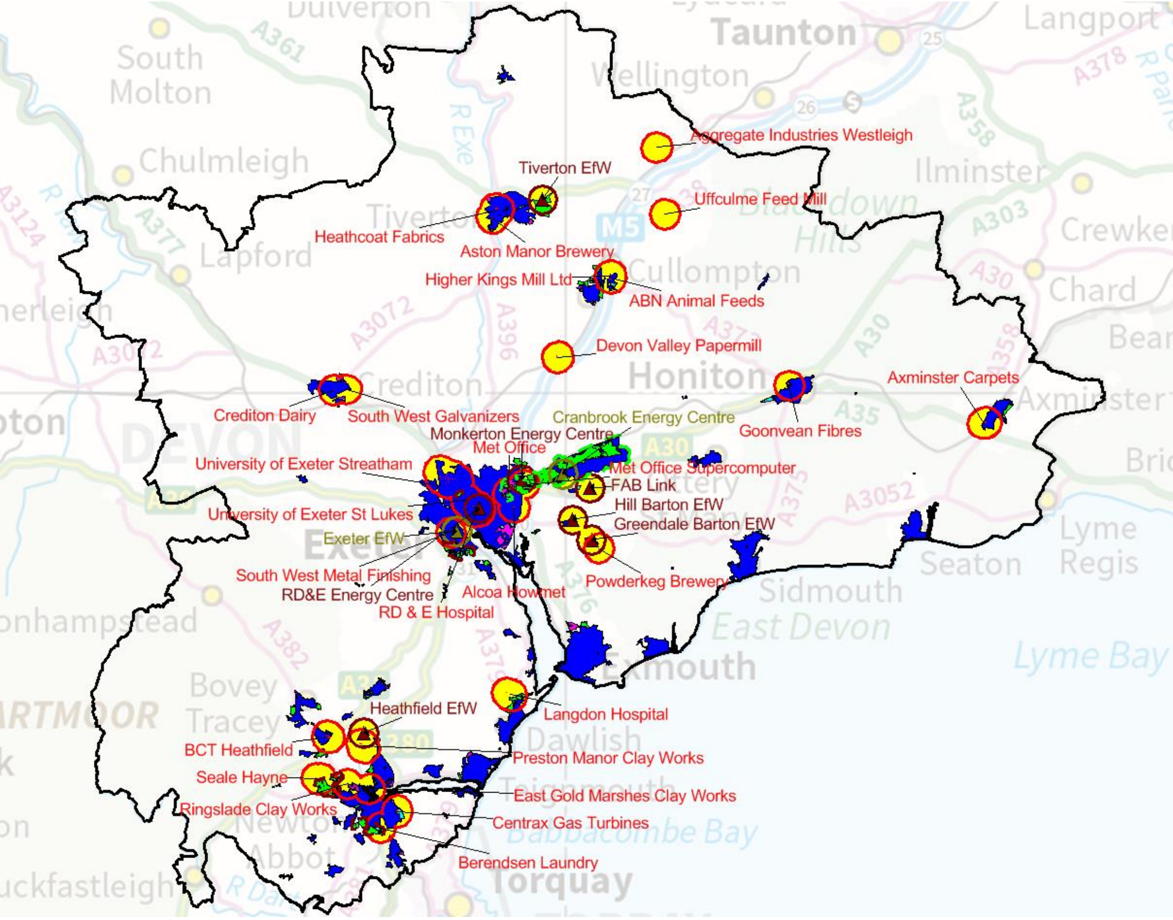
Site Name	**Location**	**MSOA Large Gas Estimate** (MW h p.a.)	**MSOA Large Electricity Estimate** (MW h p.a.)
Alcoa Howmet	Sowton	58,282	9,509[88]
Met Office			
Heathcoat Fabrics	Tiverton	55,361	5,081
Aston Manor Brewery			
Higher Kings Papermill	Cullompton	53,722	4,084
ABN Animal Feed			
RD&E Hospital	Wonford	49,101	1,473
SW Metal Finishing	Marsh Barton	48,308	14,432
Seale Hayne	Howton Barton	41,675	1,339
Ringslade Clay Works			
Preston Manor Clay Works			
East Gold Marshes Clay Works			
Crediton Dairy	Crediton	32,255	5,362
South West Galvanizers			
University of Exeter (Streatham)	Duryard	27,182	1,669
Berendsen Laundry	Newton Abbot	*15,636*	2,601
Axminster Carpets	Axminster	*9,153*	5,272
Aggregate Industries UK	Westleigh	8,654	5,946
Centrax Gas Turbines	*Newton Abbot*	*3,304*	*1,770*
Met Office Supercomputer (new)	*Monkerton*	*2,120*[89]	*9,145*[89]
Langdon Hospital	*Dawlish*	*2,118*	*2,863*
Powderkeg Brewery	*Greendale Barton*	*1,811*	*3,710*
British Ceramic Tile	*Heathfield*	*1,252*	*8,309*
Goonvean Fibres	*Honiton*	*927*	*4,135*
Uffculme Feed Mill	*Uffculme*	*530*	*4,098*
Devon Valley Mill	*Hele*	*447*	*5,739*

