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

CENTRE FOR ENERGY AND THE ENVIRONMENT

Internal Document 948

March 2018

Report Name:	Low Carbon and Climate Change Evidence Base for the Greater Exeter Strategic Plan
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Report Number:	Internal Document 948
Publication Date:	March 2018

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Rev. No.	*Comments*	*Approved By*	*Date*
0.15	Final incorporation of comments	A Norton	28/03/18
0.16	Minor text changes	A Norton	26/06/18
0.17	Corrections to Figures 13, 14, and 21 and Table 25	D Lash	20/07/18

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 which commits the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels 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.

Current emissions in the GESP area in 2014 were 2.8 $MtCO_2$ with emissions being split between the transport (38%), Industrial and Commercial (I&C) (35%) and domestic (27%) sectors. Emissions have in the main fallen year-on-year since 2005. Projections for carbon dioxide emissions in the GESP area show that a business-as-usual approach would result in emissions of almost 3 $MtCO_2$ in 2040. In order to be consistent with the national trajectory, carbon dioxide emissions in 2040 should be nearer 1.1 $MtCO_2$. It has been shown that there is currently a significant policy gap to meeting that target. If the target is achieved, it is estimated that emissions associated with new buildings constructed over the GESP period (but not including any associated transport) would account for approximately 16% of total carbon dioxide emissions in the GESP area.

An analysis of new residential development has shown that there is the potential to reduce emissions from new development if tougher standards could be set. If an overall carbon dioxide emission rate for the GESP of 1.1 $MtCO_2$ could be achieved in 2040, then setting an equivalent of CSH4 would result in a further 1.5% reduction in total emissions in the GESP area, whilst setting CHS5 would result in a 5.8% reduction in 2040. This assumes that the yet to be filled policy gap at a national level will not include such improvements to Part L, though given the high risk to achieving the required level of carbon reduction from national policy, improving beyond the minimum Part L thresholds represents a potentially important means of achieving carbon reduction in the GESP area. The analysis shows that it is more cost effective to achieve carbon reduction if offsite "allowable solutions" are allowed, though it is important to test whether those allowable solutions are capable of achieving the stated carbon reduction offset in the GESP area.

An analysis of new non-domestic development has shown that setting required improvements on Part L2A of the building regulations for non-residential buildings may not in fact deliver significant carbon reduction by the end of the GESP period. This is because developers working towards such a standard now (and hence what the analysis here has assumed) would likely make improvements to the electricity consumption of a building, whereas by 2040 the electricity is projected to be largely decarbonised. This is reflected in the resultant high effective cost per lifetime tCO_2 of carbon saved for non-domestic buildings. There may however still be benefits to reducing emissions beyond the Part L2A threshold for example reduced bills to occupants, and a reduced demand for new capacity and infrastructure on the supply side.

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 10ha 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 5ha 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 66 wind sites has been identified with potential capacity of 64 MWe and corresponding output of 157GWhe. The potential solar photovoltaic (PV) resource is an order of magnitude larger; potential capacity is up to 2,053MWe with corresponding output of

1,987 GWhe. 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 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 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 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.

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).

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 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 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.

A marginal abatement cost assessment has shown that the greatest potential for carbon reduction over the GESP period is bringing forward large scale PV. It is also amongst the lowest cost measures. Onshore wind is more expensive as exploiting the wind resource would require in the main smaller turbines which are less efficient and cost effective than larger ones. If homes could be constructed to higher energy standards, then these would need to all be at "Code" 5 or 6 to make a meaningful difference. Building to higher energy standards for non-domestic buildings will likely be expensive and not save much carbon, a finding which is strongly influenced by the assumption that improvements would be made to electricity demand which would become worth less over time as the carbon intensity of the national electricity grid decreases. If an allowable solutions mechanism could be introduced, then both the potential abatement cost could decrease and the amount of carbon saved increase. However, care would need to be taken that any allowable solutions would achieve the stated amount of carbon reduction both in practice, and in the locality.

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%.

It is important that the GESP includes policy to ensure that development can accommodate changes already locked into the climate system. It is estimated that over the period to 2040 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.

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) with each chapter of this report describing the methods deployed, and outcomes.

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

This 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.

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), 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 95 states that *"to support the move to a low carbon future, local planning authorities should…plan for new development in locations and ways which reduce greenhouse gas emissions"*. In addition Section 4 of the NPPF (Promoting Sustainable Transport) contains a range of measures to address sustainable transport, including *"plans and decisions should ensure developments that generate significant movement are located where the need to travel will be minimised and the use of sustainable transport modes can be maximised"*.

Previous work[1] 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:

[1] SWEEG Scientist's Report 145 2013, "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.

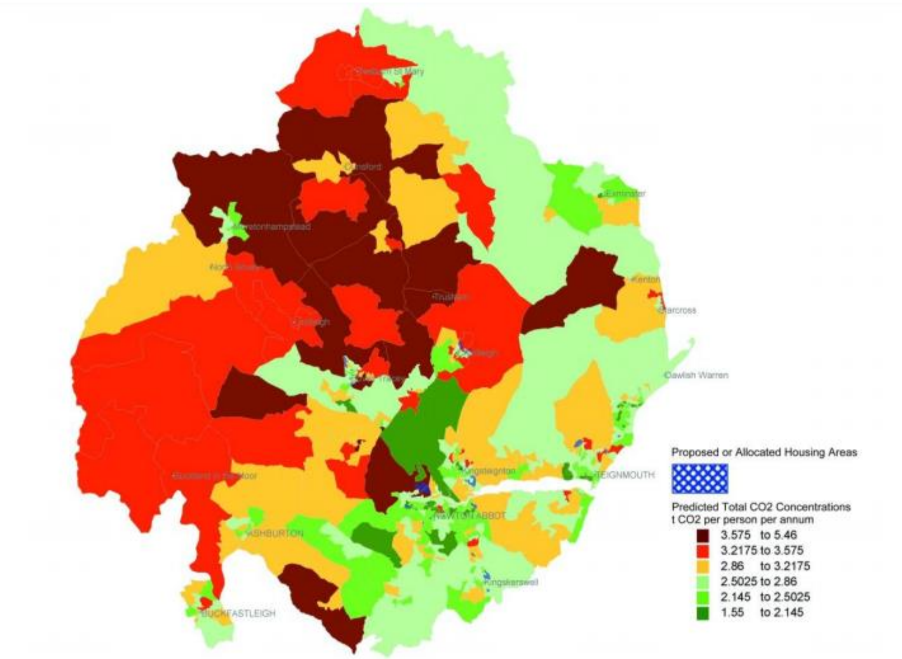

Figure 1: Emissions per person for an 80 m^2 dwelling at 11 $kgCO_2/m^2$ regulated emissions and a range of sustainable transport measures applied from previous work undertaken by the CEE for Teignbridge District Council

2.3.2 Site Masterplanning

The NPPF paragraph 96 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[2] 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[3], where the Pre-Submission Draft contains policy DEV34.4 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. For major developments, a solar master plan should show how solar gain 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[4]. 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[5].

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 lock in demand reduction measures that could persist for decades. Consideration should therefore

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

[3] Plymouth and South West Devon Joint Local Plan 2014 – 2034 Pre-submission March 2017 version http://web.plymouth.gov.uk/reduced_jlp_with_covers.pdf

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

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

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[6] which is also referenced in the UK Government's Clean Growth Strategy[7] aims to link energy bills to mortgage affordability[8] 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 96 states:

To help increase the use and supply of renewable and low carbon energy, local planning authorities should recognise the responsibility on all communities to contribute to energy generation from renewable or low carbon sources. They 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;*
- *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 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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[6] 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

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

[8] 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[9] 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[10] 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.

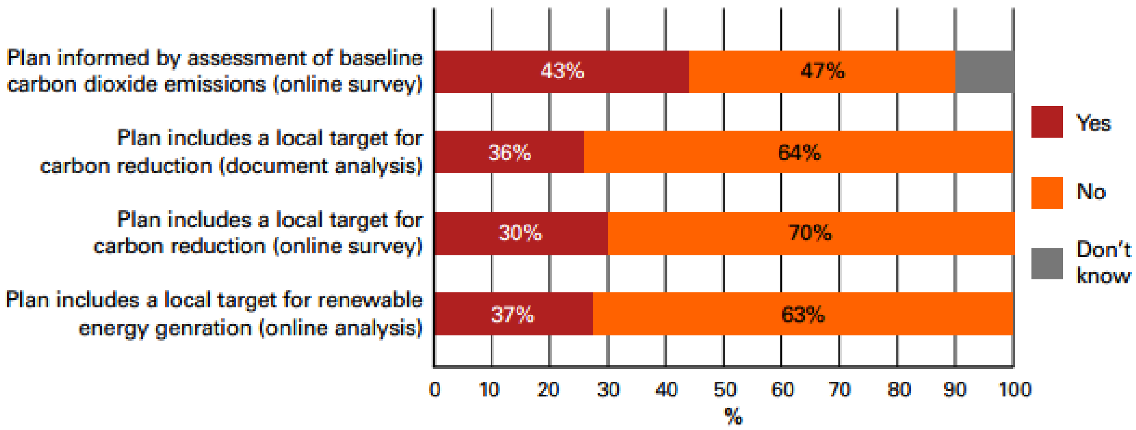

Figure 2: Climate change mitigation policies within Local Plans as studied via surveys and document analyses (Source: JRF 2016)

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

[10] 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

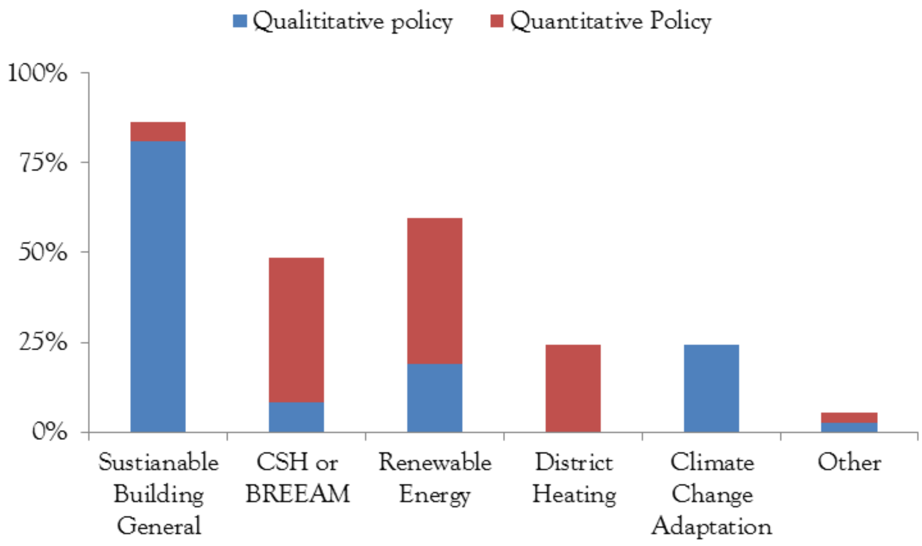

Figure 3: Climate change mitigation and adaptation policies within Local Plans in LPAs in the South West of England

The Housing Standards Review[11] estimated the additional cost of achieving the "Merton Rule" for various dwelling sizes (Table 1). These extra-over costs are an uplift from the 2010 version of Part L and so the cost of improving on the 2013 version of Part L should be lower (as Part L 2013 required a 6% improvement in carbon compared to the 2010 version and so a 10% reduction on this would require less LZC capacity – in addition technology costs over the intervening period (and beyond it) have fallen). For example, the median cost[12] of a small PV system (0 – 4 kW) was £1,949/kW in 2014 – 2015 and £1,692/kW in 2016 – 2017.

Table 1: Extra over cost, per dwelling, of achieving the "Merton Rule" compared to a Part L 2010 baseline

Dwelling Type	10% Merton Rule	20% Merton Rule
2 bed apartment	£1,560	£3,120
2 bed house	£1,400	£2,800
3 bed house	£1,850	£3,608
4 bed house	£2,400	£4,600

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*

[11] DCLG 2013 Housing Standards Review Consultation: Impact Assessment
[12] https://www.gov.uk/government/statistics/solar-pv-cost-data

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 draft Plymouth Plan (which is geographically adjacent to the GESP) includes "delivering carbon reductions through off-site measures" within the energy hierarchy. The National Energy Foundation has undertaken a thorough review[13] 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, 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[14]. 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

[13] National Energy Foundation 2016, Review of Carbon Offsetting Approaches in London
[14] 2015, Statutory Instrument 595 Town and Country Planning, England

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 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[15] 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 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[16] 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[17] or to achieve specific credits within BREEAM such as "Man 01 Project Brief and Design", "Man 04 Commissioning and Handover" and "Man 05 Aftercare".

[15] https://www.designingbuildings.co.uk/wiki/Performance_gap_between_building_design_and_operation
[16] https://www.homequalitymark.com/what-is-the-hqm
[17] https://www.bsria.co.uk/services/design/soft-landings/

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[1].

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 building to the standard incurs significant additional cost for developers. There is currently uncertainty[18] 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

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

Government will clarify various WMS, after which it is expected there will be some form of revision to the National Planning Policy Framework (NPPF), a draft of which is expected in March 2018. It remains unclear when/if revision/clarification of this element of Government policy will happen. Most recently, the Clean Growth Strategy has indicated the intent of the Government to consult on improving the energy efficiency of new homes. 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[19]. That 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 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:

- 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 1,800 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 is going 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 planned 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 planned 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"[20] shows that there is

[19] Element Energy 2008, East of Exeter Growth Point: Energy Strategy
[20] CEE, 2017, Heat Network Strategies for the West End of East Devon

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 and estimates the carbon emissions reduction from a concentrated or dispersed GESP development model.

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[21, 22, 23].

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

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

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

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

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[24] funding will provide finance at rates between these examples.

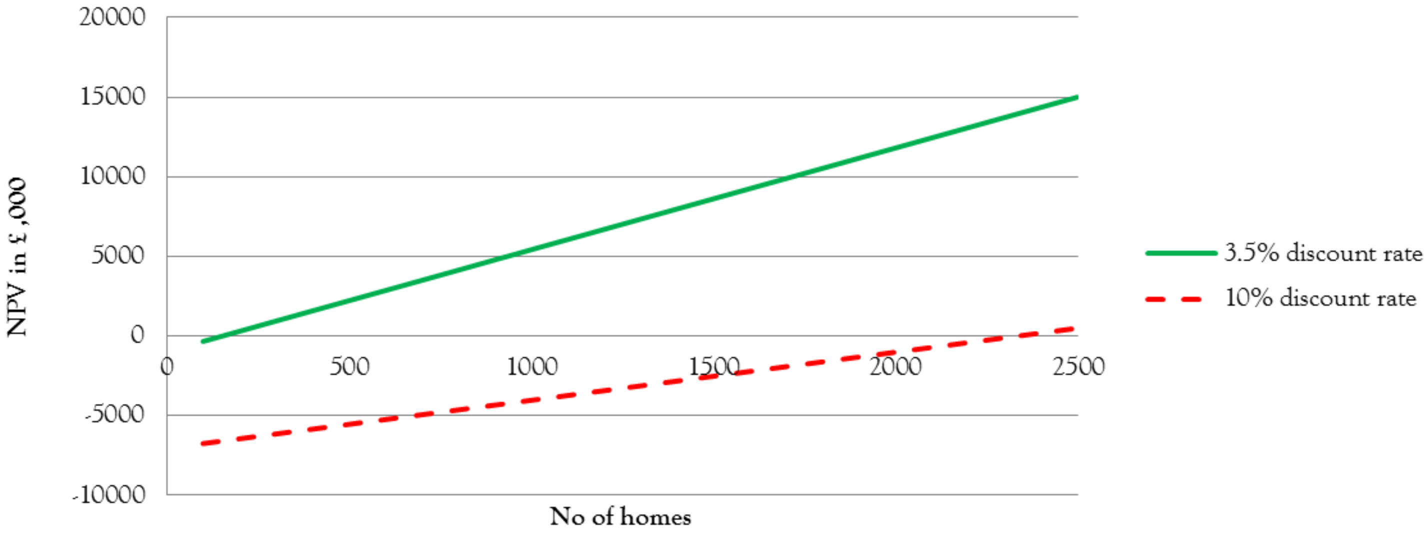

Figure 4: Results from the heat network viability calculator

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.

[24] 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

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

Greenhouse gases (GHG) from human activities are the most significant driver of observed climate change since the mid-20th century. There are a number of GHGs, the most significant of these being carbon dioxide. The performance of the UK against the carbon budgets established through the Climate Change Act is assessed by the Committee on Climate Change (CCC) who produce annual progress reports across a number of sectors. The most recently available report when this project commenced was published in the summer of 2016[25]. From that report, carbon dioxide emissions are responsible for about 85% of total UK GHG emissions with a further 8% from agriculture (mainly methane and nitrous oxide), waste at 4% (mainly methane) and F-gases at 3% (mainly from refrigeration). As existing agricultural practices would not be strongly influenced by local planning policy, waste sites being already considered in this study as a potential source of energy (e.g. via combined heat and power and district heating [see Section 5]), and the regulations for F-gases being set elsewhere, the scope of the analysis was taken to be carbon dioxide only. In addition, given the uncertainty in predicting future emissions, and the difficulty in measuring and reporting methane and nitrous oxide this added further incentive to consider carbon dioxide only. Finally, carbon dioxide emissions at district level are reported annually by government across three main sectors, namely Industrial and Commercial (I&C), Domestic and Transport. Similarly, Land Use, Land Use Change and Forestry (LULUCF) was excluded from consideration as it was responsible for only 0.4% of total emissions across the three districts in 2014.

Carbon dioxide data was taken from the statistics published by central government *"UK local authority and regional carbon dioxide emissions national statistics: 2005-2014"* dataset[26]. The geographical scope of the study was taken to be the entirety of East Devon, Exeter, Mid Devon and Teignbridge districts, i.e. including the area of Dartmoor that falls within these districts. This was due to the data being available at no finer than district resolution meaning that separating Dartmoor would require additional estimation – both for baselining and future monitoring purposes; this was not deemed worthwhile given the relatively small proportion of overall emissions that would arise from within the National Park. The period of analysis was taken to be 2005 to 2040.

In order to estimate the projected change in carbon dioxide emissions across the study area, the trajectory for emissions reported by the CCC in their progress report was analysed. This report considered the impact of a range of policy measures across the power sector, buildings, industry and

[25] Meeting Carbon Budgets – 2016 Progress Report to Parliament, Committee on Climate Change, June 2016

[26] https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2014

transport[27]. The CCC present carbon dioxide trajectories resulting from a range of policies, which they classified as either "lower risk", "at-risk", and the resulting "policy gap" in order for the UK's carbon budget targets under the Climate Change Act to be met. These trajectories extend to 2032. The period required for consideration within the GESP is to 2040, and so in the absence of any other data the CCC trajectories were extrapolated to 2040 at the average annual rate required to meet the UK's long term target of an 80% reduction in 1990 GHG levels by 2050.

The policies reported at a national level were in general directly apportioned to emissions in the local area based on metrics such as percentage change. The local carbon dioxide data aggregates the industrial and commercial sectors. These were separated by apportioning these emissions based on national splits of fuel use. Emissions projections for Buildings (which included domestic and non-domestic), and Industry were directly applied to the local carbon dioxide data. The projections for the power sector were applied to each sector based on the electricity demand from each of these sectors. Transport emissions were adjusted based on expected population changes locally compared to nationally.

The proportion of projected carbon emissions in the GESP area attributable to new residential development was established by undertaking a series of calculations:

- A "typical" new dwelling for the GESP area was established based on previous analysis undertaken in the West End of East Devon, which analysed proposed housing developments in that locality. An average dwelling was 88.2 m^2 and weighted by area based on 40% detached, 40% semi-detached, 13% terraced and 7% apartment from a sample of 354 dwellings.
- The projection for dwellings in the GESP area to 2040 was established based on a combined assumption of committed and already allocated housing projections plus an indicative GESP housing trajectory.
- The energy demand of a new dwelling built to the current Building Regulations (Part L 2013) was estimated based on Standard Assessment Procedure (SAP) calculations. This was split into heating demand, electrical demand, electricity generation, and therefore net electricity demand.
- Further energy performance specifications were developed. These were:
    - Code Level 4 Energy: Taken as being similar to a Part L 2013, but with an uprated building fabric, meaning that the improvement to achieve compliance was entirely by reducing heating energy consumption.
    - Code Level 5 Energy all onsite: Assumed to be similar specification to Code Level 4, but with a ground source heat pump (assumed coefficient of performance 2.2) and additional PV.
    - Code Level 5 Energy with allowable solutions: As Code 4 with additional PV, then "Allowable Solutions" as originally proposed by the Zero Carbon Hub, namely at £60/tCO_2 for a period of 30 years.
    - Code Level 6 Energy all onsite: Based on a much enhanced building fabric, PV and biomass boiler.
    - Code Level 6 Energy with allowable solutions: As Code 4 specification, but with additional allowable solutions

[27] In addition to this, the CCC report covered Agriculture, Land Use Change, Waste, and F-gases. As was previously discussed the focus of the report here is on carbon dioxide only, and for the three main sectors for which carbon dioxide data is available for at a local resolution.

- Note: The analysis undertaken has aimed to quantify the potential carbon reduction from setting standards that are in advance of the current building regulations (Part L 2013). Implicit in this is that national standards are not amended (improved) over time. The EU Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy by the end of 2020[28]. However, there is currently uncertainty as to how this will be applied in the UK.

- These specifications were based on two sources; the Impact Assessment from the Housing Standards Review[29] for the three onsite specifications, and the Zero Carbon Hub[30] for the two with allowable solutions. In both cases, the outputs were applied to a typical GESP dwelling. All costs were inflated to current prices based on the CPI index[31] and are shown in Table 2.

Table 2: Additional costs for various potential residential energy standards (note: allowable solutions costed at £60 per tonne for 30 years)

Standard	Per dwelling Cost over Part L 2013	Per square metre Cost over Part L 2013
Part L1A 2013	£ -	£-
Code level 4 energy	£ 1,588	£18
Code level 5 energy all onsite	£ 11,027	£125
Code level 5 energy with allowable solutions	£ 5,138	£58
Code level 6 energy all onsite	£ 21,451	£243
Code level 6 energy with allowable solutions	£ 8,490	£96

Estimation of emissions from non-residential development followed a similar format. It was assumed that the current 2013 Part L2A represented the business as usual scenario. A number of additional scenarios were developed which comprised:

- A 10% improvement on Part L.
- A 20% improvement on Part L.
- A 20% improvement on Part L + allowable solutions to offset balance of regulated emissions.
- A 20% improvement on Part L + allowable solutions for regulated and unregulated emissions.

In order to estimate the energy demand from each of these scenarios, simplified models of planning Class B1, B2 and B8 buildings were modelled in the Simplified Building Energy Model (SBEM) – the tool used to demonstrate compliance with Part L2A of the Building Regulations – with two variants of B1 to represent deep plan and shallow plan offices. The SBEM modelling was used to estimate energy demand for various end uses. It was assumed the office buildings were electrically heated using heat pumps and the warehouse spaces with gas boilers. Total energy demand in the GESP area was based on projected floor areas of each of B1, B2 and B8 development in the area across the period. The B1 space was apportioned into deep plan and shallow plan using the same weighting assumed in the modelling within the impact assessment for Part L 2013. Carbon emissions over the GESP period were estimated based on national projections for energy carbon intensity. The costs of

[28] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/nearly-zero-energy-buildings
[29] Housing Standards Review 2013, Impact Assessment
[30] Zero Carbon Hub 2014, Cost Analysis: Meeting the Zero Carbon Standard
[31] https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/l522/mm23

improving on Part L by 10 and 20% were estimated (Table 3) based on the impact assessment from the 2013 changes to the building regulations which presented cost uplifts (£/m^2) for different building typologies (deep plan air conditioned office, shallow plan air conditioned office, and distribution warehouse). The additional cost of allowable solutions was based on offsetting at a rate of £60 per tonne for a period of 30 years.

Table 3: Additional per square metre costs for % uplift on Part L 2010

Improvement	Shallow Plan AC Office	Deep Plan AC Office	Distribution Warehouse
10% over Part L 2013	£11	£12	£12
20% over Part L 2013	£24	£31	£26

4.3 Work Package Outputs

4.3.1 Historic and Current Carbon Dioxide Emissions

Analysis of local carbon dioxide emission data shows that across the GESP area in 2014 total emissions were approximately 2.8 $MtCO_2$ (Table 4 and Figure 5). Emissions from the industry and commercial (I&C) and transport sectors were of a similar magnitude (35% and 38% of total respectively), with domestic emissions marginally lower (27% of total). Total emissions were higher in East Devon and Teignbridge (each about 30% of total) compared to Exeter and Mid Devon (each about 20%).

Table 4: Total emissions in 2014 for each of the four districts and the combined value in $ktCO_2$ with % of the combined total in brackets

	I&C	Domestic	Transport	Total
East Devon	252 (9%)	245 (9%)	324 (12%)	821 (29%)
Exeter	275 (10%)	166 (6%)	104 (4%)	544 (19%)
Mid Devon	193 (7%)	135 (5%)	266 (9%)	594 (21%)
Teignbridge	261 (9%)	216 (8%)	372 (13%)	849 (30%)
GESP Total	***981 (35%)***	***762 (27%)***	***1,065 (38%)***	***2,808 (100%)***

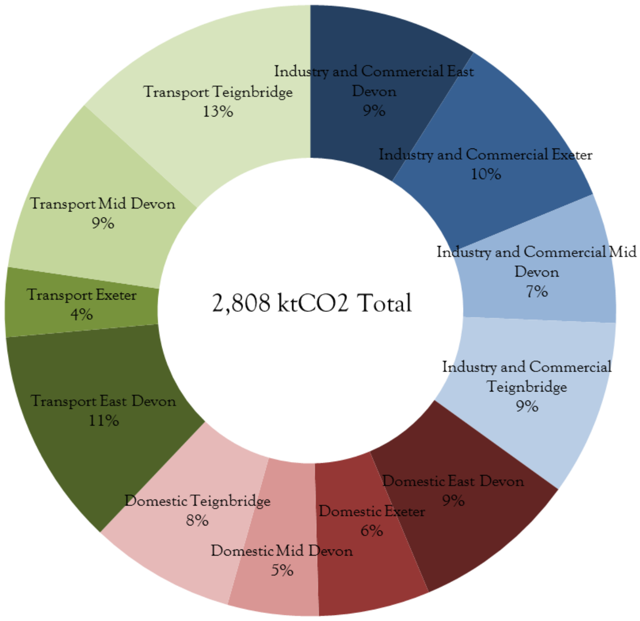

Figure 5: Split of carbon dioxide emissions in 2014 across the GESP area for each of the three broad sectors

Emissions have fallen year-on year both in absolute terms (Figure 6) and per capita (Figure 7) with the values in the GESP being similar to the South West region as a whole. Compared to the UK, emissions from the I&C sector are lower in the GESP area as there is less heavy industry than in other parts of the country.

Whilst total emissions are highest in East Devon and Teignbridge, per capita emissions are highest in Mid Devon and Teignbridge. Total emissions are highest in East Devon primarily as a result of the higher population, whilst per capita emissions are highest in Mid Devon primarily as a result of a dividing emissions from the I&C sector over a smaller population (Mid Devon's population is much smaller than the other three GESP authority areas) and higher transportation emissions. Exeter consistently has the lowest total and per capita emissions primarily driven by lower transport emissions (shorter distances to travel and more sustainable options).

The trend in carbon reduction in the GESP area compared to the UK has been similar for the domestic and transport sectors, though emissions have not fallen as rapidly in the power and I&C sectors locally (Figure 8). It should be noted that the local data in the domestic and I&C sectors fluctuates more than the national trend as the local data has not been weather corrected, for example in cold years like 2010 there was a peak in the local emissions data.

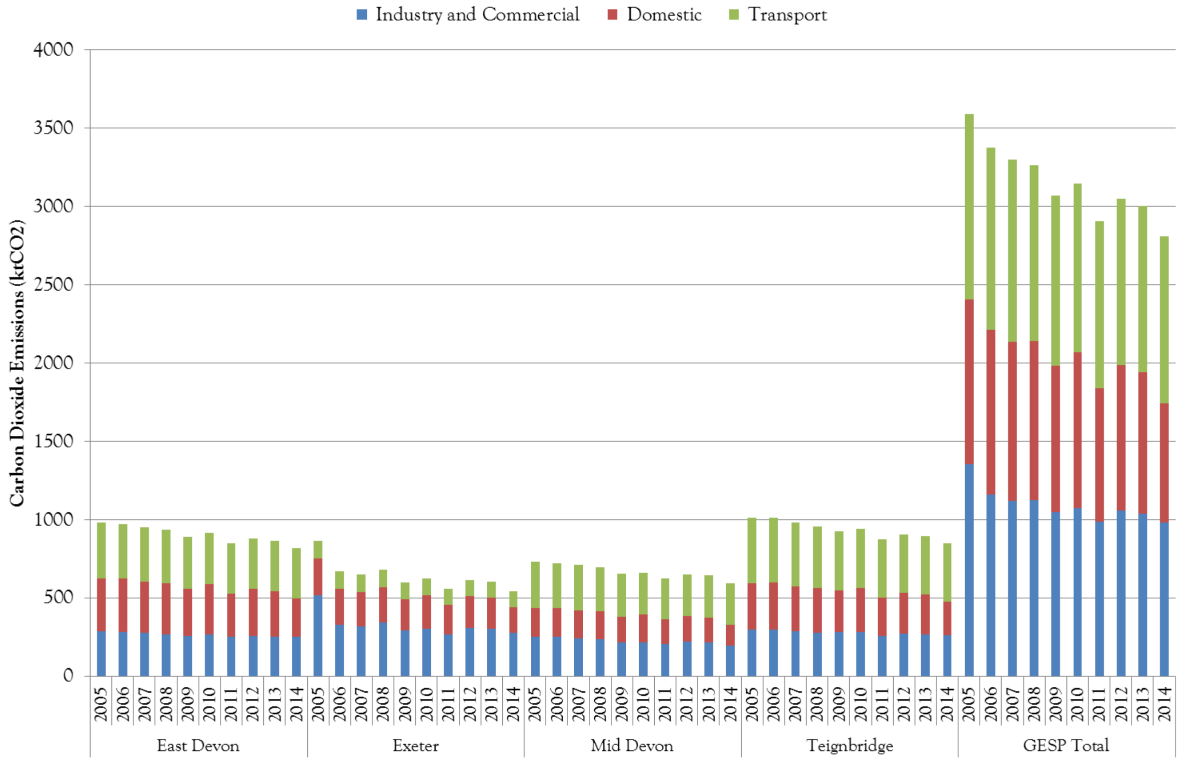

Figure 6: Absolute carbon emissions across the GESP area for each of the three broad sectors from 2005 to 2014

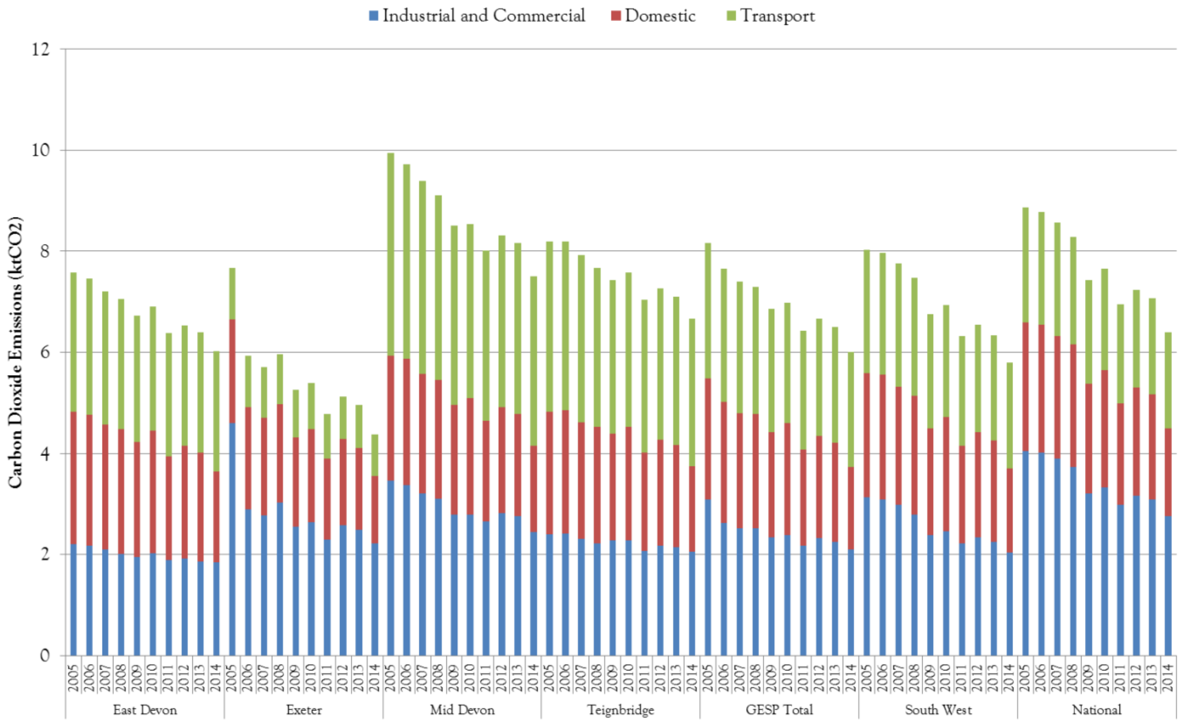

Figure 7: Carbon emissions per capita across the GESP area for each of the three broad sectors from 2005 to 2014 (note: the spike in Exeter's emissions in 2005 is due to an error in the source data, whereby emissions from a power plant were mistakenly allocated to the I&C sector)

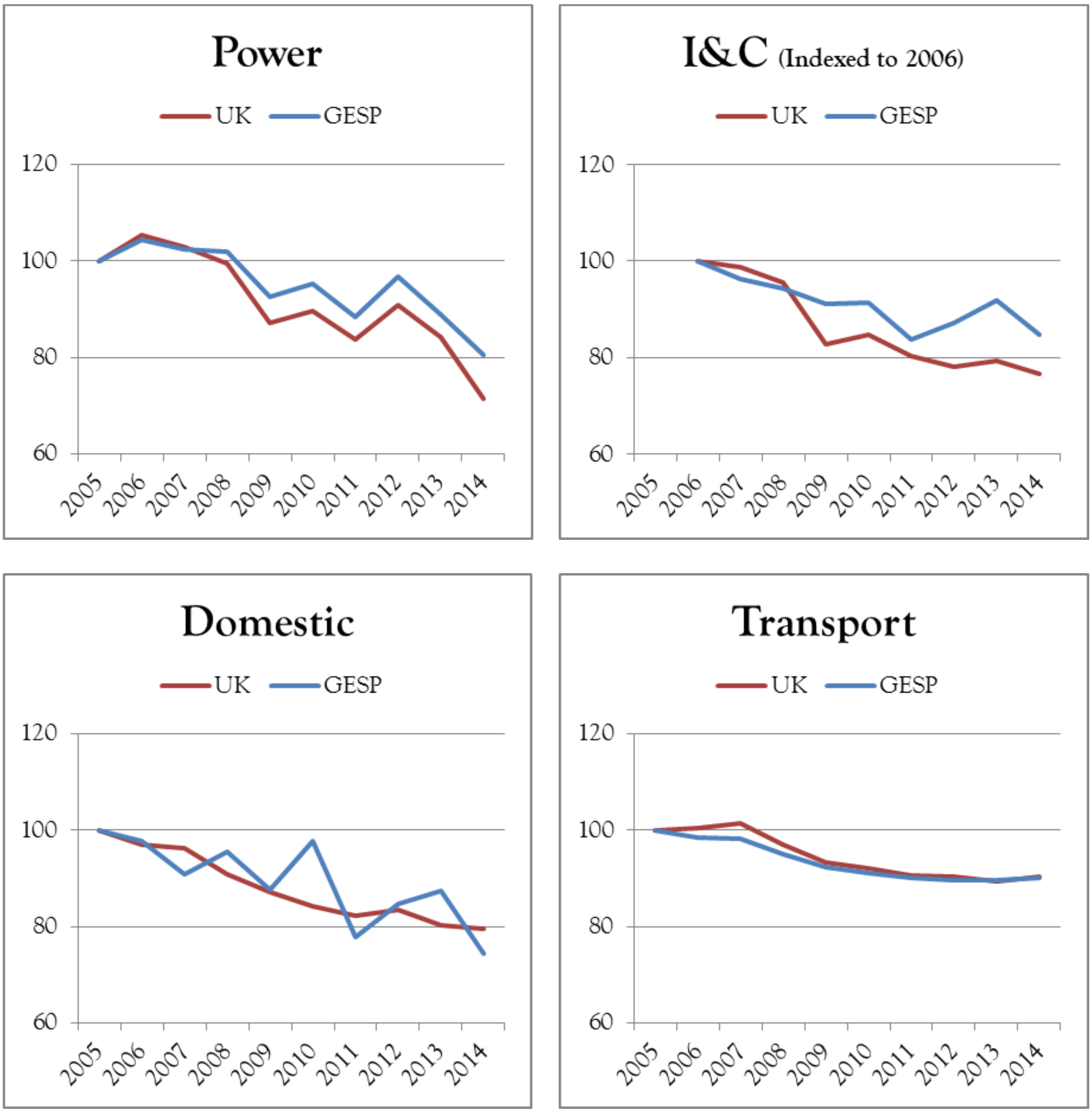

Figure 8: Indexed emission across the power sector (electricity) and three other sectors (direct combustion only), for the GESP and the UK

4.3.2 Projected Carbon Dioxide Emissions

By apportioning national policy to the local GESP area, it can be seen that by 2040 emissions will need to fall to approximately 1.1 $MtCO_2$ in order to hit national legally bound targets (Figure 9). A list of national policies on which the low risk, at risk and policy gap designations has been based can be seen in Table 5. However, this will be strongly dependent on the extent to which national policy delivers the intended quantum of carbon reduction. It can be seen that to 2032 the majority of the required carbon reduction is either "at risk" or there is a policy gap. There is no information available beyond 2032, as this represents the end of the 5th national carbon budget period and no analysis has been undertaken beyond this point.

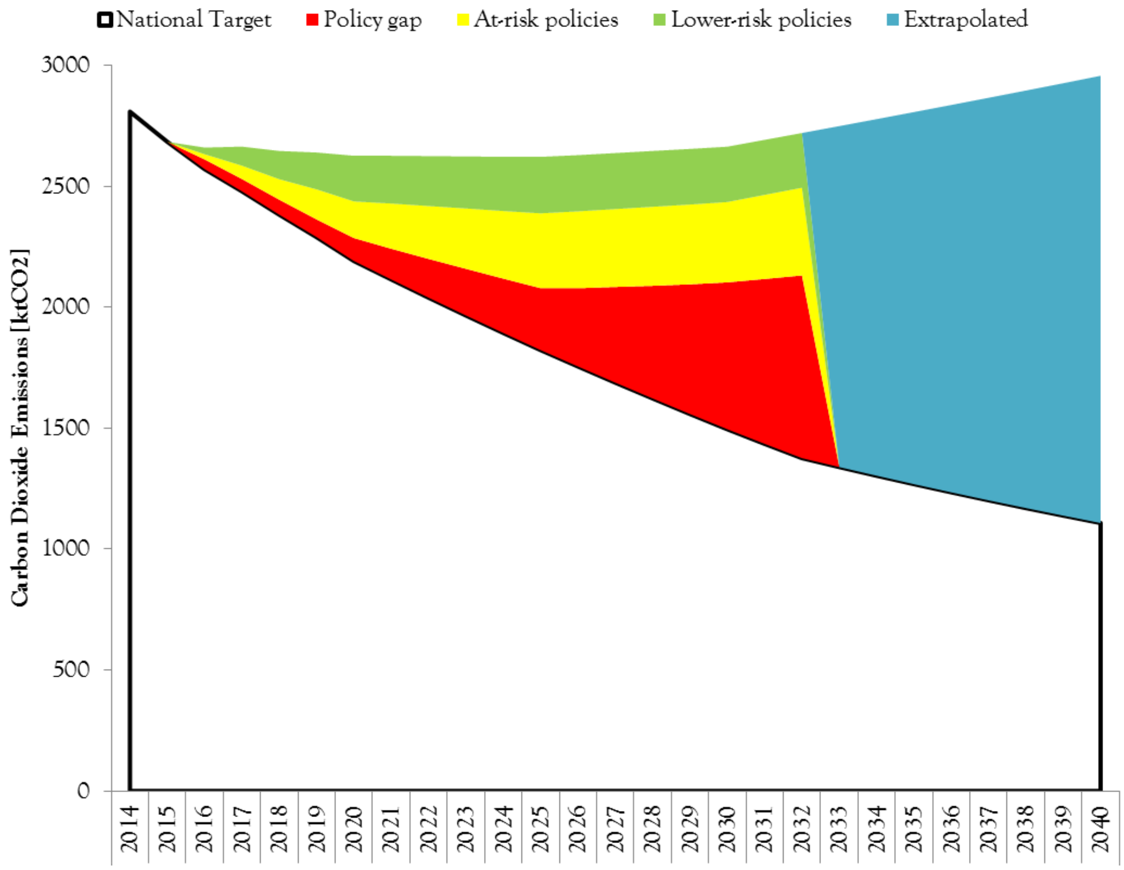

Figure 9: Projected total carbon dioxide emissions to 2040 for the GESP area combined with the trajectory separated into segments representing "low risk", "at risk" and where there are "policy gaps" at a national level. There is no policy data available between 2032 and 2040 so an extrapolated area has been shown for indicative purposes.