In Figure 34, the large users identified above and heat generation sites are overlaid onto local plan base maps showing areas allocated for development. Most notably, regions shaded yellow are within 1 km of identified heat loads or heat sources, but are not currently allocated for development.

---

[88] The actual value for Alcoa Howmet alone is likely to be considerably higher based on data previously provided by the business.

[89] The Met Office supercomputer is a new installation and is not reflected in the consumption estimates, which date from 2015.



▲	Existing heat source
🟨	1 km zone around existing heat source
▲	Potential heat source
🟨	1 km zone around potential heat source
🟥	Potential or existing non-domestic heat load
🟨	1 km zone around potential or existing non-domestic heat load
⬚	Existing district heating scheme
⬚	Planned district heating scheme
🟪	Area allocated for residential development
🟦	Area allocated for employment development
🟩	Area allocated for mixed development
🟦	Limit of existing and proposed built-up area
▨	Postcode containing gas supply (Figure 35 to Figure 44 only)

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Figure 34. Identified sites with heat loads or heat generation potential, with existing allocated areas for development.

Figure 35 to Figure 44 indicate individual areas in greater detail. Note the extent of the gas grid may be overestimated due to the size of postcode areas[90].

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[90] The data are mapped for individual postcodes, e.g. EX2 4SB.

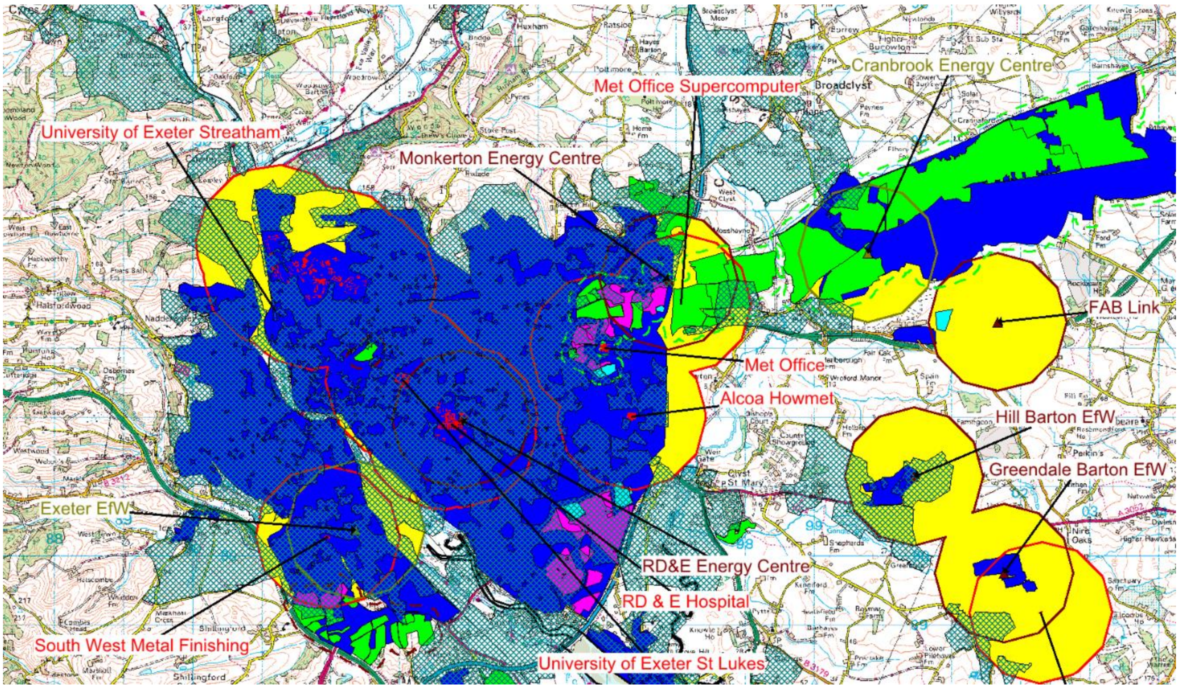

Figure 35. Identified sites with heat loads or heat generation potential in Exeter, with existing allocated areas for development (for legend see Figure 34).

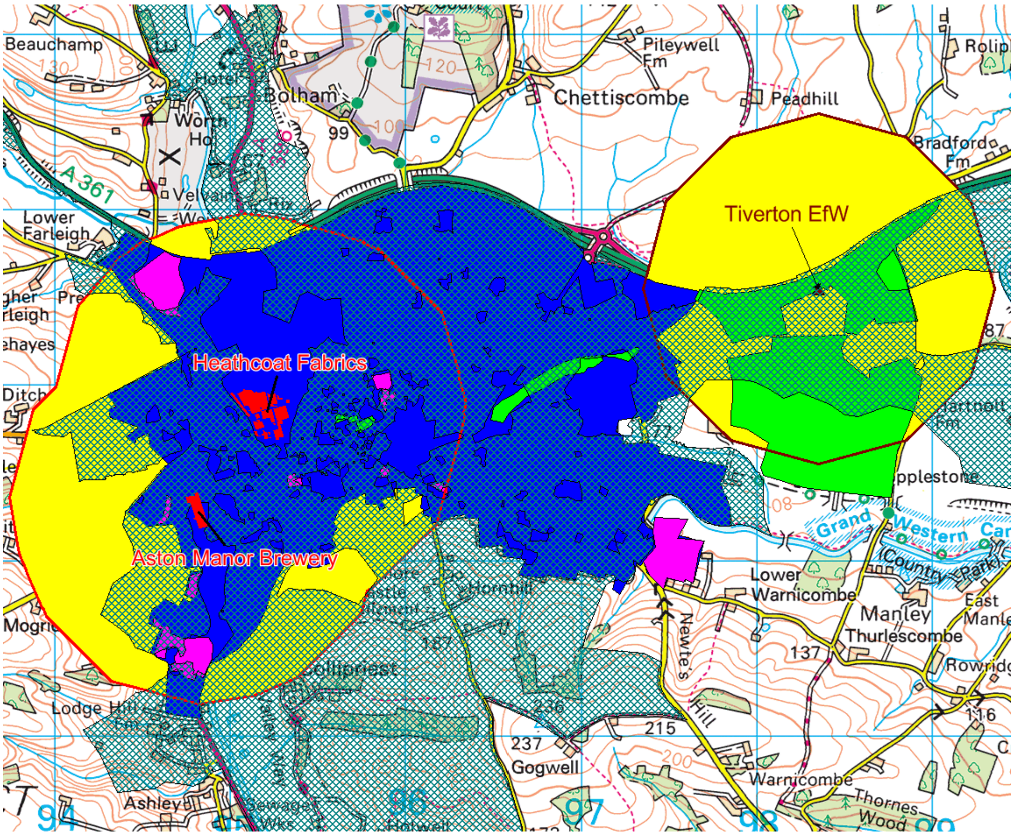

Figure 36. Identified sites with heat loads or heat generation potential in Tiverton, with existing allocated areas for development (for legend see Figure 34).