Table 5: Descriptions of policies that are "low risk", "at risk" or where there is a "policy gap" for four key sectors

Sector	Description
Power	
Low Risk	- Schemes in the pipeline nationally (mainly wind [both onshore and offshore], and biomass) that will collectively generate 39 TWh by 2021. - Commitment to phase out coal-fired capacity by 2025, conditional on deploying new replacement gas capacity.
At Risk	- The deployment of renewable energy post-2020 e.g. 3 to 6 GW of onshore wind - Ongoing uncertainly that surrounds the new nuclear reactor at Hinkley Point C - Concerns that there are no formal plans to address flexibility in the UK's electricity system, including removing barriers to entry in the market for flexibility services such as electricity storage and demand side response.
Policy Gap	- Cancellation of the Carbon Capture & Storage (CCS) Commercialisation Programme in November 2015 leaves the UK without a strategy to develop CCS. - Providing a subsidy-free route to market for cost-competitive renewables, namely onshore wind and solar PV.
Buildings	
Low Risk	- There are a number of low risk policies, though together they only comprise a small amount of overall abatement. These policies include some residual savings from the Carbon Emissions Reduction Target (CERT) domestic efficiency scheme, the improvement in efficiency of products due to the EU Ecodesign Directive, the renewable heat incentive (RHI) and the introduction of private-rented sector energy efficiency regulations.
At Risk	- Delays and potential upgrade requirement to the rollout of smart meters - The performance gap and backlog of pre-registered development under less stringent previous versions of Part L of the Building Regulations - The implementation of the EU Products Policy regarding the efficiency of, for example, appliances - Issues of trust and lack of interest in the Renewable Heat Incentive (RHI) - With the abolition of the Green Deal there is no longer a financing option to implement improved energy standards relating to the forthcoming legislation regarding standards in the private rented sector, together with the very low uptake rates through the Energy Company Obligation (ECO) regarding improving the efficiency of fuel poor, hard-to-treat and rural households. - In the non-domestic sector the closure of the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme in 2019 and poor compliance with the Energy Savings Opportunity Scheme (ESOS) undermines confidence that it will deliver expected levels of carbon reduction.
Policy Gap	- Cancelling of the "Zero Carbon Homes" policy that was due to be delivered via Part L of the Building Regulations. - Government responses to the Housing Standards Review has meant that it is now difficult for local planning authorities to set higher carbon reduction standards for new development than has been set by the national timetable. - The cancellation of the Green Deal scheme - Lack of policy in place for the delivery of building-scale low carbon heat in existing buildings from 2021.
Industry	
Low Risk	The Renewable Heat Incentive in the very near term
At Risk	- Delays and implementation surrounding the EU Ecodesign directive - Improvements to Part L of the Building Regulations - Uptake of the RHI in large scale low-carbon heat projects - The abolition of the CRC Energy Efficiency Scheme - The abolition of the Green Deal - Concerns about the effectiveness of the ESOS scheme.
Policy Gap	- Building on past road-mapping work for energy intensive industries by developing delivery plans to improve the energy efficiency of these sectors. - There is a gap with regard to using low-carbon and bioenergy post-2021. - Cancellation of the CCS commercialisation programme for the power sector

Transport	
Low Risk	- Biofuels policy to 2020 - The residual impacts of the Local Sustainable Transport Fund (LSTF) scheme - The planned electrification of the rail network.
At Risk	- Fuel efficiency policies to cars and vans to 2020 - Financial incentives and infrastructure improvements to support electric vehicles - Support to schemes that promote walking, cycling and use of public transport.
Policy Gap	- Post-2020 targets for the efficiency of cars and vans (currently none exist) - No policy in place to increase biofuel within the fuel mix to 8% of total energy - Concern about the flat-lining of the efficiency of HGVs

Figure 10 shows the same projection as Figure 9 with the classification of policy risk removed. The red area shows projected emissions associated with development in the GESP area (assumed to be predominantly heat from gas boilers, and electricity, with emissions from electricity over the period falling due to grid decarbonisation). The lightest and darkest blue zones are indicative of emissions from electricity from new dwellings and non-residential buildings respectively that will be avoided due to the decarbonisation of the electricity grid. The boundary between the red and the blue areas in Figure 10 corresponds to the boundary of the "policy gap" and the national trajectory from Figure 9. This highlights the proportion of future emissions associated with projected new development and the importance of addressing the emissions of the existing building stock (not specifically shown in Figure 10, but would make up a proportion of the white area beneath the red and blue areas).

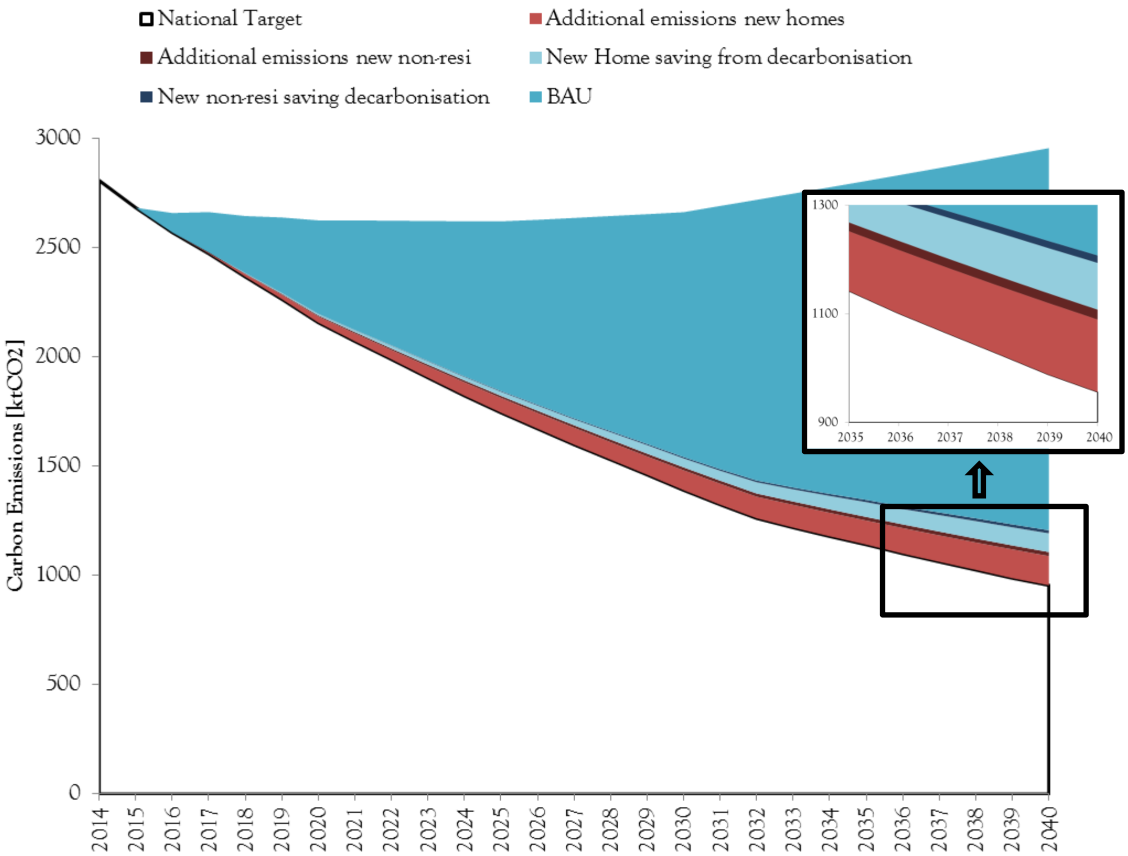

Figure 10: Potential additional emissions in the GESP area from new buildings (last 5 years zoomed to enable non-residential emissions to be seen)

4.3.3 Emissions associated with new dwellings

The annual carbon emissions associated with new dwellings in the GESP area in 2040 are shown in Figure 11, below. It can be seen that as standards for dwellings are improved, emissions are reduced. For the Code Level 5 onsite standard emissions net are not zero as the value of carbon reduction of PV reduces in practice over time as the grid decarbonises, whereas at the point of build, regulations assume a carbon intensity factor of the day. Also of note are the large contributions made by allowable solutions, which in the case of Code 6 results in negative emissions. This again is due to the decarbonisation of the grid meaning that the allowable solutions, over time, more than offset emissions if calculated at the start of the analysis period when grid intensities are higher. It should be stated that the Zero Carbon Hub proposed value of £60/tCO_2 over 30 years may not actually be capable of being utilised on projects that achieve that level of carbon reduction in practice; indeed, previous analysis undertaken by the ZCH[32] indicated that this was unlikely. For example, it was shown that based on a sample of social housing retrofit solutions the effective cost of intervention ranged from £85 to £127/tCO_2 additional funding (those projects were already in receipt of CERT funding and so the actual range if no CERT were available would be £100 to £172/tCO_2) whilst renewable energy technologies were estimated to range from £85/tCO_2 to several hundred pounds per tCO_2.

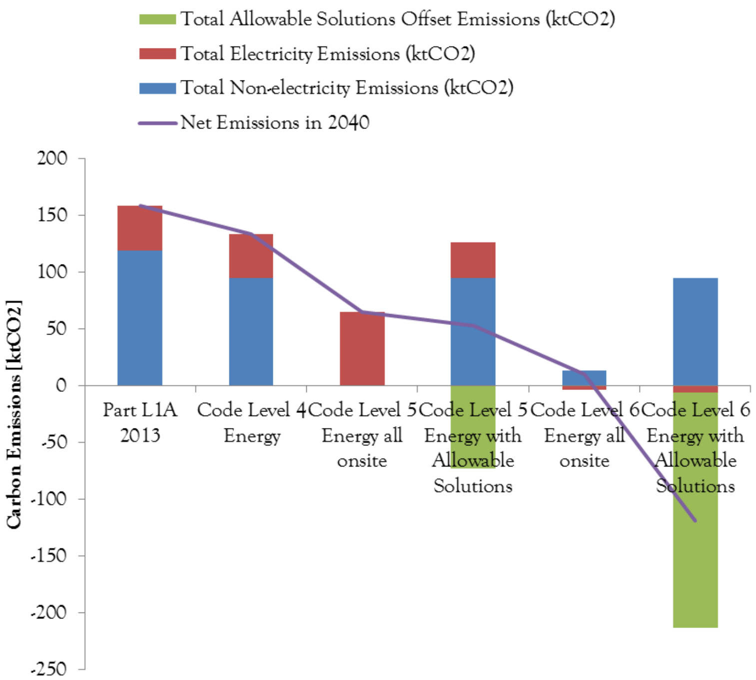

Figure 11: Annual emissions at 2040 for a range of energy specifications for new dwellings. The purple line shows net emissions.

Figure 12 shows the annual savings in 2040 for various higher standards of dwelling energy performance above Part L 2013. Requiring Code Level 4 for all new dwellings (and assuming national building regulations are not tightened over the period), in 2040 the annual carbon reduction achievable in the GESP area would be 0.9 – 1.5% (the lower end of the range is relative to business as usual, the upper end is based on the national carbon reduction trajectory being achieved locally, in spite of current policy gaps). If Code Level 5 onsite is made a requirement, then this

[32] ZCH 2012, Allowable Solutions: Evaluating Opportunities and Priorities

saving increases to 3.6 – 5.8%. At Code 6 onsite the range is 5.8 – 9.3%. For the allowable solutions scenarios, savings are potentially higher (Code 5: 4.1 – 6.6%, Code 6: 10.8 – 17.3%) though these are predicated on those allowable solutions being put towards carbon reduction projects in the local area and that those levels of carbon abatement can be achieved at £60/tCO_2, which is (as explained above) debatable.

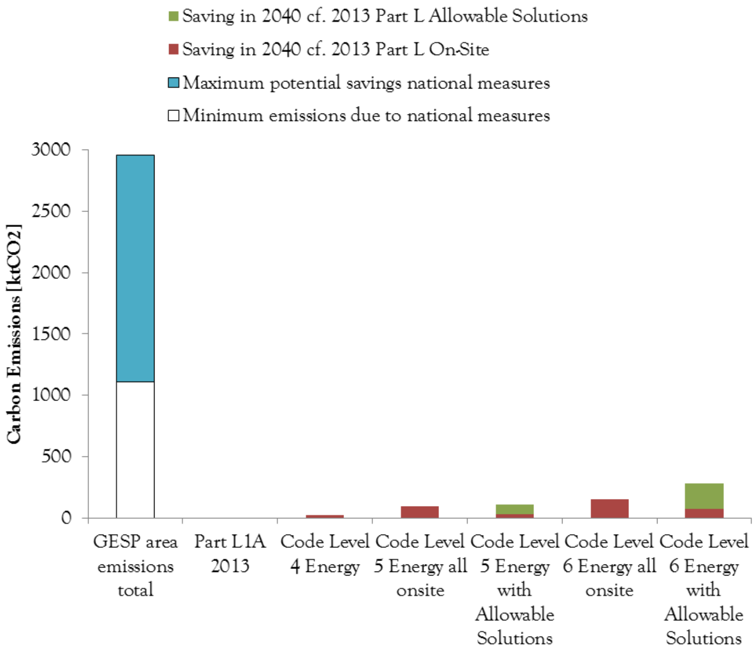

Figure 12: Savings from each of the specification standards compared to Part L 2013 standard in 2040, set within the overall context of total emissions in the GESP area. The blue region for GESP emissions is the zone between the national carbon trajectory being met in the area, and business as usual in 2040 as shown in Figure 9.

Table 6 shows the carbon savings over the GESP plan period (2020 to 2040) for the different dwelling standards compared to Part L 2013 together with the extra over build costs of achieving those standards. At both Code 5 and Code 6, the calculations indicate that allowable solutions deliver greater carbon reduction, and at a lower cost. Again, this must be viewed with caution as it is unlikely in practice that allowable solutions at that rate would offset that amount of carbon emissions in practice.

Table 6: Cumulative emissions, extra over capital cost, and abatement of the different dwelling specifications (note: costs do not include potential operational savings)

Scenario	Total Emissions 2020-2040 ($ktCO_2$)	Emission Saving cf. 2013 Part L 2020-2040 ($ktCO_2$)	Total Cost Uplift Across GESP Area(£ millions)	£/tCO2
Part L1A 2013	2,104	0	£ -	£ -
Code Level 4 Energy	1,797	307	£ 108	£ 352
Code Level 5 Energy all onsite	1,004	1100	£ 751	£ 682
Code Level 5 Energy with Allowable Solutions	760	1344	£ 350	£ 260
Code Level 6 Energy all onsite	112	1992	£ 1,460	£ 733
Code Level 6 Energy with Allowable Solutions	-1,512	3616	£ 578	£ 160

4.3.4 Emissions associated with new non-residential buildings

The annual carbon emissions associated with new non-residential buildings in the GESP area in 2040 are shown in Figure 13, below. It can be seen that there is very little difference in emissions from the new non-domestic buildings in 2040 for the on-site compoents. This is because due to the assumptions of the modelling, most of the energy demand is for electricity, and by 2040 the carbon intensity of the grid is extremely low. Larger savings can be seen with the allowable solutions scenarios, but as with dwellings, care must be taken as the proposed £60/tCO_2 over 30 years may not actually be capable of being utilised on projects that achieve that level of carbon reduction in practice; indeed, previous analysis undertaken by the ZCH indicated that this was unlikely.

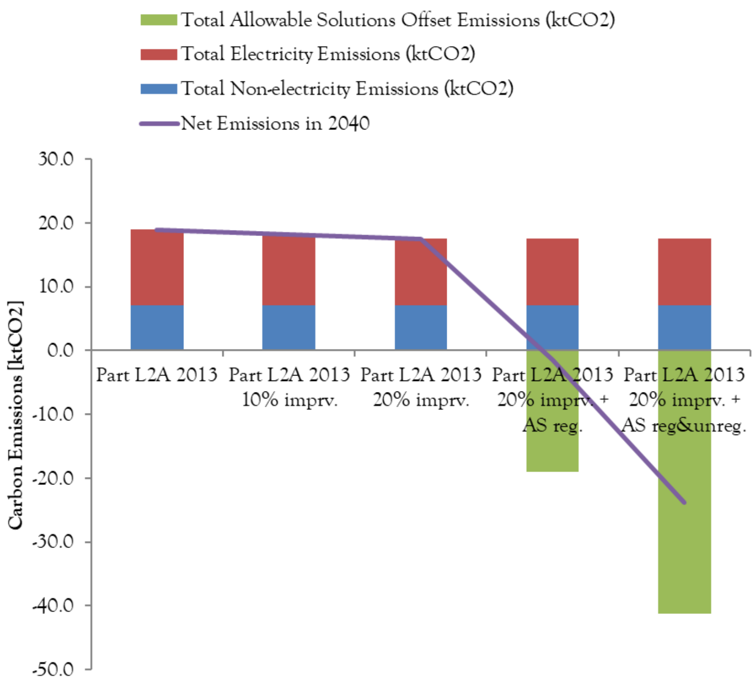

Figure 13: Annual emissions at 2040 for a range of energy specifications for new non-residential buildings. The purple line shows net emissions.

Figure 14 shows the annual savings in 2040 for various higher standards of building energy performance above Part L 2A 2013. When placed in the context of total emissions in the GESP area, they constitute under 0.1% for on-site aspects and as such are barely visible. This is in part because Part L calculations are undertaken at the point of build whereas carbon factors – especially for electricity – are projected to significantly change over time. It has been assumed in the calculations (as was the case in the impact assessment to the last change to Part L) that meeting and exceeding Part L would be achieved by making improvements to electricity demand (and supply) to buildings. As the carbon intensity of electricity is projected to rapidly fall over the GESP period (the value used in Part L is over 0.5 $kgCO_2/kWh$ whereas the grid is projected to fall to under 0.1 $kgCO_2/kWh$ by 2040), these savings above Part L in 2040 (as shown in Figure 14) are minimal. If What this approach does not consider is the value of reducing electricity demand or increasing renewable electricity supply with regard to the capacity of local electricity infrastructure, nor any financial benefits to building occupiers.

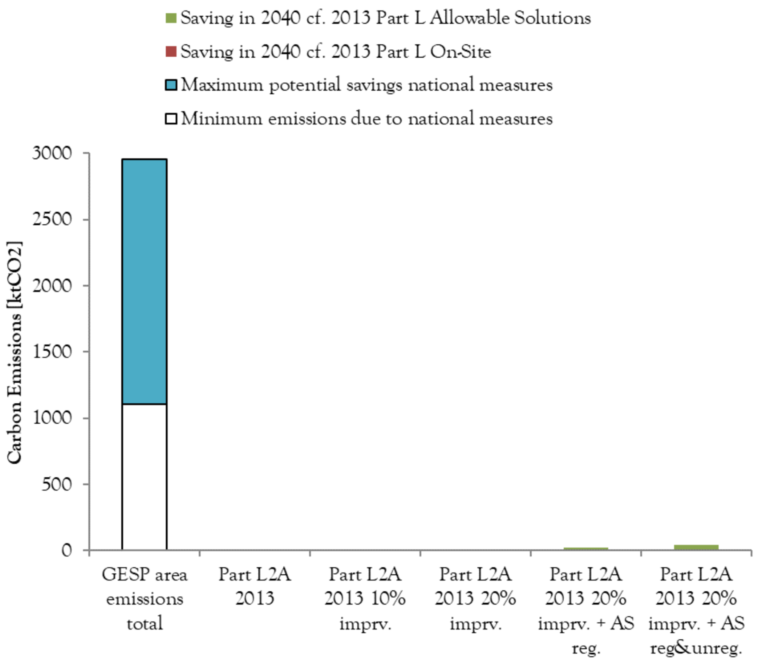

Figure 14: Savings from each of the specification standards compared to Part L 2A 2013 standard in 2040, set within the overall context of total emissions in the GESP area. The blue region for GESP emissions is the zone between the national carbon trajectory being met in the area, and business as usual.

Table 7 shows the carbon savings over the GESP plan period (2020 to 2040) for the different building standards compared to Part L 2A 2013 together with the extra over build costs of achieving those standards. The overall costs when considered across the GESP period are extremely high. This is because as the carbon intensity of the grid decarbonises, the value of making savings in electricity (as has been assumed here) diminishes. As the grid carbon intensity approaches zero, the cost in £/tCO_2 will rise exponentially.

Table 7: Cumulative emissions, extra over capital cost, and abatement of the different building specifications (note: costs do not include potential operational savings)

Scenario	Total Emissions 2020-2040 (ktCO2)	Emission saving cf. 2013 Part L 2020-2040 (ktCO2)	Total Cost Uplift Across GESP Area (£ millions)	£/tCO2 (not including running cost savings)
Part L2A 2013	19	0	£ -	£ -
Part L2A 2013 10% improvement	18	1	£ 15	£ 20,881
Part L2A 2013 20% improvement	17	1	£ 39	£ 27,022
Part L2A 2013 20% improvement + allowable solutions regulated emissions	-1	20	£ 73	£ 3,583
Part L2A 2013 20% improvement + allowable solutions regulated and unregulated emissions	-24	43	£ 113	£ 2,652

4.3.5 Conclusions

Current emissions in the GESP area in 2014 were 2.8 $MtCO_2$ with emissions being split between the transport (38%), I&C (35%) and domestic (27%) sectors. Emissions have in the main fallen year-on-year since 2005. Projections for carbon dioxide emissions in the GESP area show that a business as usual approach would result in emissions of almost 3 MtCO2 in 2040. In order to be consistent with the national trajectory, carbon dioxide emissions in 2040 should be nearer 1.1 MtCO2. It has been shown that there is currently a significant policy gap to meeting that target. If the target is achieved, it is estimated that emissions associated with new buildings constructed over the GESP period would account for approximately 16% of total carbon dioxide emissions in the GESP area.

An analysis of new residential development has shown that there is the potential to reduce emissions from new development if tougher standards could be set. If an overall carbon dioxide emission rate for the GESP of 1.1 $MtCO_2$ could be achieved in 2040, then setting an equivalent of CSH4 would result in a further 1.5% reduction in total emissions in the GESP area, whilst setting CHS5 would result in a 5.8% reduction in 2040. This assumes that the yet to be filled policy gap at a national level will not include such improvements to Part L, though given the high risk to achieving the required level of carbon reduction from national policy, improving beyond the minimum Part L thresholds represents a potentially important means of achieving carbon reduction in the GESP area. The analysis shows that it is more cost effective to achieve carbon reduction if offsite "allowable solutions" are allowed, though it is important to test whether those allowable solutions are capable of achieving the stated carbon reduction offset in the GESP area.

An analysis of new non-domestic development has shown that setting required improvements on Part L2A of the building regulations for non-residential buildings may not in fact deliver significant carbon reduction by the end of the GESP period. This is because developers working towards such a standard now (and hence what the analysis here has assumed) would likely make improvements to the electricity consumption of the building, whereas by 2040 the electricity is projected to be largely decarbonised. This is reflected in the resultant high effective cost per lifetime tCO_2 of carbon saved for non-domestic buildings. There may however still be benefits to reducing emissions beyond the Part L2A threshold for example reduced bills to occupants, and a reduced demand new capacity and infrastructure on the supply side.

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*[33]*;*
- *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.

[33] *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 8: 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 [34,35,36] was followed by work using the SQW methodology in 2010. This work was summarised and consolidated for Devon in 2011[37]. More recently relevant resource assessments have been published as part of assessment of regional electricity grid capacity limitations[38] and as part of aspirations for local energy independence[39].

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).*

[34] "REvision 2010", CSE, Peter Capener et al for GOSW, 2004
[35] "REvision 2020", CSE, Peter Capener et al for GOSW, 2005
[36] "South West Renewable Energy Atlas DVD", Wardell Armstrong, 2005
[37] "A review of renewable energy resource assessments and targets for Devon", University of Exeter, 2011
[38] "Distributed generation and demand study – technology growth scenarios to 2030", Western Power Distribution & Regen SW, 2016
[39] "Energy independence 2025" City Science, 2017

Table 9: 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 10: 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[40], 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 [41, 42].

Table 11 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 < 5.5 m s^{-1} @ 10 m elevation (60%),
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%).

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

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

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

Table 11: 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[43]			
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%[44]
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[45]	Exclude	Ordnance Survey Greenspace	1.1%
Landfill Site	> 1 km from centroid[46]	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[47]	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	> 5.5 m s^{-1} @ 10 m	NOABL	60.5%
WPD Grid connection (33, 132 kV)	< 2 km	WPD	48.0%

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

1. The NATS self-assessment constraints for wind developments[48] pertain to national air traffic control infrastructure, and "*are an aid to developers in understanding where interference with NERL*[49]

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[43] Formerly National Air Traffic Services.
[44] For a 120 m tip height.
[45] Includes allotments, bowling greens, cemeteries, churchyards, golf courses, play areas, public parks and sports fields.
[46] Only point data (centroids) were identified for this feature, the applied buffer should encompass the feature itself.
[47] Council Tax centroids.

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 15). It was therefore decided to evaluate alternative constraints based on reducing the diameter of the constraints by 25%, 50% and 75%.

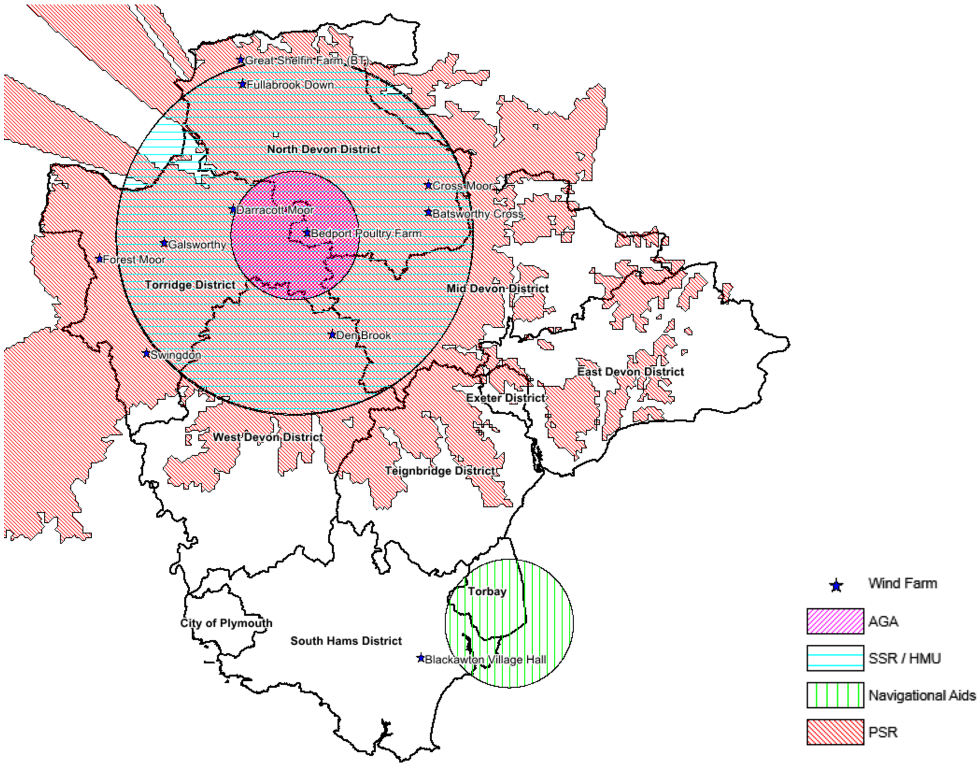

Figure 15: Existing wind farms in Devon compared to the NATS wind farm development self-assessment constraint areas

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

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

[49] NATS[43] En Route plc, licenced to provide en-route air traffic services in the UK.

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 [42] were eliminated. The resulting maps for the two scenarios are presented in Figure 16 and Figure 17.

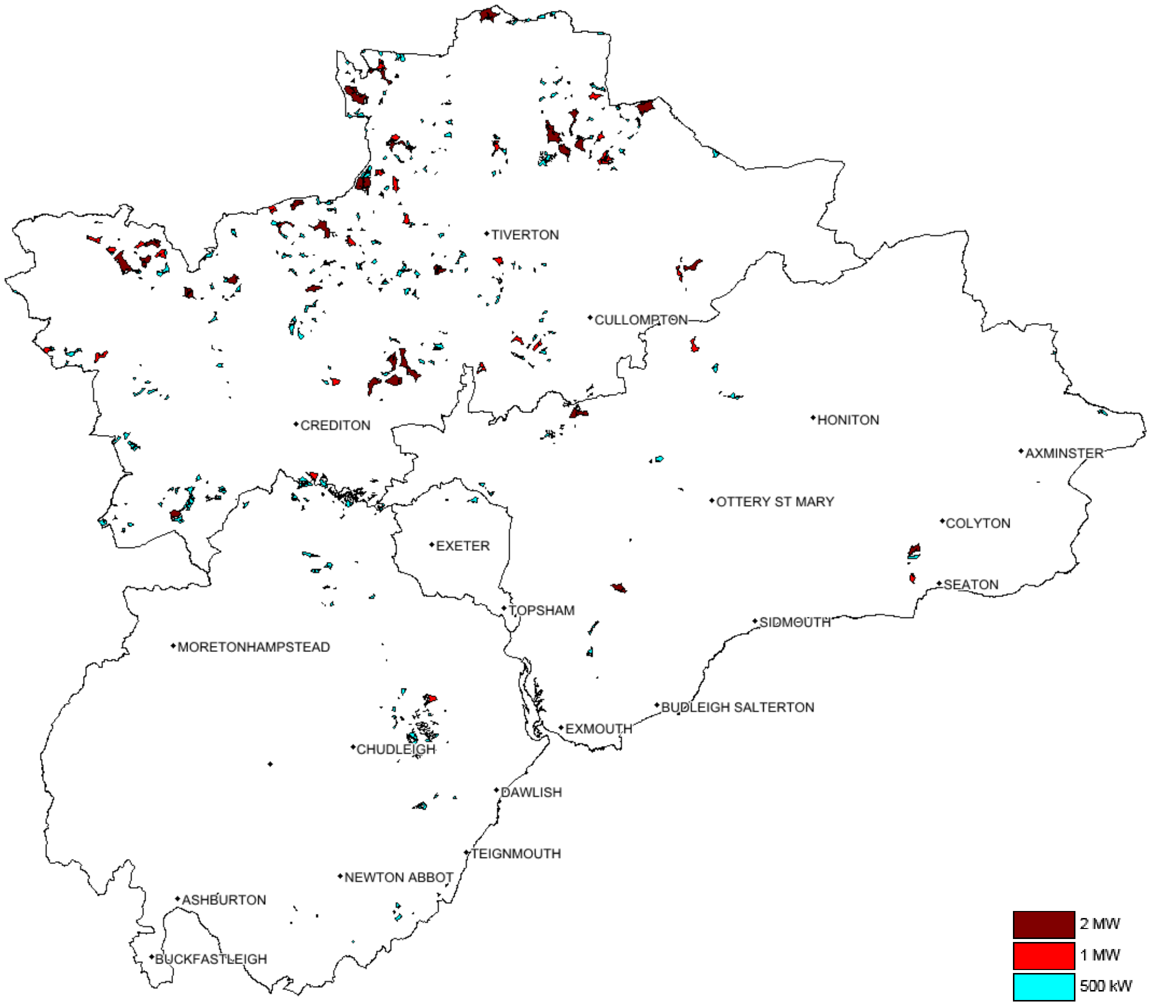

Figure 16: Scenario 1: Areas identified for onshore wind development with no constraint on the maximum distance from the WPD electricity distribution grid (the shading refers to the turbine sizes identified in the resource assessment)

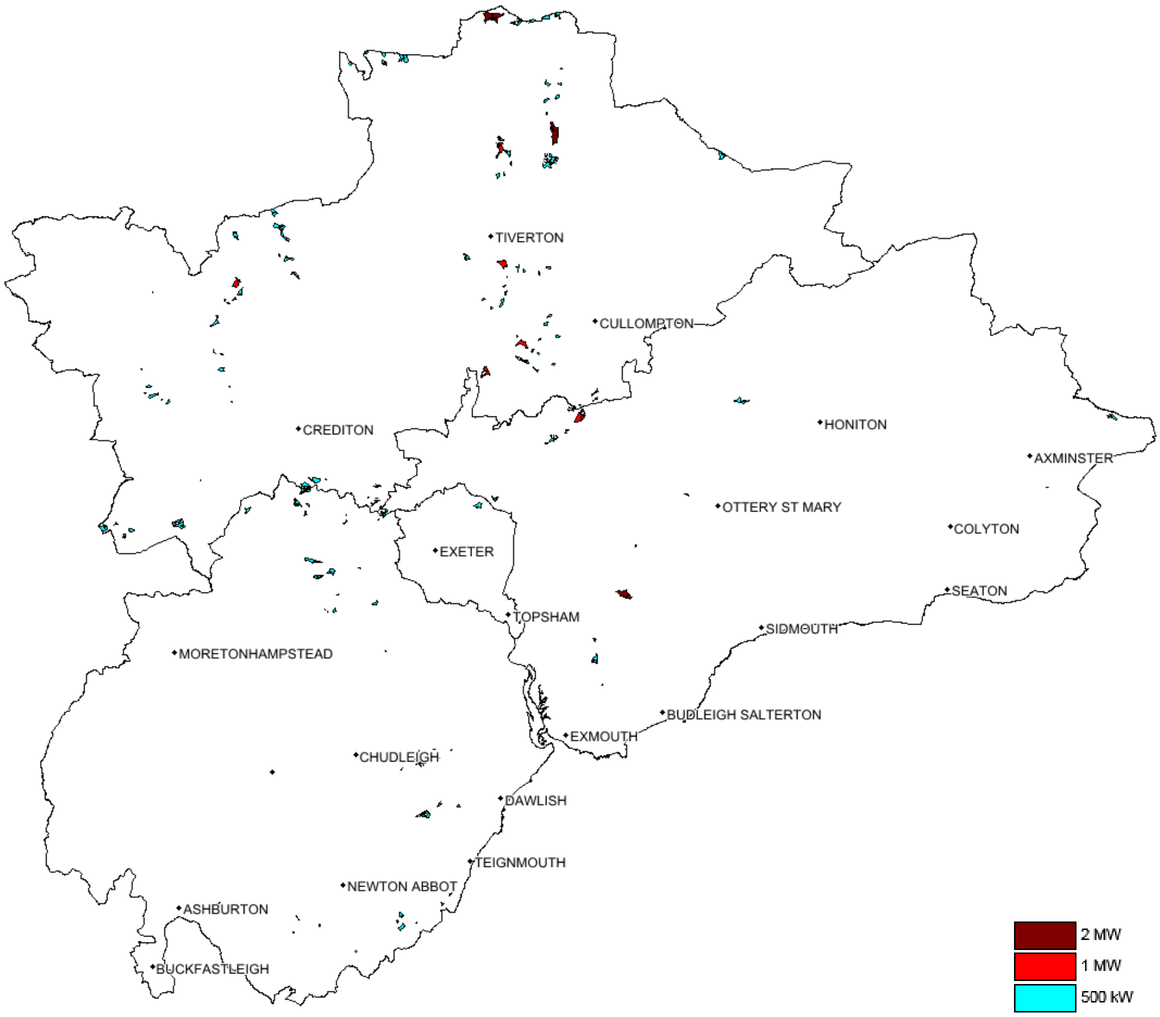

Figure 17: Scenario 2: Areas identified for onshore wind development with a 2 km constraint on the maximum distance from the WPD electricity distribution grid (the shading refers to the turbine sizes identified in the resource assessment)

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 [41,42]. In line with other studies[41], 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[41]. 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 [36, 41, 42]. 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 26% for the scenario with a 2 km maximum distance from the grid, and 42% 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 12 and Table 13 (the numbers of sites and turbines resulting from the application of the density factor have been rounded to the nearest whole number).

Table 12: 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	26	2	2	17	41.7
Exeter	1	0	0	0.5	1.2
Mid Devon	219	20	28	165.5	405.9
Teignbridge	59	0	0	29.5	72.4
Total	**305**	**22**	**30**	**212.5**	**521.2**

Table 13: 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	15	1	1	9.5	23.3
Exeter	1	0	0	0.5	1.2
Mid Devon	69	2	2	38.5	94.4
Teignbridge	32	0	0	16.0	39.2
Total	**117**	**3**	**3**	**64.5**	**158.1**

In reality the resource is likely to lie somewhere between the values in Table 12 and Table 13 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 14 summarises 2016 wind development in the GESP area by local authority[50].

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

Table 14: 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 1.0% of the grid-constrained resource or 0.3% without the grid proximity constraint. Table 15 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 15: Unexploited wind potential within the GESP area

Local authority	Number of sites	Capacity (MW)	Annual Output (GW h)
Without grid constraint			
East Devon	15	16.8	41.3
Exeter	1	0.5	1.2
Mid Devon	205	165.0	404.9
Teignbridge	52	29.4	72.3
Total	**273**	**211.7**	**519.7**
With grid constraint			
East Devon	3	9.3	22.9
Exeter	1	0.5	1.2
Mid Devon	37	38.0	93.4
Teignbridge	25	15.9	39.1
Total	**66**	**63.7**	**156.6**

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 [41, 42].

Table 16 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 16: Spatial constraints applied to determine the PV resource in the GESP area

Parameter	Constraint	Source of Data	% of GESP Area removed
Transport & Communications			
Airfield[51]	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[45]	Exclude	Ordnance Survey Greenspace	1.1%
Landfill Site	> 1 km from centroid[46]	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[52]	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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[51] 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.

[52] 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 [42] were eliminated. The resulting maps for the two scenarios are presented in Figure 18 and Figure 19. 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.

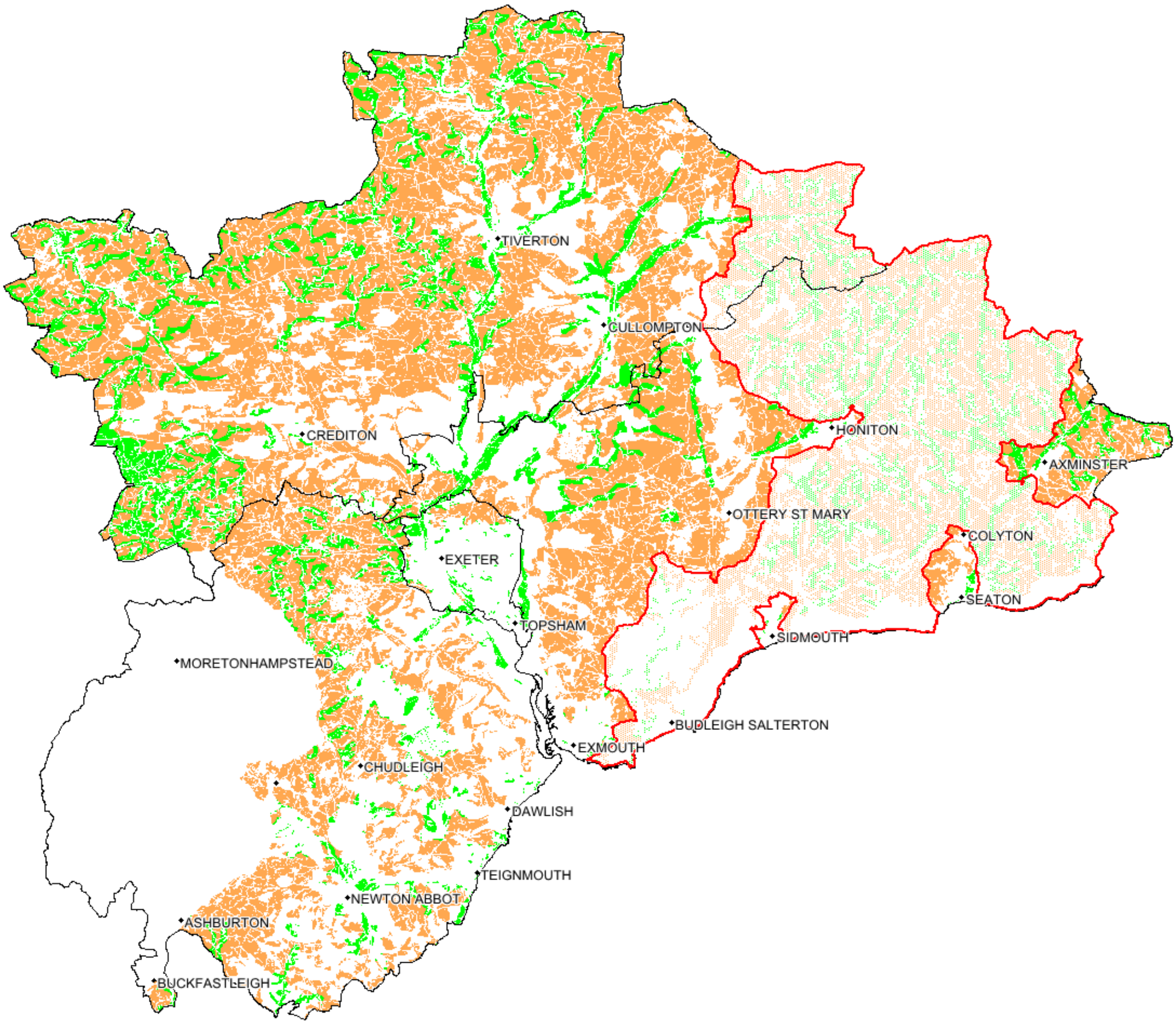

Figure 18: Areas identified for PV development with no constraint on the maximum distance from the WPD electricity distribution grid. Areas in green are agricultural land grade 4 or 5. Areas in orange are agricultural land grade 3. The AONB boundary is shown in red, and possible development within the AONB as hatched areas.