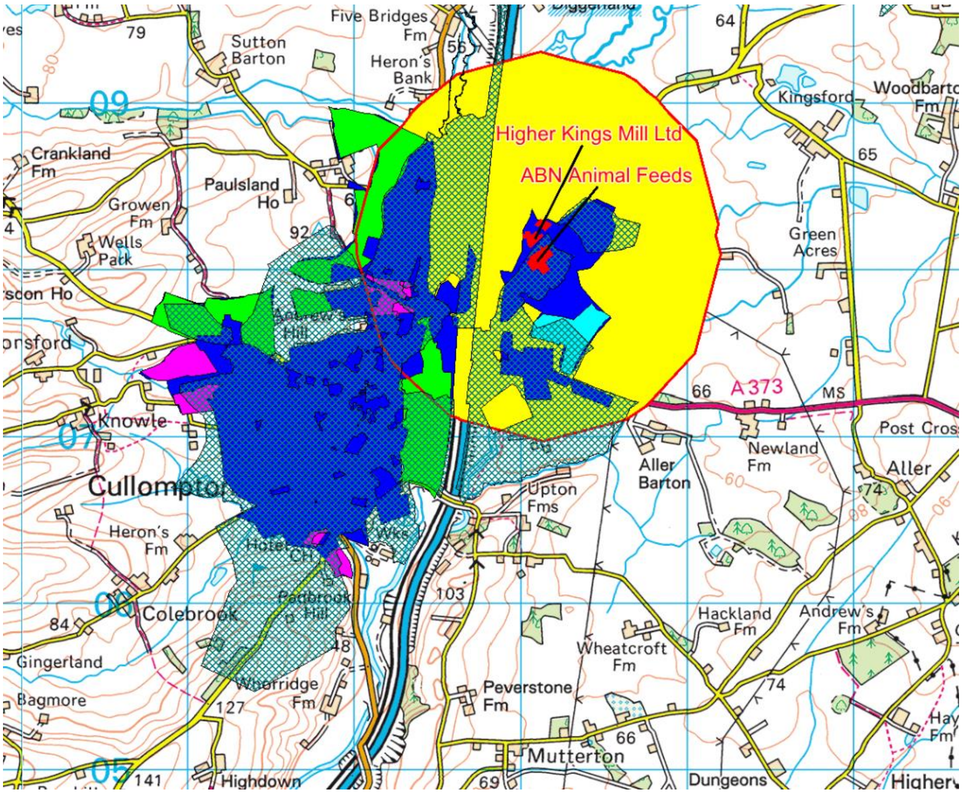

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Figure 37. Identified sites with heat loads or heat generation potential in Cullompton, with existing allocated areas for development (for legend see Figure 34).

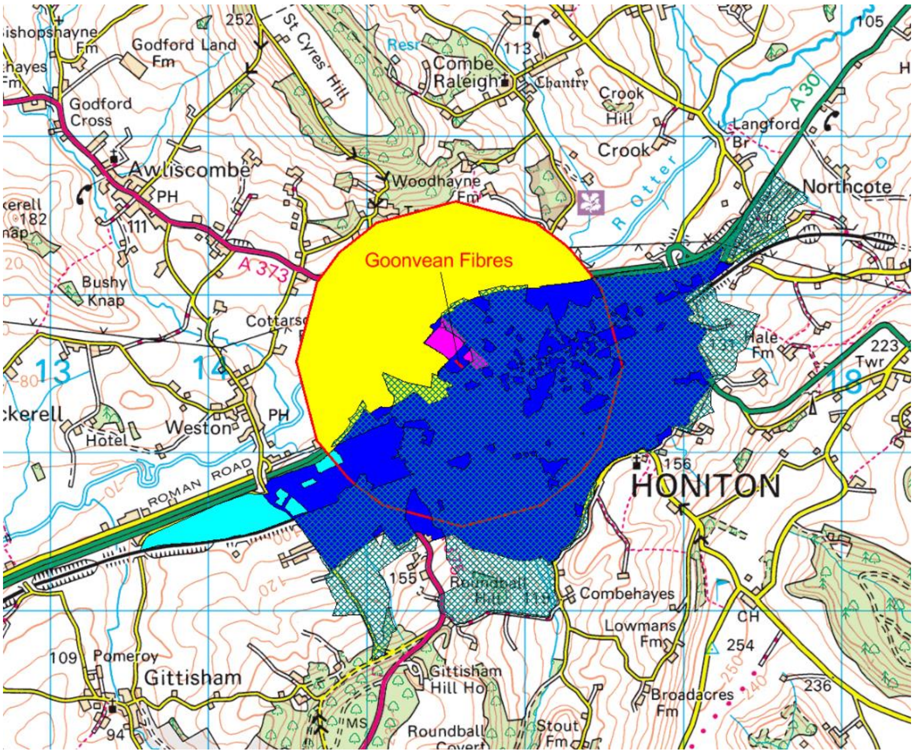

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Figure 38. Identified sites with heat loads or heat generation potential in Honiton, with existing allocated areas for development (for legend see Figure 34).