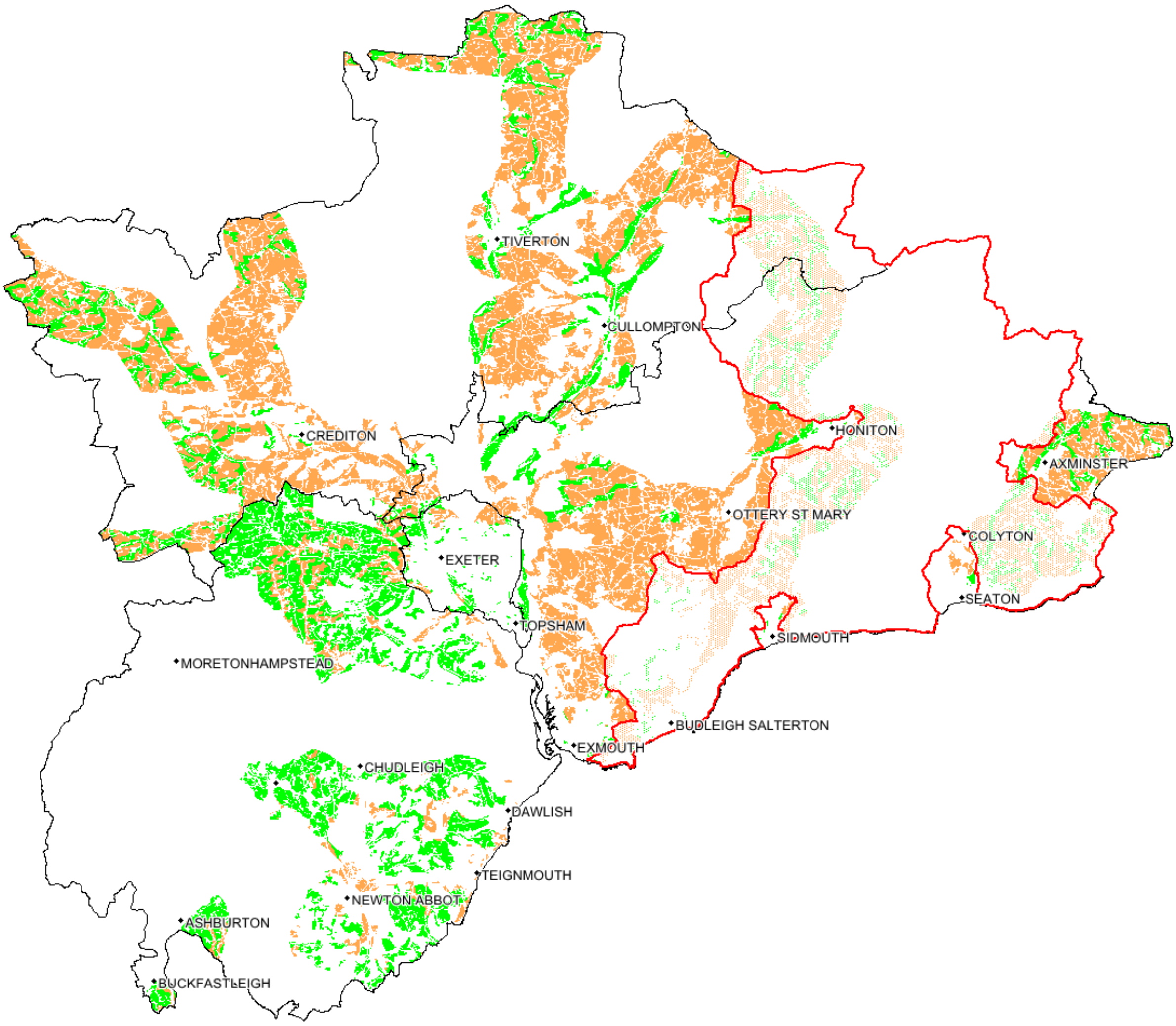

Figure 19: Areas identified for PV development with a 2 km constraint on the maximum distance from the WPD electricity distribution grid. Areas in green are agricultural land grade 4 or 5. Areas in orange are agricultural land grade 3. The AONB boundary is shown in red, and possible development within 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 [41,42]. In line with other studies[41], 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 [42] (other studies[41] 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%[53] was applied to account for the intermittency of solar insolation when calculating the annual energy output. A similar figure was used in other studies[41, 54]. These factors

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

[54] 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 17 and Table 18 (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 17: 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 18: 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 19 and Table 20 incorporate an adjustment to estimate the amount of Grade 3a agricultural land in each local authority (shown in Table 19) 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 8: Economic Impact of Building and Standards and Renewables .

Table 19: 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 20: 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 21 summarises 2016 PV development in the GESP area by local authority [50].

Table 21: 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 22 and Table 23 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 22: 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 23: 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 24: 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 [55]	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

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.

[55] 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)

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."[56] The Silkeborg solar thermal array in Denmark is 156,000m^2 with capacity of 110MWth (see Figure 20).

Figure 20: 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.

[56] 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. Low Carbon Marginal Abatement Assessment

6.1 Work Package Aim

The aim of this work package was to address objectives 2, 3 and 4 as described in Section 1 by collating the cost and carbon saving outputs from the building standard and renewable energy sections into a curve (MACC). A MACC visualises the potential total magnitude of carbon reduction measures, together with the ranked normalised cost of each measure.

6.2 General Approach

In order to develop a MACC, the costs per tonne of carbon saved, and the potential total amount of carbon that could be saved from each standard for new dwellings and non-domestic buildings as well as for the large scale renewable energy technologies considered were established.

For buildings, the potential cumulative carbon saved over the GESP period as well as the cost uplift compared to meeting Part L of the building regulations had already been established using the method described in Section 4. These were calculated for five dwelling and four non-domestic scenarios as follows:

- Dwellings, Code Level 4 Energy: Taken as being similar to a Part L 2013, but with an uprated building fabric.
- Dwellings, Code Level 5 Energy all onsite: Assumed to be similar specification to Code Level 4, but with a ground source heat pump and additional PV.
- Dwellings, Code Level 5 Energy with allowable solutions: As Code 4 with additional PV, then "Allowable Solutions" at £60/tCO_2 for a period of 30 years.
- Dwellings, Code Level 6 Energy all onsite: Based on a much enhanced building fabric, PV and biomass boiler.
- Dwellings, Code Level 6 Energy with allowable solutions: As Code 4 specification, but with additional allowable solutions
- Non-domestic: A 10% improvement on Part L all onsite.
- Non-domestic: A 20% improvement on Part L all onsite.
- Non-domestic: A 20% improvement on Part L onsite plus allowable solutions to offset balance of regulated emissions.
- Non-domestic: A 20% improvement on Part L plus allowable solutions for regulated and unregulated emissions.

It should be noted that the costs were taken as the extra-over capital costs, and that no account was taken for the potential savings, for example in terms of reduced energy bills or the social cost of carbon. As such, all costs reported were positive (as opposed to negative costs which would be representative of a net benefit).

For renewable energy, the potential resource for large scale wind and PV was taken from Section 5 and combined with the estimated cost of each of these as detailed in Section 9. The scenarios assumed within this section of the analysis were that both wind and PV were constrained by the proximity (2 km) to the electricity grid, and for wind 3km airport buffer and 25% NATS buffers were also applied. In order to calculate the carbon saved from the electricity generated, it was assumed that the total resource available was brought forward linearly over the GESP period, and that the carbon saved in any given year within this period was obtained by multiplying the generated energy by the conversion factor ($kgCO_2/kWh$) used for exported energy generated by CHP as published by BEIS (which averages at 0.318 $kgCO_2/kWh$ between 2020 and 2040).

6.3 Work Package Outputs

The generated MACC can be seen in Figure 21 and Table 25. In the case of the building related standards, the potential carbon saving of each scenario cannot be added together; rather they represent different options in terms of ambition regarding setting standards. A number of observations can be made:

6.3.1 Large Scale Renewable Energy

It can be seen that the large scale PV scenario has considerably greater potential to save carbon emissions compared to the wind scenario. In addition, the abatement cost is lower. This is because the wind resource identified under the grid constrained scenario is dominated by small wind turbines (500 kW) which are relatively more expensive per unit of output compared to larger wind turbines. Excluding scenarios that make extensive use of allowable solution payments, large scale PV both has the greatest potential impact and is the cheapest of the options considered.

6.3.2 Onsite Standards

The results show that for the building scenarios that do not include allowable solutions, the dwelling scenarios are cheaper than the non-domestic scenarios, and are potentially capable of saving more carbon. This is because of the greater number of homes planned compared to non-domestic area, but also that the savings in dwellings have mainly been applied to heating demand (which is generally not electric) and the savings to non-domestic buildings are applied to electricity use, for which the value of the carbon saving diminishes over time as the carbon intensity of the grid improves. At present, the calculation undertaken within Part L of the Building Regulations uses a factor of approximately 0.5 $kgCO_2/kWh$ whereas the current value is nearer 0.3 $kgCO_2/kWh$ and by the end of the GESP period it is projected to fall below 0.1 $kgCO_2/kWh$. Therefore the current building regulations regime incentivises making savings relating to electricity consumption, whereas over time the value of those savings compared to fossil fuels (e.g. gas or oil) would decrease. Until such a time where the carbon factors used in the building regulations are updated to account for this, the emphasis will be to make savings to electricity consumption.

The results also show that specifying Code 4 energy for dwellings only has the potential to save a relatively minor amount of carbon over the GESP period when compared to both the Code 5 and Code 6 scenarios. This is not a surprising result as the current pass threshold for Part L 2013 is already between Codes 3 and 4, whilst Codes 5 and 6 require significant additional carbon abatement.

6.3.3 Allowable Solutions

The output shows that the scenarios with allowable solutions are the cheapest, particularly where they are used most extensively, and that there is a significant opportunity for carbon reduction. Care must be taken in interpreting these results. The calculation assumes that carbon emissions can actually be abated at a rate of £60/tCO_2 for a period of 30 years by taking payments made by developers and using them to directly fund carbon reduction in the GESP area. In practice, evidence from elsewhere has shown that at this level, allowable solution payments are insufficient to achieve this level of carbon reduction on real projects. In addition there are challenges to ensuring that the projects happen within the locality. This is not to say that allowable solutions cannot make a useful contribution to carbon reduction in the GESP area; at levels that could arguably be justified based on precedents elsewhere, they are unlikely to make the theoretical savings reported here.

The graph essentially identifies the value for money of each potential abatement option with options on the left of the graph being of best value for money and options on the right of the graph being least value for money in terms of carbon saved. However, whilst the results show for example that the dwelling scenario at Code 6 with allowable solutions has the lowest abatement cost, it must be remembered that in absolute terms this is still a more expensive option for a developer than achieving Codes 4 or 5, as reported in Section 4.

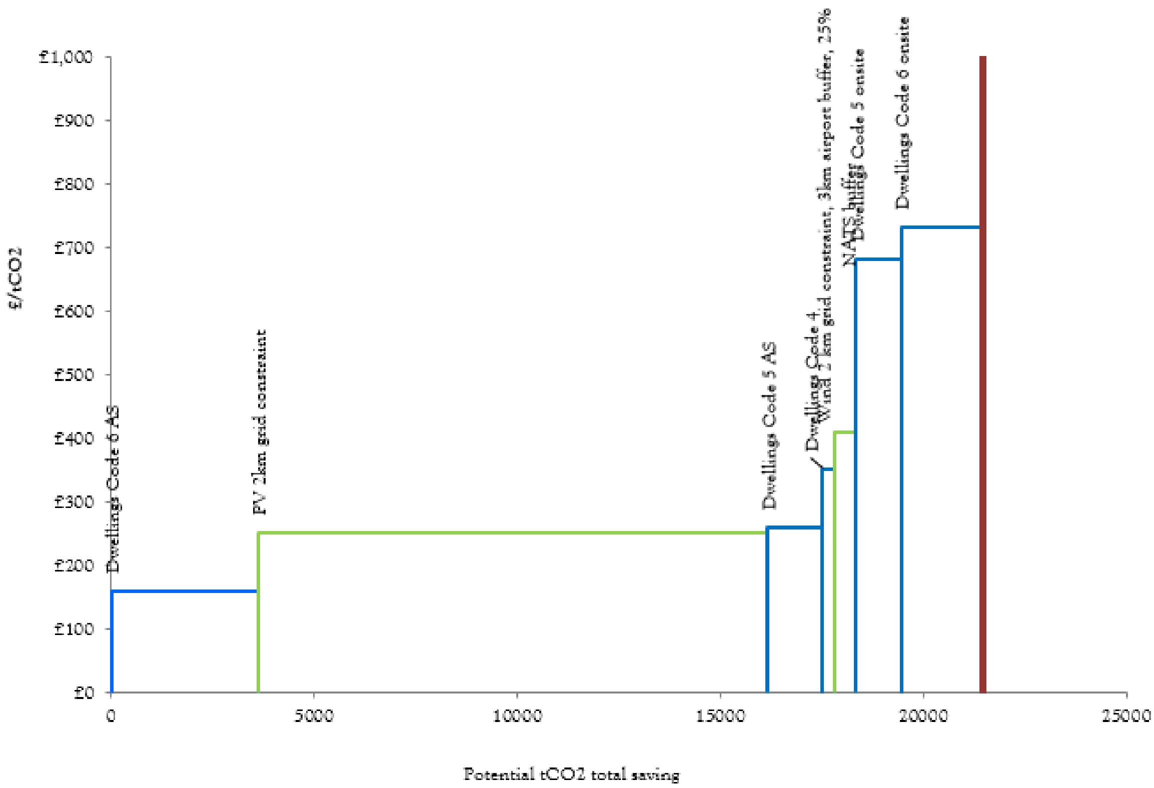

Figure 21: MACC for building standards and renewable resource in the GESP area 2020 – 2040 (Note: Non-domestic MACC values significantly exceed the limits of the plotted axis)

Table 25: Abatement costs and carbon saved of the GESP 2020 – 2040 period.

Scenario	Total carbon saved 2020-2040 ($ktCO_2$)	Cost Uplift (£ millions)	£/tCO_2)
Dwellings, Code Level 4 Energy	307	£108	£352
Dwellings, Code Level 5 Energy all onsite	1,100	£751	£682
Dwellings, Code Level 5 Energy with allowable solution	1,344	£350	£260
Dwellings, Code Level 6 Energy all onsite	1,992	£1,460	£733
Dwellings, Code Level 6 Energy with allowable solutions	3,616	£578	£160
Non-domestic: A 10% improvement on Part L all onsite	1	£15	£20,881
Non-domestic: A 20% improvement on Part L all onsite	1	£39	£27,022
Non-domestic: A 20% improvement on Part L onsite plus allowable solutions to offset balance of regulated emissions	20	£73	£3,583
Non-domestic: A 20% improvement on Part L plus allowable solutions for regulated and unregulated emissions	43	£113	£2,652
Wind 2 km grid constraint, 3km airport buffer, 25% NATS buffer	325	£135	£416
PV 2km grid constraint	13,405	£3,356	£250

6.3.4 Conclusions

A marginal abatement cost assessment has shown that the greatest potential for carbon reduction over the GESP period is bringing forward large scale PV. It is also amongst the lowest cost measures. Onshore wind is more expensive as exploiting the wind resource would require in the main smaller turbines which are less efficient and cost effective than larger ones. If homes could be constructed to higher energy standards, then these would need to all be at "Code" 5 or 6 to make a meaningful difference. Building to higher energy standards for non-domestic buildings will likely be expensive and not save much carbon, a finding which is strongly influenced by the assumption that improvements would be made to electricity demand which would become worth less over time as the carbon intensity of the national electricity grid decreases. If an allowable solutions mechanism could be introduced, then both the potential abatement cost could decrease and the amount of carbon saved increase. However, care would need to be taken that any allowable solutions would achieve the stated amount of carbon reduction both in practice, and in the locality.

7. Climate Change Adaptation

7.1 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.

7.2 General Approach

The first step undertaken was to consult the UK Climate Projections most recent projections (UKCP09)[57] 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[58]. 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.

7.3 Work Package Outputs

7.3.1 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.

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

[58] 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[59]. 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 22 and Figure 23), 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.

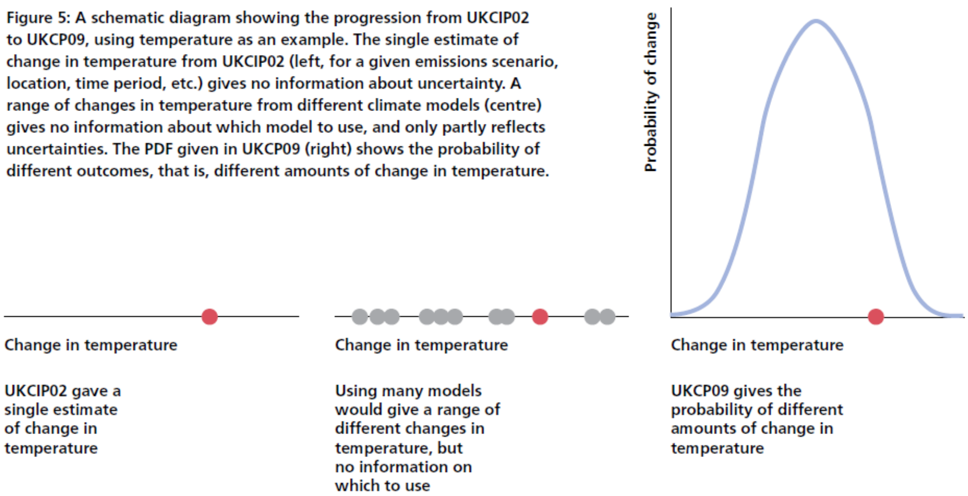

Figure 22: Excerpt from UKCP09 report. Illustration of how probabilistic projections are obtained and the difference between UKCP09 and the previous climate projections UKCIP02.

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

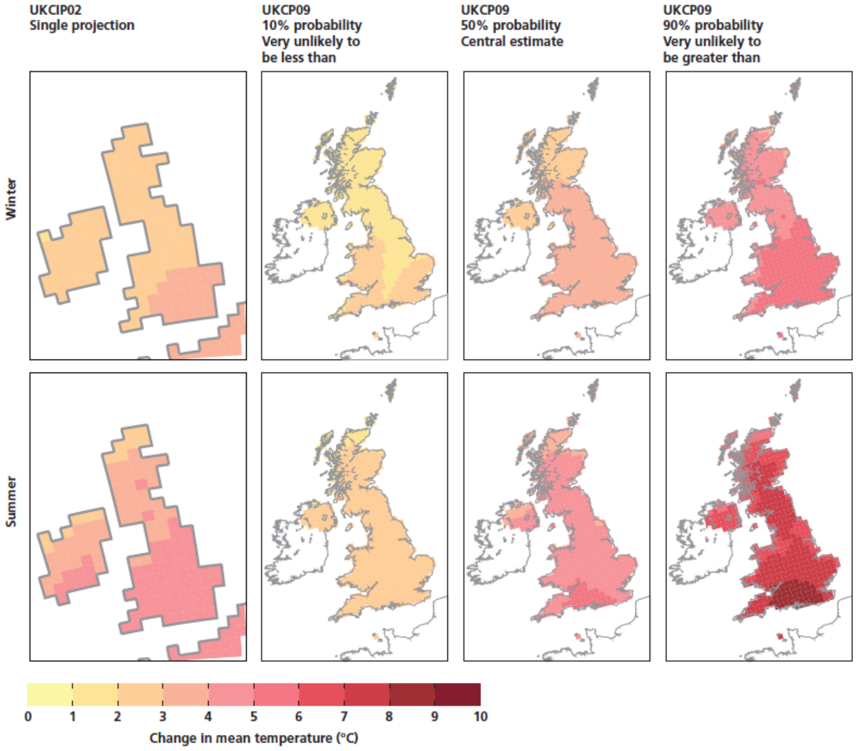

Figure 23: Indicative outputs from UKCP09 and how they differ from UKCIP02.