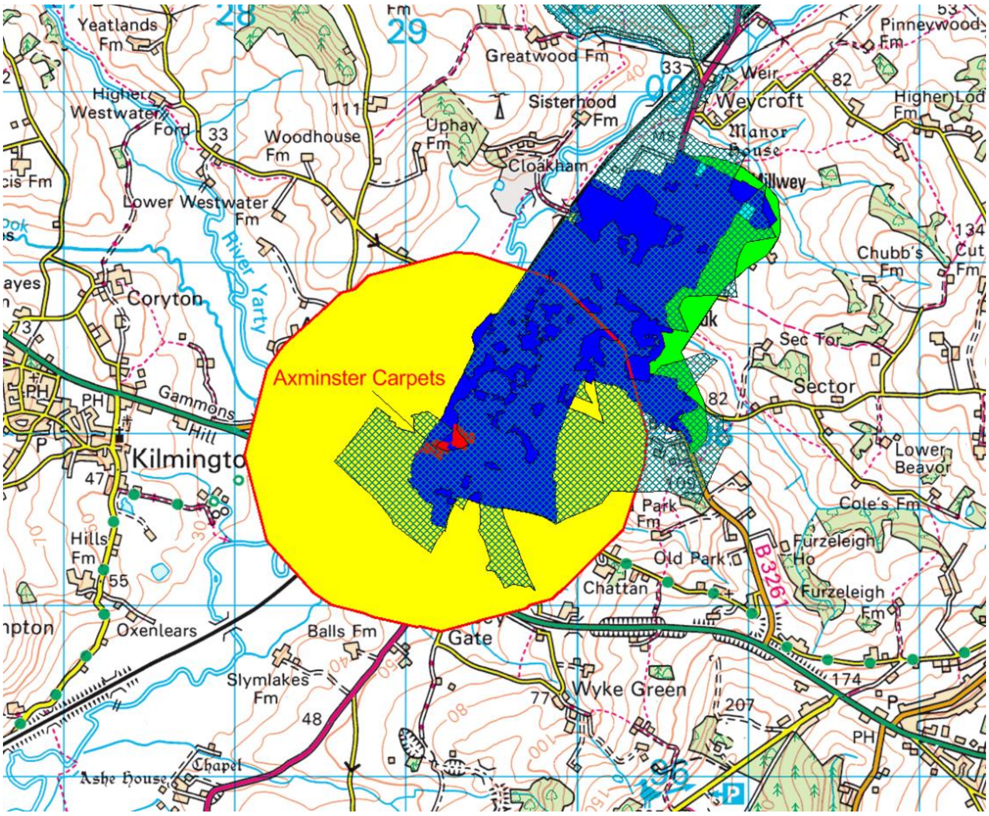

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Figure 39. Identified sites with heat loads or heat generation potential in Axminster, with existing allocated areas for development (for legend see Figure 34).

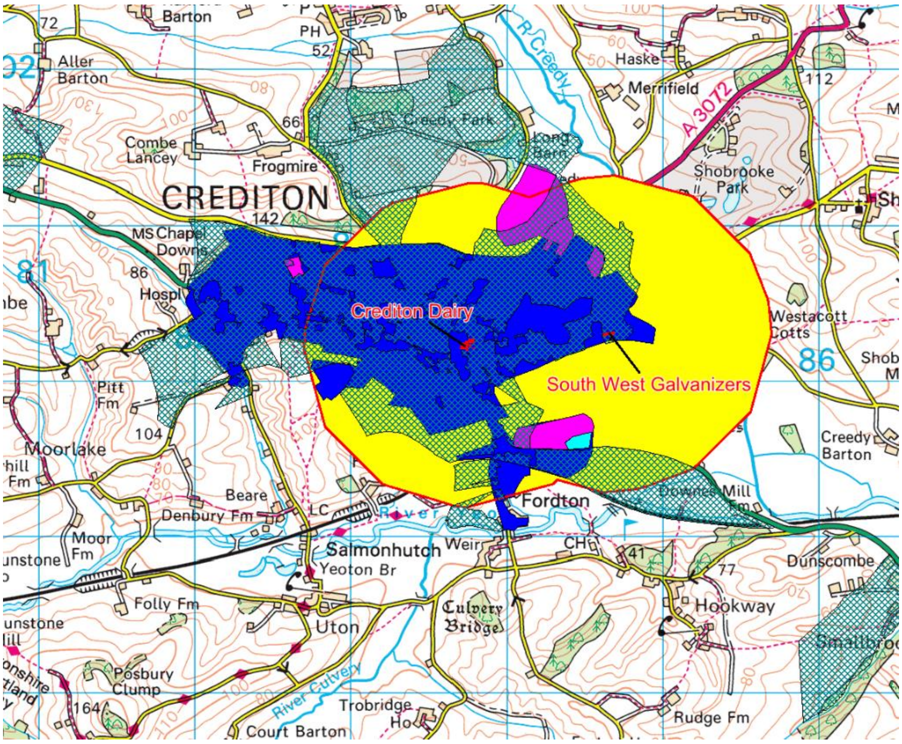

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Figure 40. Identified sites with heat loads or heat generation potential in Crediton, with existing allocated areas for development (for legend see Figure 34).