The changes to key environmental parameters under the "High" emissions scenario for a range of probabilities are shown in Table 26. These are shown mapped for projected changes to summer temperature, winter and summer precipitation, water stress, and soil shrinkage in Figure 24 to Figure 28.

Table 26: 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 1ºC	2 to 3ºC	3 to 4ºC
		2080s	1 to 2ºC	2 to 3ºC	4 to 5ºC
	Mean	2050s	0 to 1ºC	2 to 3ºC	2 to 3ºC
		2080s	1 to 2ºC	2 to 3ºC	3 to 4ºC
	Mean Maximum	2050s	1 to 2ºC	3 to 4ºC	6 to 7ºC
		2080s	2 to 3ºC	5 to 6ºC	9 to 10ºC
	Warmest Day	2050s	-2 to 0ºC	2 to 4ºC	8 to 10ºC
		2080s	-2 to 0ºC	4 to 6ºC	10 to 12ºC
Change in Winter Temperatures	Mean Minimum	2050s	1 to 2ºC	2 to 3ºC	4 to 5ºC
		2080s	1 to 2ºC	3 to 4ºC	5 to 6ºC
	Mean	2050s	1 to 2ºC	2 to 3ºC	3 to 4ºC
		2080s	1 to 2ºC	3 to 4ºC	5 to 6ºC
	Mean Maximum	2050s	0 to 1ºC	2 to 3ºC	3 to 4ºC
		2080s	1 to 2ºC	2 to 3ºC	5 to 6ºC
% 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%

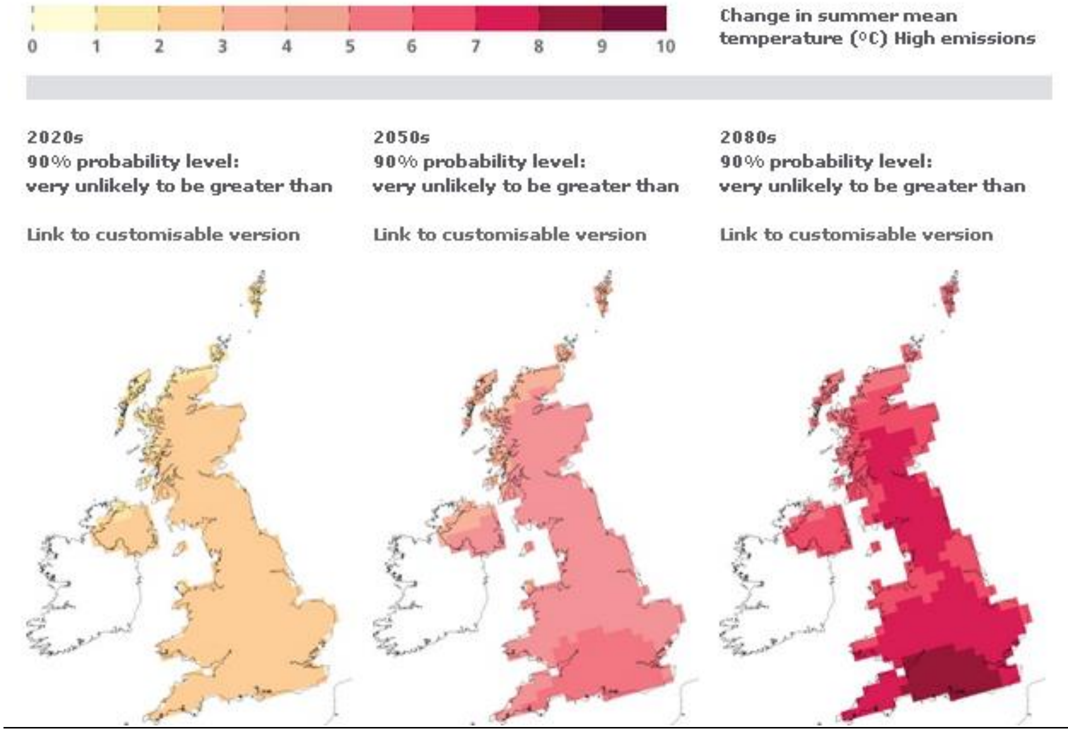

Figure 24: Changes in summer mean temperature under the High emissions scenario at the 90% probability level i.e. Very unlikely to be exceeded (Source: UKCP09)

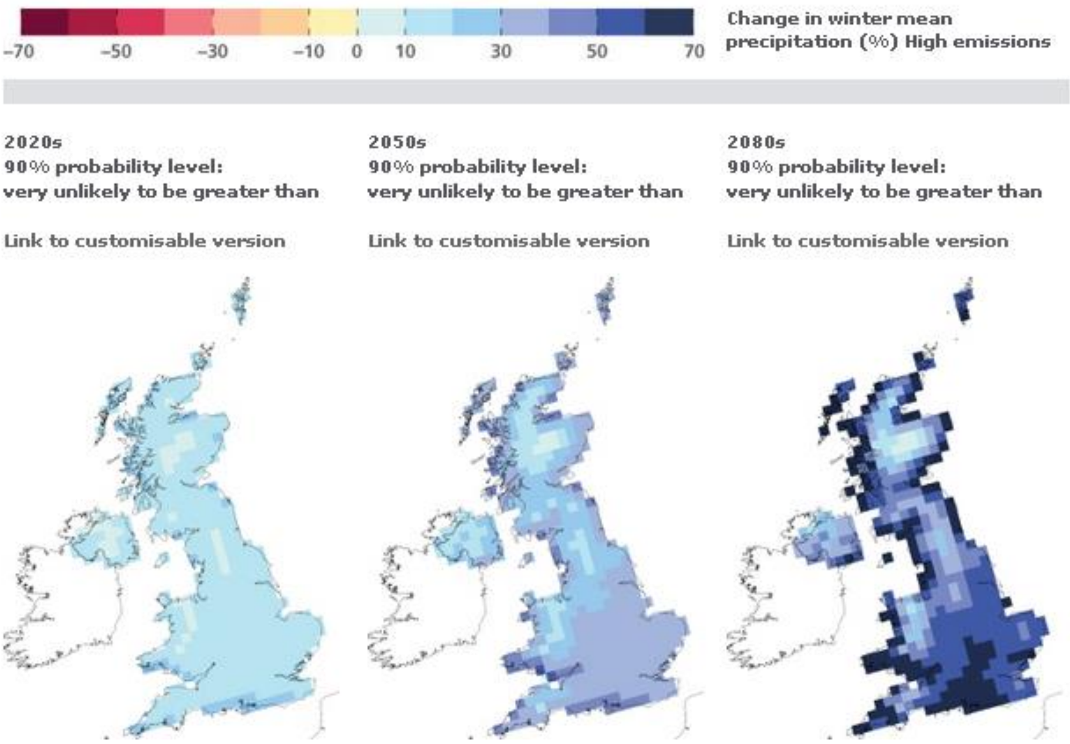

Figure 25: Changes in winter mean precipitation under the High emissions scenario at the 90% probability level i.e. Very unlikely to be exceeded (Source: UKCP09)

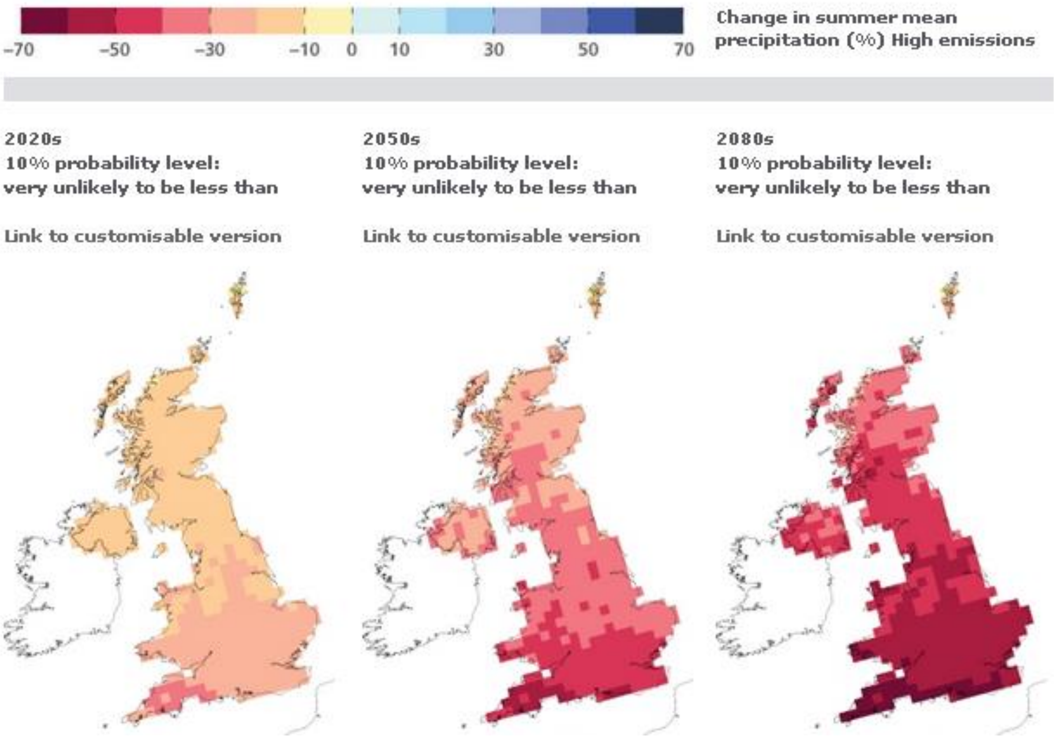

Figure 26: Changes in summer mean precipitation under the High emissions scenario at the 10% probability level i.e. Very unlikely to be less than (Source: UKCP09)

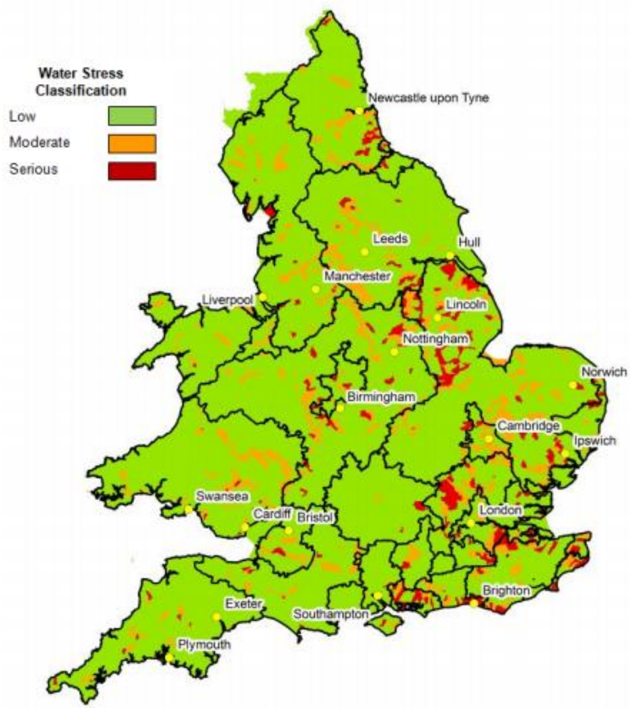

Figure 27: Areas of water stress in England and Wales at a water body scale (Source: Environment Agency[60])

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

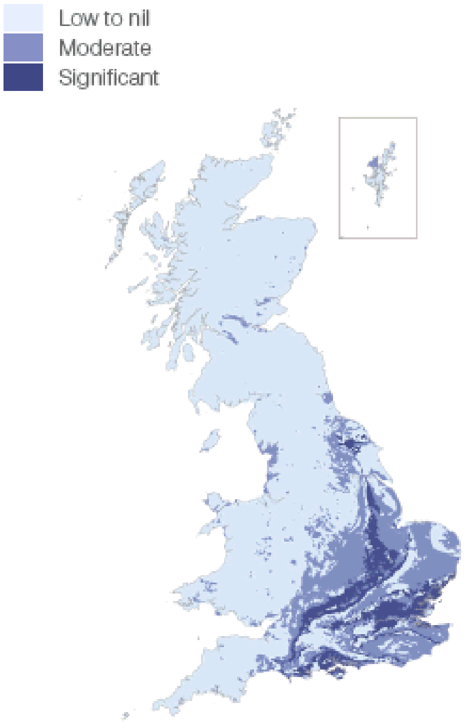

Figure 28: The risk of subsidence due to soil shrinkage (IUK[61])

7.3.2 Impacts of Climate Change on the GESP Area

The IUK report on designing for future climate change[58] 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

[61] 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 28) 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[61] 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.

7.3.3 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 29 to Figure 31).

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	
(sun icon)	Hotter, drier summers
(cloud icon)	Warmer, wetter winters
(warning icon)	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time*	
(quarter icon)	Short – 10 years
(half icon)	Medium – 25 years
(three-quarter icon)	Long – 50 years

Climate	Design opportunities	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**		
Hotter, drier summers	Shading – manufactured	P	P	S	S	S				P	S	S		S	P		S					Short	Medium	
Hotter, drier summers	Shading – building form	P	P	S	S	S				P	S	S		S	P		S							Long
Hotter, drier summers	Glass technologies	P	P	S	S	S				P	S	S			P		S						Medium	
Hotter, drier summers	Film technologies	P	P	S	S	S				P	S	S			P		S					Short		
Hotter, drier summers	Green roofs / transpiration cooling	P	P	S	S	S				P	S	S			P		S						Medium	Long
Hotter, drier summers	Shading – planting	P	P	S	S	S				P	S	S			P		S					Short	Medium	Long
Hotter, drier summers	Reflective materials	P	P	S	S	S				P	S	S			P		S					Short	Medium	
Hotter, drier summers	Conflict between maximising daylight and overheating (mitigation vs adaptation)	P	P	S	S	S				P	S	S			P		S					Short	Medium	Long
Hotter, drier summers	Secure and bug-free night ventilation	P	P	P	P	P				P	S	S			P		S					Short	Medium	
Hotter, drier summers	Interrelationship with noise and air pollution	P	P	P	P	P				P	S	S			P		S						Medium	Long
Hotter, drier summers	Interrelationship with ceiling height	P	P	P	P	P				P	S	S			P		S						Medium	Long
Hotter, drier summers	Role of thermal mass in significantly warmer climate	P	P	P	P	P				P	S	S			P		S							Long
Hotter, drier summers	Enhancing thermal mass in lightweight construction	P	P	P	P	P				P	S	S			P		S						Medium	Long
Hotter, drier summers	Energy efficient / renewable powered cooling systems	P	P	P	P	P				P	S	S			P		S						Medium	
Hotter, drier summers	Groundwater cooling	P	P	S	S	S				P	S	S			P	S	S		P				Medium	
Hotter, drier summers	Enhanced control systems – peak lopping	P	P	S	S	S				P	S	S			P		S					Short	Medium	
Hotter, drier summers	Maximum temperature legislation	P	P	P	P	P				P	S	S			P		S						Medium	Long
Climate	**Design opportunities: Keeping cool – external spaces**	**Climate information**																				**Time**		
Hotter, drier summers	Built form – building to building shading	P	P	S	S	S				P	S	S			P		P							Long
Hotter, drier summers	Access to external space – overheating relief	P	P	S	S	S				P	S	S			P		P							Long
Hotter, drier summers	Shade from planting	P	P	S	S	S				P	S	S			P		P					Short	Medium	Long
Hotter, drier summers	Manufactured shading	P	P	S	S	S				P	S	S		S	P		P					Short	Medium	
Hotter, drier summers	Interrelationship with renewables	P	P	S	S	S				P	S	S			P		P						Medium	
Hotter, drier summers	Shading parking / transport infrastructure	P	P	S	S	S				P	S	S			P		P					Short	Medium	
Hotter, drier summers	Role of water – landscape / swimming pools	P	P	S	S	S				P	S	S			P		P				S		Medium	Long
Climate	**Design issue and opportunities: Keeping warm**	**Climate information**																				**Time**		
Warmer, wetter winters	Building fabric insulation standards						P	P					S	S	P								Medium	Long
Warmer, wetter winters	Relevance of heat reclaim systems						P	P					S	S	P								Medium	
Warmer, wetter winters	Heating appliance design for minimal heating – hot water load as design driver						P	P					S	S	P							Short	Medium	

Figure 29: 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	Climate information	Time*
Hotter, drier summers	P – Primary issue	Short – 10 years
Warmer, wetter winters	S – Secondary issue	Medium – 25 years
More extreme events		Long – 50 years

Climate	Item	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	**Structural stability – below ground**																					
Hotter, drier summers; Warmer, wetter winters; More extreme events	Foundation design – subsidence / heave / soils / regions													S		P	P	S	S	S	S	Long
Hotter, drier summers; Warmer, wetter winters; More extreme events	Underpinning													S		P	P	S	S	S	S	Long
Hotter, drier summers; Warmer, wetter winters; More extreme events	Retaining wall and slope stability															P	P	S	P	P	P	Long
Climate	**Structural stability – above ground**																					
More extreme events	Lateral stability – wind loading standards													P								Long
Warmer, wetter winters; More extreme events	Loading from ponding													S					S	P	P	Long
Climate	**Fixings and weatherproofing**																					
More extreme events	Fixing standards – walls, roofs													P							P	Medium; Long
More extreme events	Detail design for extremes – wind – 3-step approach													P							P	Medium; Long
More extreme events	Lightning strikes (storm intensity)											P		P				P			P	Medium; Long
More extreme events	Tanking / underground tanks in relation to water table – contamination, buoyancy, pressure																		P	P	P	Medium; Long
More extreme events	Detail design for extremes – rain – thresholds / joints													P						S	P	Medium; Long
Climate	**Materials behaviour**																					
Warmer, wetter winters; More extreme events	Effect of extended wetting – permeability, rotting, weight														S				P	P	P	Short; Medium
Hotter, drier summers	Effect of extended heat / UV – drying out, shrinkage, expansion, de-lamination, softening, reflection, admittance, colour fastness	S	P	P	S										P							Short; Medium
More extreme events	Performance in extremes – wind – air tightness, strength, suction / pressure																	S	S	S	P	Short; Medium
Warmer, wetter winters; More extreme events	Performance in extremes – rain																		S	P	P	Short; Medium
Climate	**Work on site**																					
Hotter, drier summers	Temperature limitations for building processes		P	P	S	S									P							Short
Hotter, drier summers; Warmer, wetter winters; More extreme events	Stability during construction													P							S	Short
Hotter, drier summers; Warmer, wetter winters; More extreme events	Inclement winter weather – rain (reduced freezing?)																		P	P	P	Short
Hotter, drier summers	Working conditions – site accommodation	S	P	P	S	S				S				S	P						S	Short
Hotter, drier summers	Working conditions – internal conditions in incomplete / unserviced buildings (overlap with robustness in use)	S	P	P	S	S				S					P							Short

Figure 30: 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

Climate: Hotter, drier summers	Climate: Warmer, wetter winters	Climate: More extreme events	Design measure	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: Short – 10 years	Time: Medium – 25 years	Time: Long – 50 years
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 31: 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[62]. 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[63]. 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[64]) 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[65]. 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[66] 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

[62] CIBSE 2017, TM59: Design methodology for the assessment of overheating risk in homes
[63] CIBSE 2013, TM52: The limits of thermal comfort: avoiding overheating in European buildings
[64] CIBSE 2009, TM48: Use of climate change scenarios for building simulation: The CIBSE future weather years
[65] https://www.gov.uk/guidance/flood-risk-and-coastal-change
[66] 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.

7.3.4 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[67] 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[68] 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[69] 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;

[67] http://www.arcc-network.org.uk/design-for-future-climate/
[68] https://connect.innovateuk.org/web/design-for-future-climate/projects-outputs
[69] 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 27. 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 27: 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.

7.3.5 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.

8. Economic Impact of Building and Standards and Renewables

8.1 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.

8.2 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 4 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[70] 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 4 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[71] 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[72] 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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[70] The Economic Contribution of the Renewable Energy and Energy Efficiency Sectors in the South West of England, DTZ for RegenSW 2010

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

[72] 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[73]. 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[74].

8.3 Work Package Outputs

The impact of building standards and taking up the renewable energy resource is shown in Table 28. 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[75].