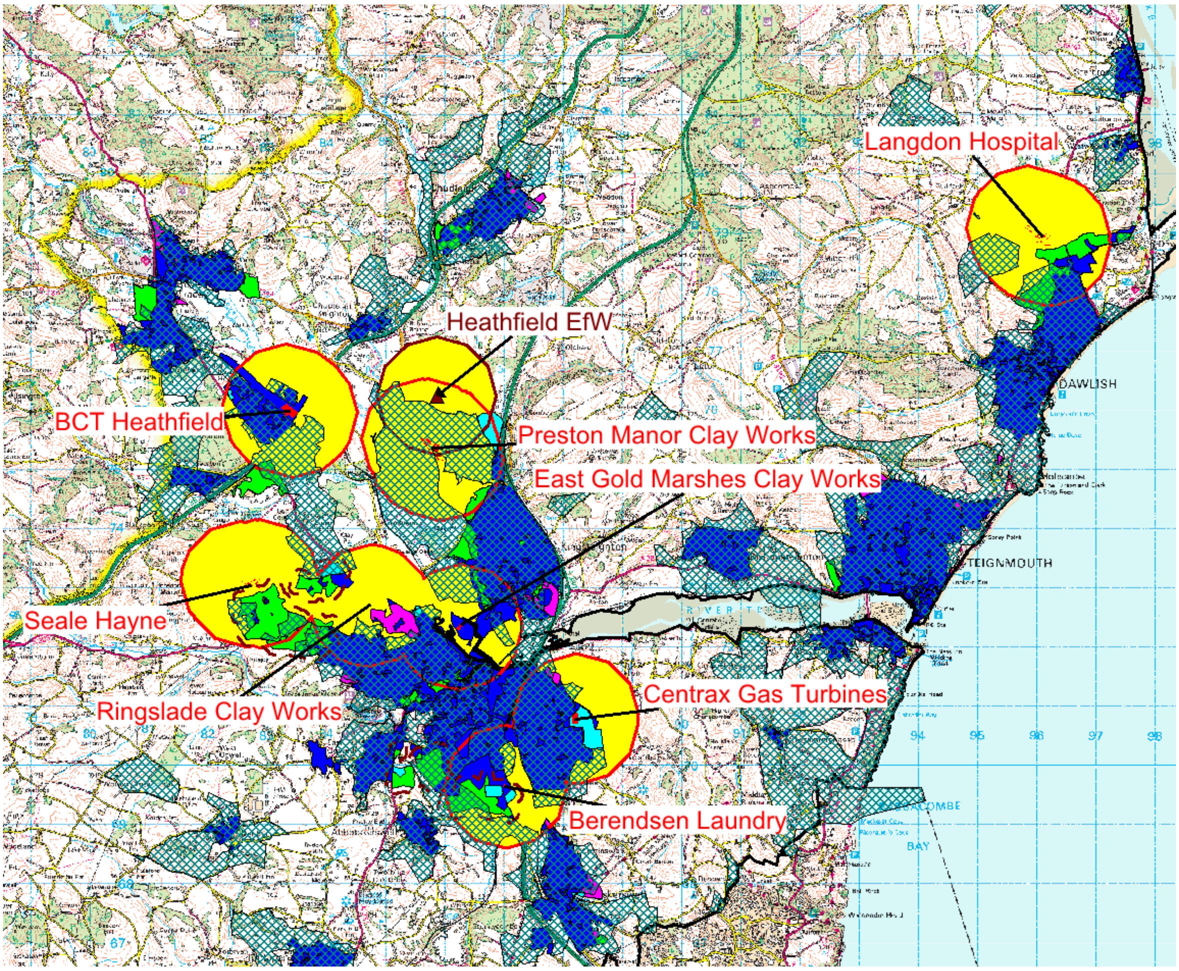

Figure 41. Identified sites with heat loads or heat generation potential in Newton Abbot and Dawlish, with existing allocated areas for development (for legend see Figure 34).

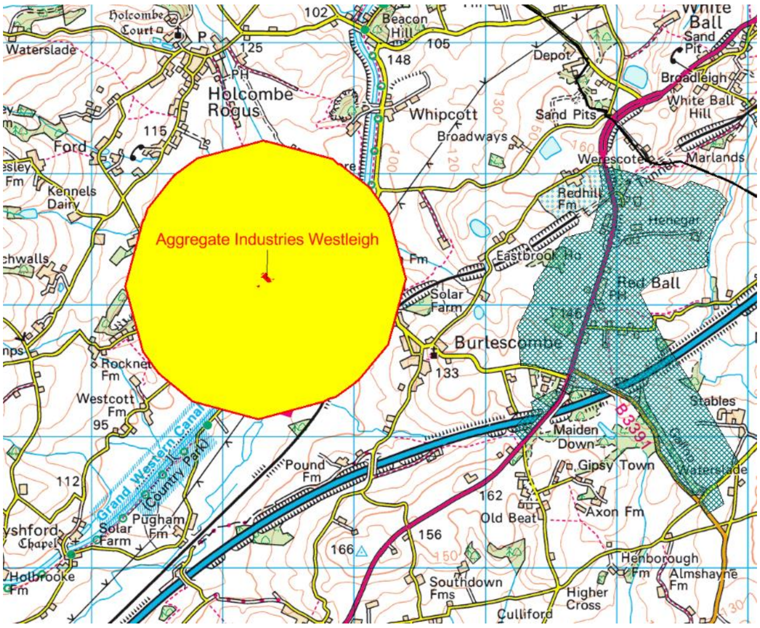

Figure 42. Identified sites with heat loads or heat generation potential north of Tiverton, with existing allocated areas for development (for legend see Figure 34).