Table 28: 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%

8.4 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%.

[73] BEIS 2016 Electricity Generation Costs, from Table 19.
[74] Greater Exeter Economic Development Needs Assessment, Hardisty Jones Associates 2017
[75] 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[43] 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[76] 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.

[76] "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.

The tool is shown overleaf.

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

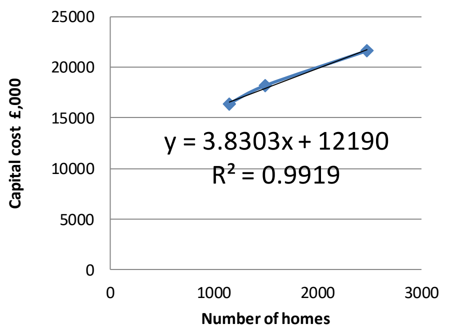
RESULT: ASSESS VIABILITY

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

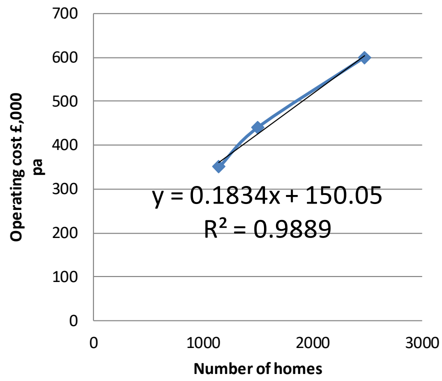
Capex model

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

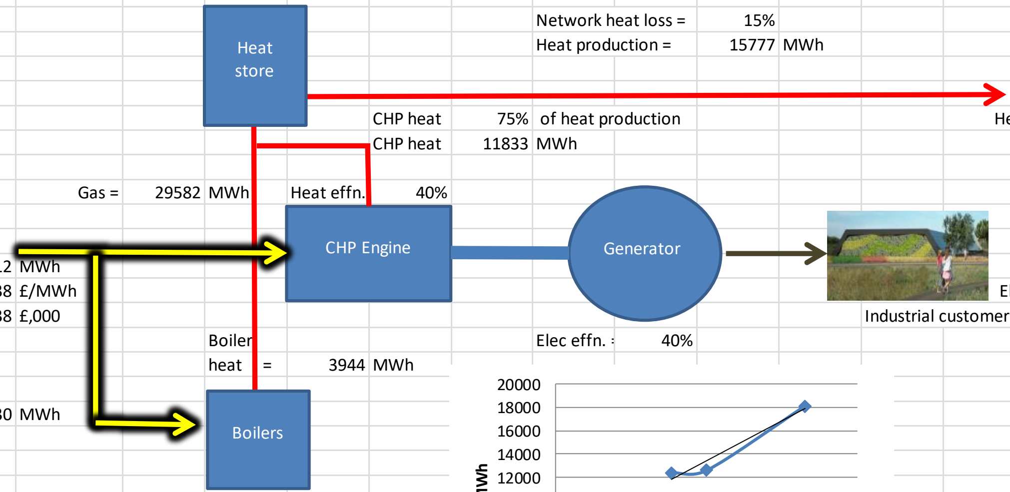


Non-fuel opex model

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

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

Elec effn. = 40%

Boiler heat = 3944 MWh

Gas = 4930 MWh

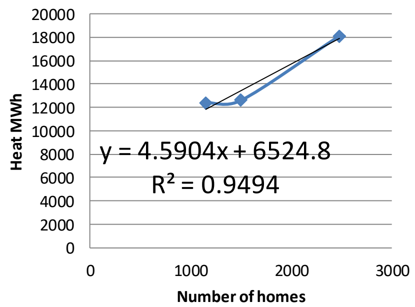
Effn. = 80%

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

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

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



APPENDIX C: Identification of Heat Loads for the Greater Exeter Strategic Plan

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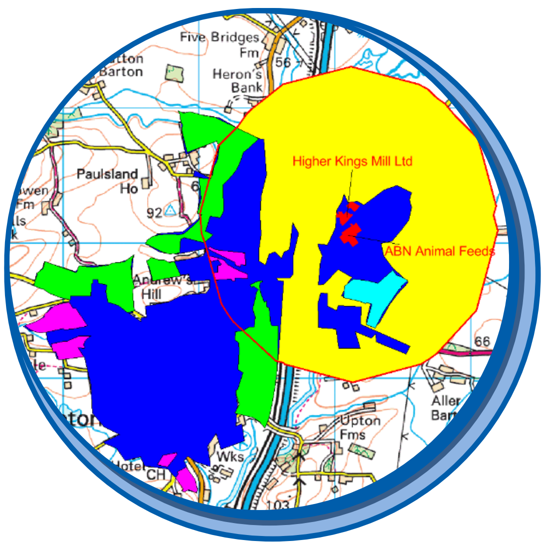
Identification of Heat Loads for the Greater Exeter Strategic Plan

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
Report Number:	Internal Document 929
Publication Date:	April 2017

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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[77] and mains gas[78]. 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 MW_e and 2 MW_{th}, which equate to annual consumption of 4.38 GW h for electricity and 17.52 GW h for gas.

[77] **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.

[78] **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[79] 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[80], the National Atmospheric Emissions Inventory register of large point sources[81] and the EU Emissions Trading Scheme National Allocation Tables[82].
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[83] 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 32 and Figure 33 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 34 and Figure 35. 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[84] in Figure 36.

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[79] **National Heat Map.** DECC, 2012. https://www.cse.org.uk/projects/view/1183. Accessed 21/3/2017.
[80] **OPRA.** Environment Agency, 2015. https://data.gov.uk/dataset/opra. Accessed 10/4/2017.
[81] **Emissions from NAEI large point sources.** National Atmospheric Emissions Inventory, 2014. http://naei.defra.gov.uk/data/map-large-source. Accessed 19/4/2017.
[82] **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.
[83] **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.
[84] **Postcode level gas estimates: 2015 (experimental).** BEIS, 2017. https://www.gov.uk/government/statistics/postcode-level-gas-estimates-2015-experimental. Accessed 24/4/2017.

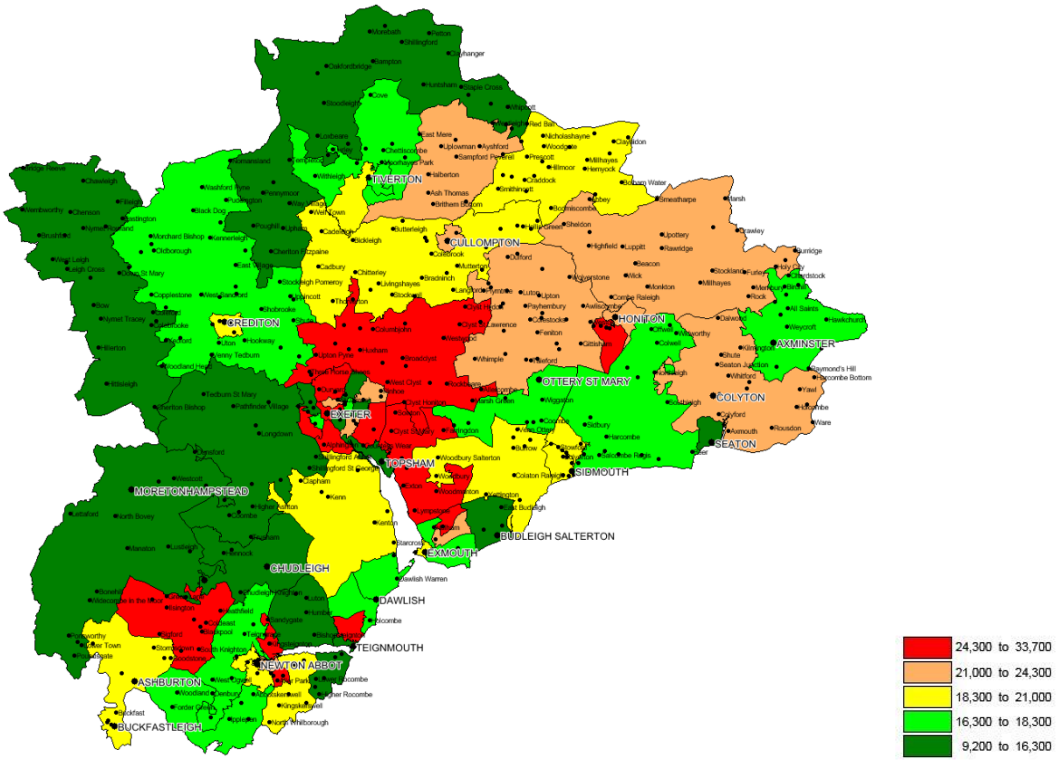

Figure 32. Mean electricity consumption in each MSOA (in kW h per meter per annum).

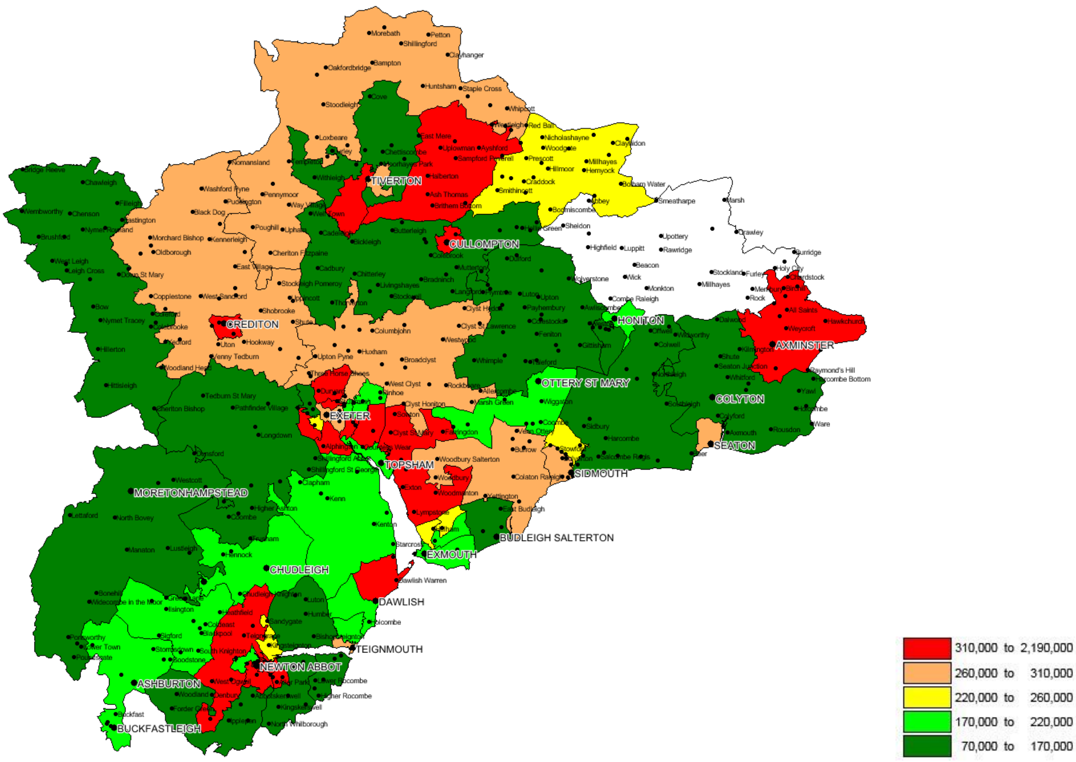

Figure 33. Mean gas consumption in each MSOA (in kW h per meter per annum). No data are available for the MSOA centred on Rawridge; it is assumed that mains gas consumption is negligible in this rural area.

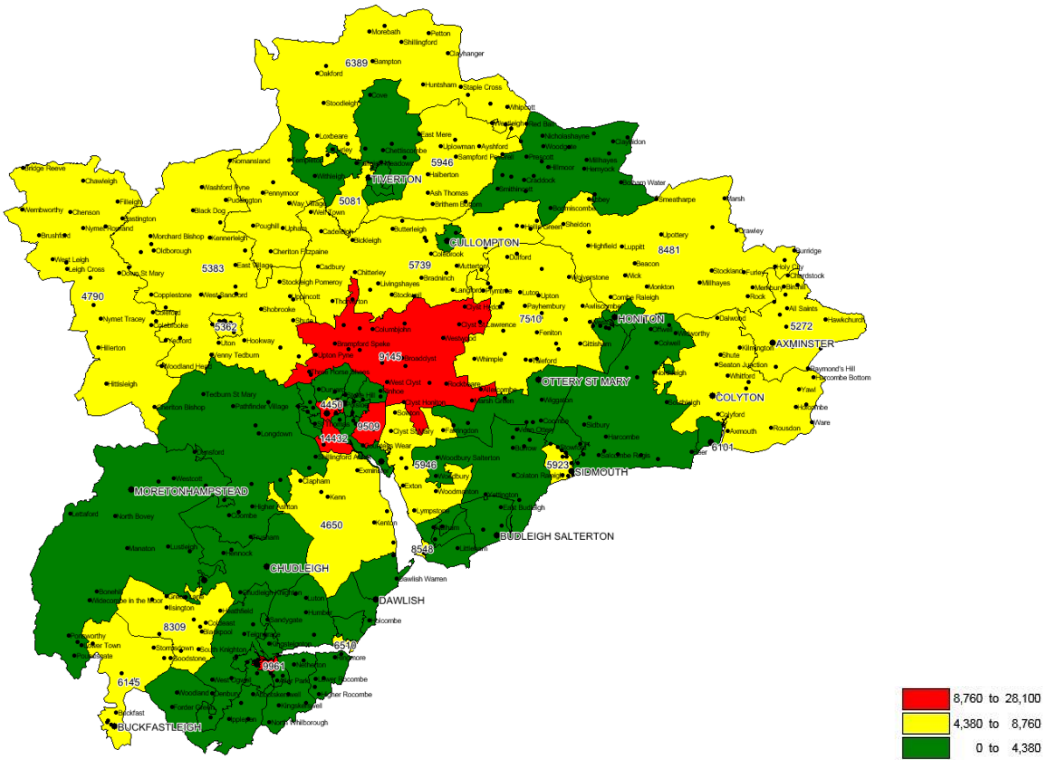

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Figure 34. Estimated electricity consumed by large consumers in each MSOA (in MW h per MSOA per annum). Consumption estimates are indicated numerically where they exceed the 4.38 GW h threshold.

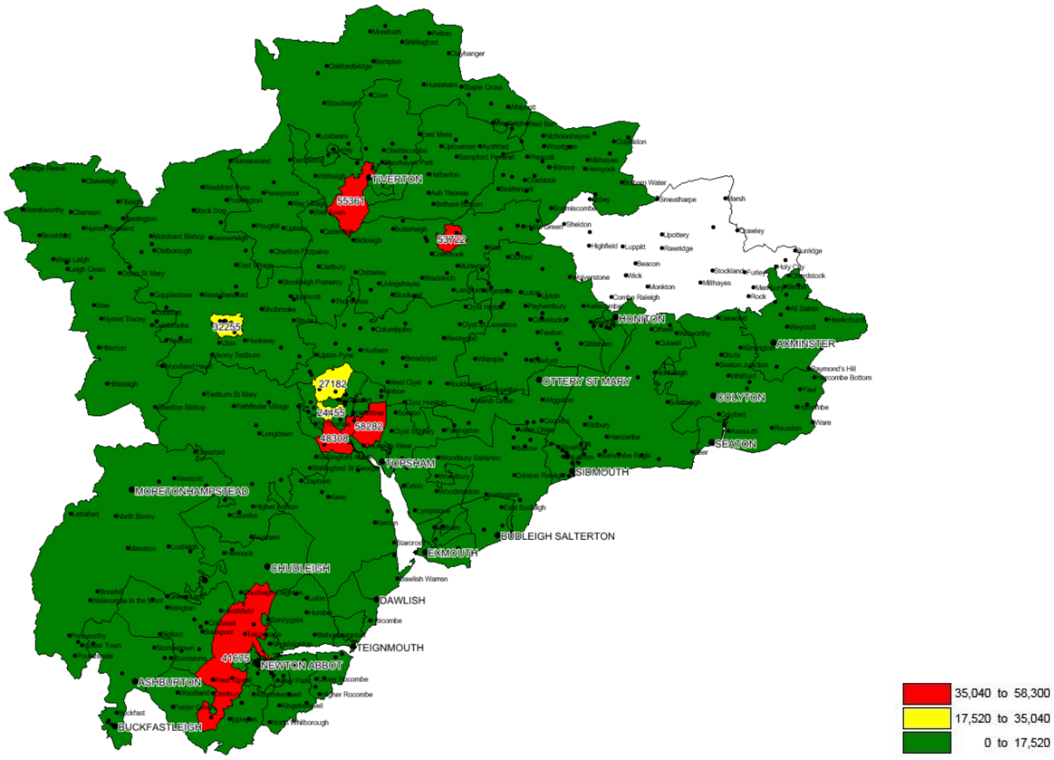

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Figure 35. Estimated gas consumed by large consumers in each MSOA (in MW h per MSOA per annum). Consumption estimates are indicated numerically where they exceed the 17.52 GW h threshold. No data are available for the MSOA centred on Rawridge; it is assumed that mains gas consumption is negligible in this rural area.

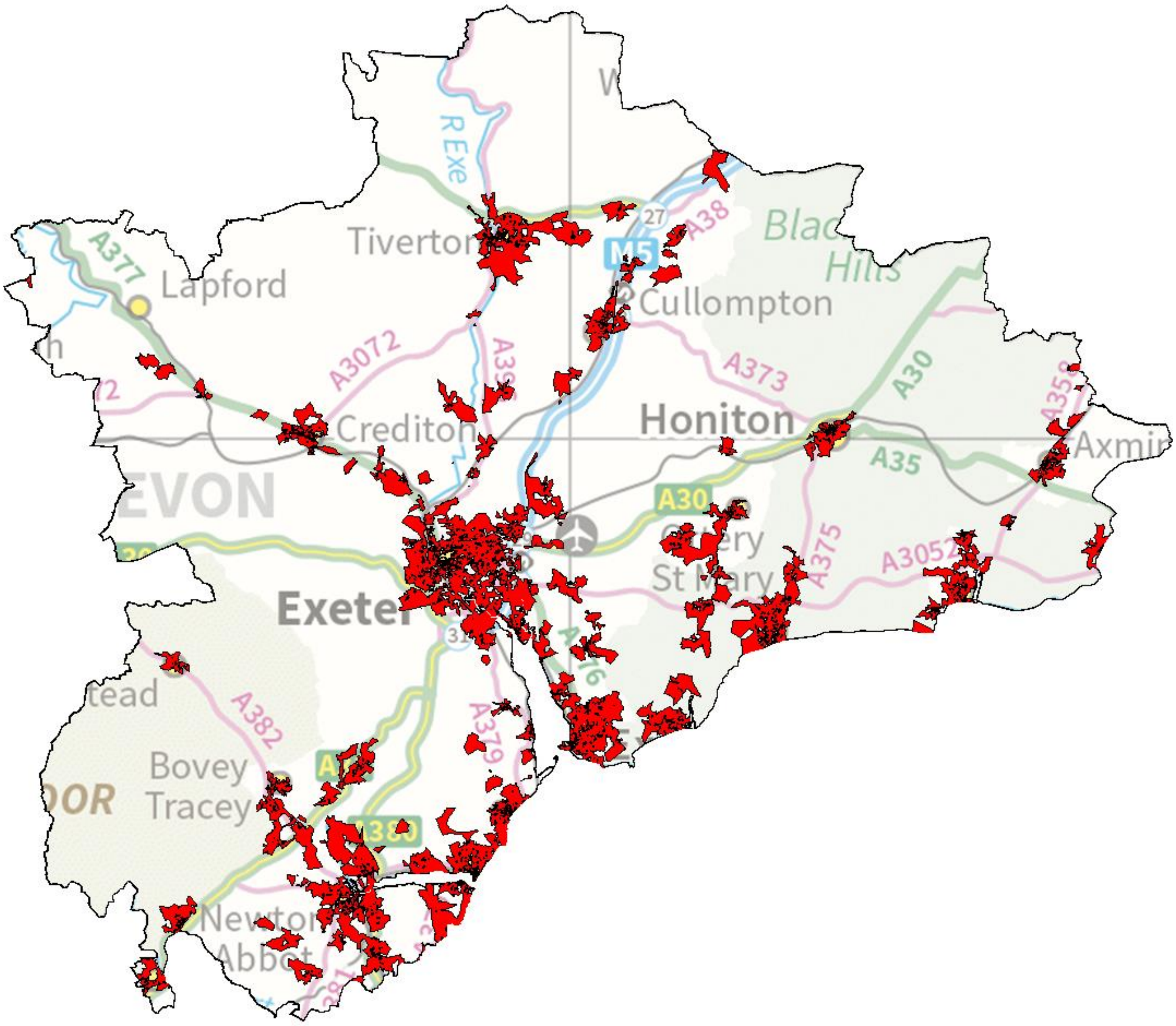

Figure 36. Extent of the mains gas network, based on postcodes containing at least one gas meter.