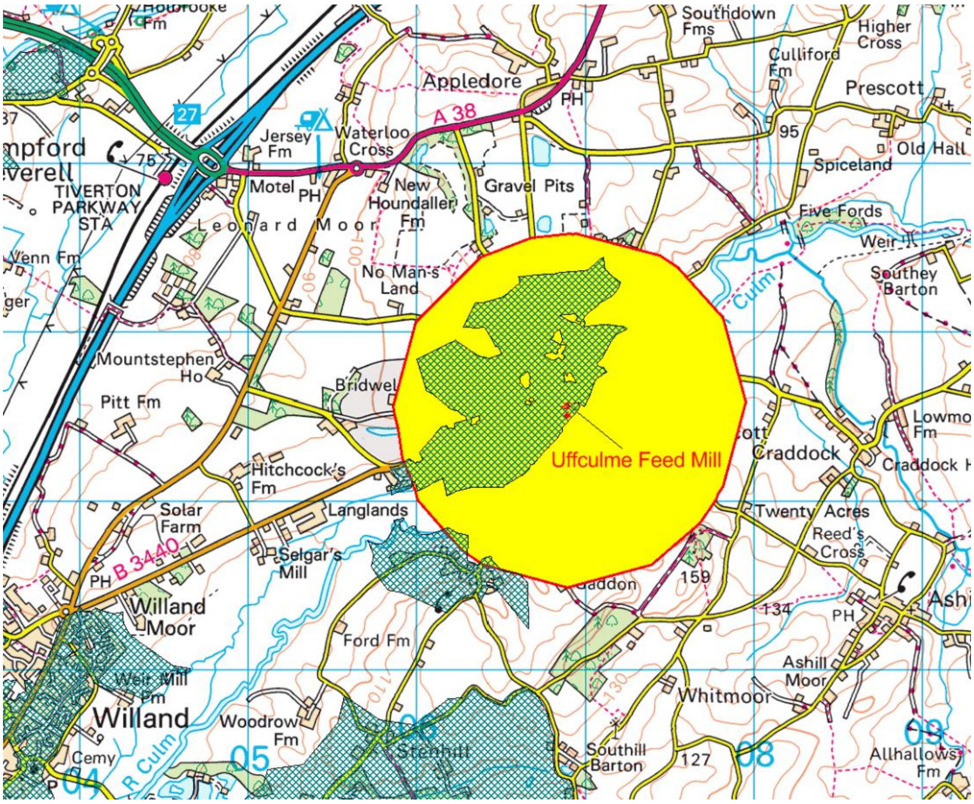

Figure 43. Identified sites with heat loads or heat generation potential in Uffculme, with existing allocated areas for development (for legend see Figure 34).

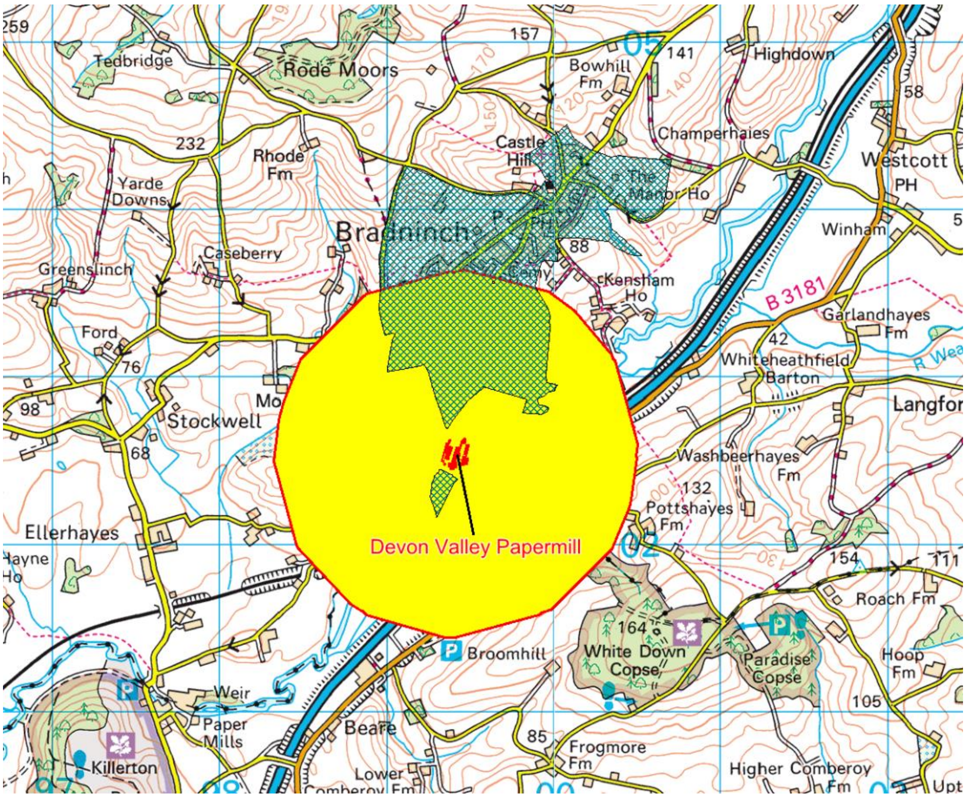

Figure 44. Identified sites with heat loads or heat generation potential in Hele and Bradninch, with existing allocated areas for development (for legend see Figure 34).

4. Conclusions

A number of potential heat sources and heat loads have been identified from planning policy reports, publically available energy consumption data and local knowledge. It is recommended that the results form part of the GESP development location discussions, and that the potential which local energy demand and supply present are discussed and evaluated in progressive levels of detail as the GESP is developed. It is important that this initial data is not used without further analysis, evaluation and interpretation.