Examination of the areas indicating large consumers of electricity and gas has led to Table 29.

Table 29. 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 Met Office	Sowton	58,282	9,509[85]
Heathcoat Fabrics Aston Manor Brewery	Tiverton	55,361	5,081
Higher Kings Papermill ABN Animal Feed	Cullompton	53,722	4,084
RD&E Hospital	Wonford	49,101	1,473
SW Metal Finishing	Marsh Barton	48,308	14,432
Seale Hayne Ringslade Clay Works Preston Manor Clay Works East Gold Marshes Clay Works	Howton Barton	41,675	1,339
Crediton Dairy South West Galvanizers	Crediton	32,255	5,362
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*[86]	*9,145*[86]
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 37, 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.

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

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

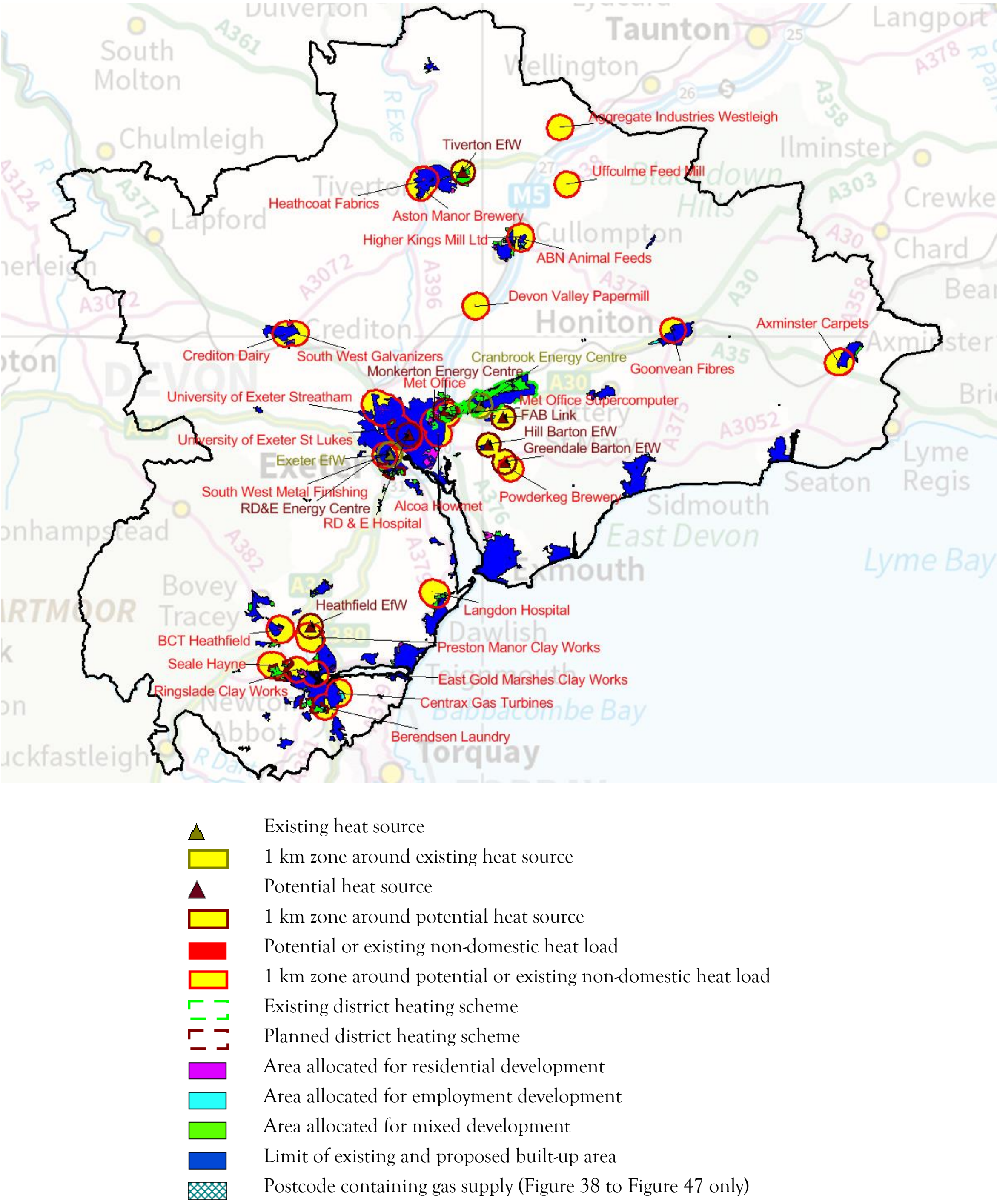

Figure 37. Identified sites with heat loads or heat generation potential, with existing allocated areas for development.

Figure 38 to Figure 47 indicate individual areas in greater detail. Note the extent of the gas grid may be overestimated due to the size of postcode areas[87].

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

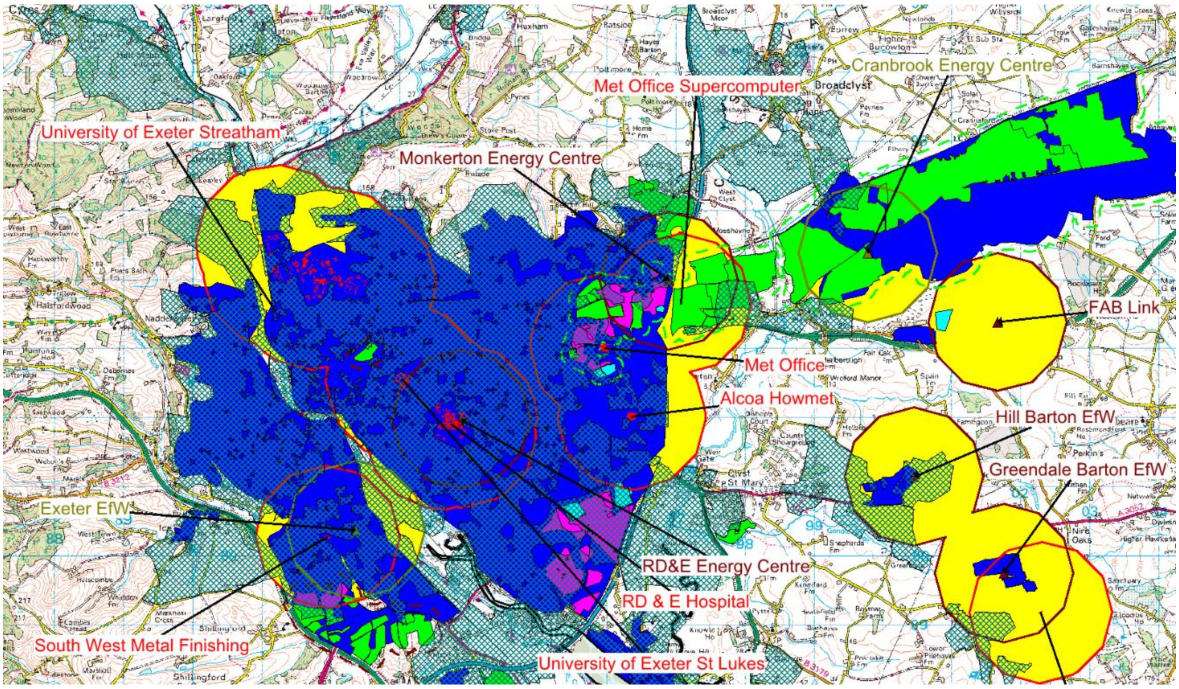

Figure 38. Identified sites with heat loads or heat generation potential in Exeter, with existing allocated areas for development (for legend see Figure 37).

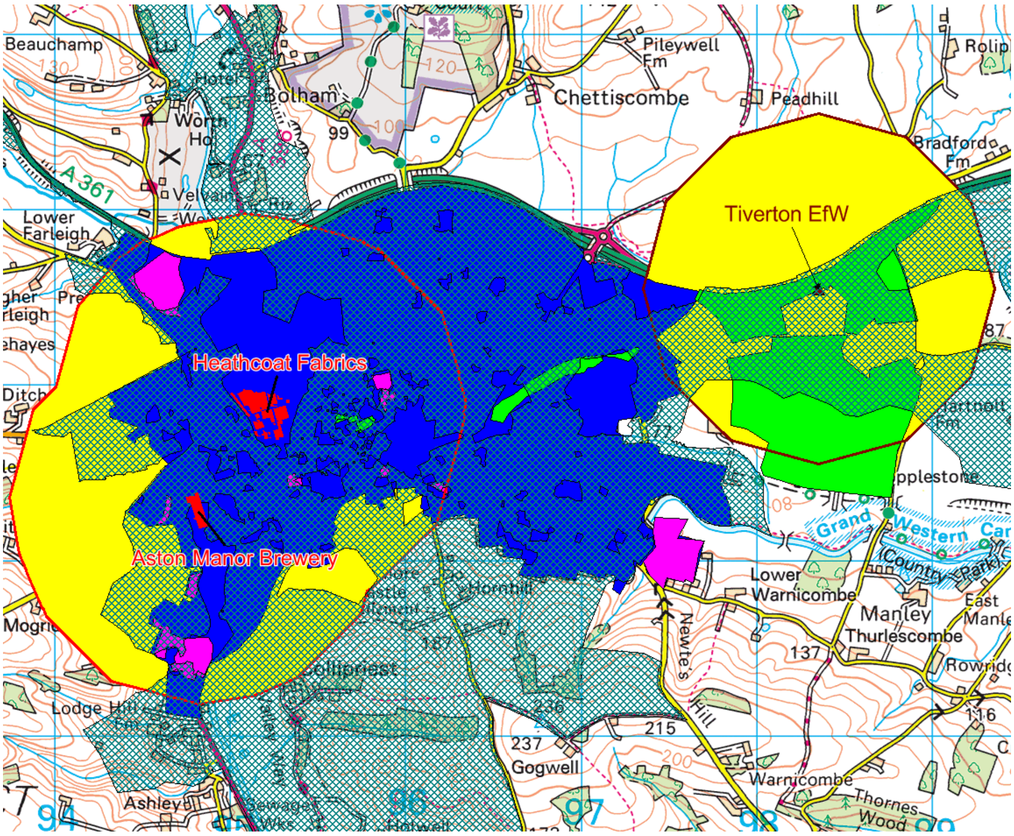

Figure 39. Identified sites with heat loads or heat generation potential in Tiverton, with existing allocated areas for development (for legend see Figure 37).

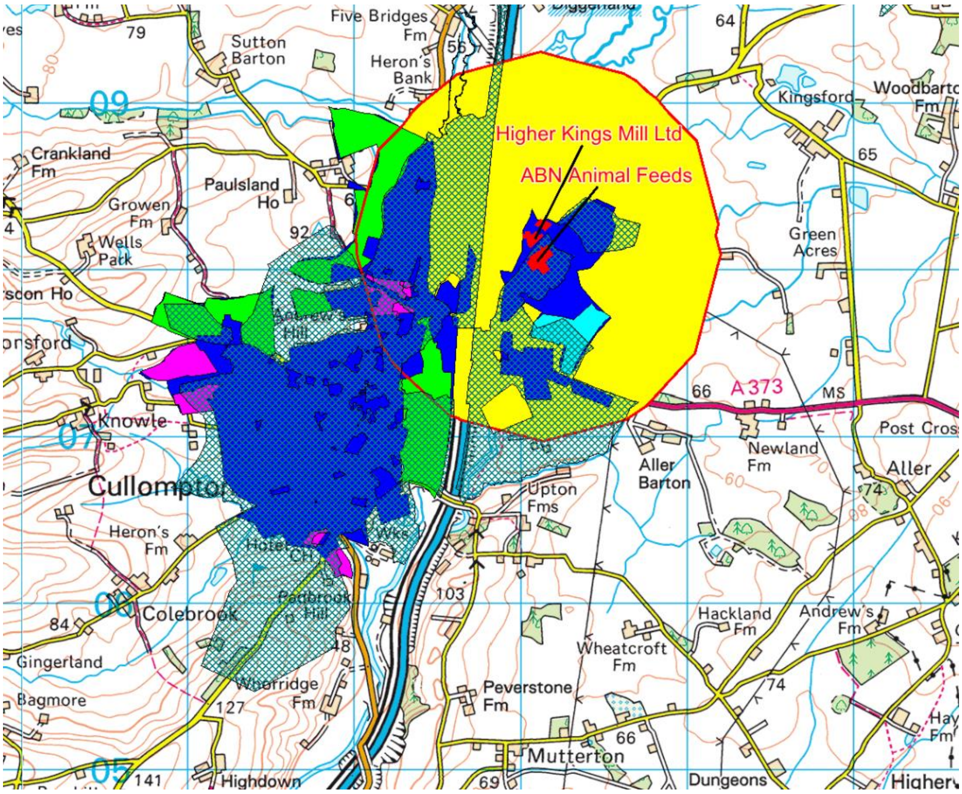

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Figure 40. Identified sites with heat loads or heat generation potential in Cullompton, with existing allocated areas for development (for legend see Figure 37).

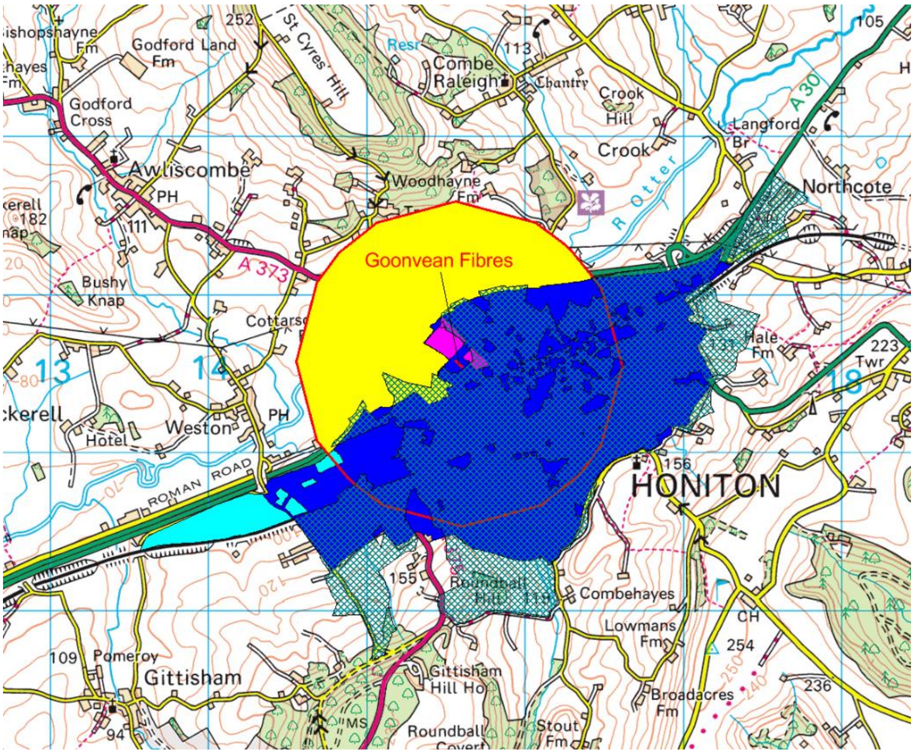

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Figure 41. Identified sites with heat loads or heat generation potential in Honiton, with existing allocated areas for development (for legend see Figure 37).

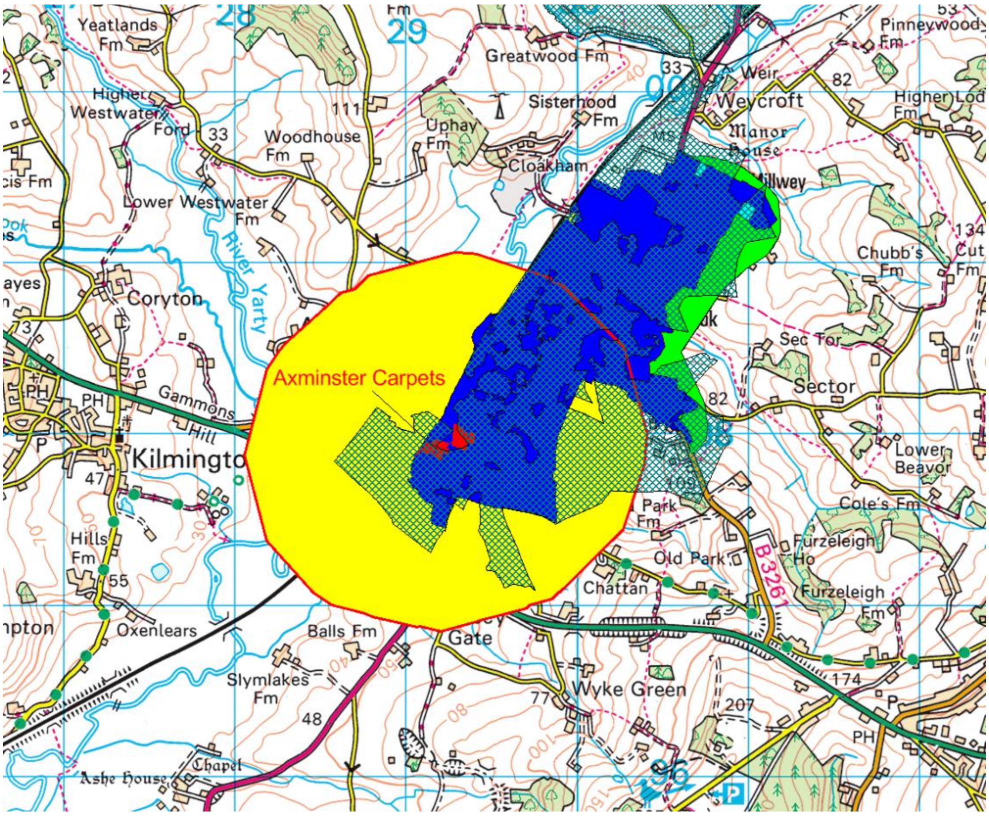

Figure 42. Identified sites with heat loads or heat generation potential in Axminster, with existing allocated areas for development (for legend see Figure 37).

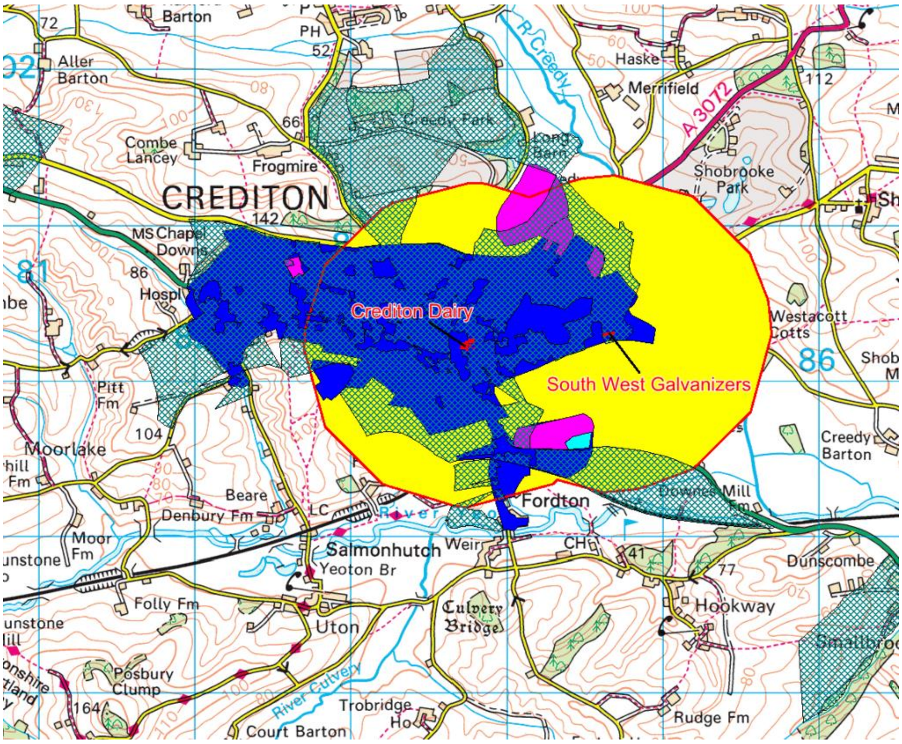

Figure 43. Identified sites with heat loads or heat generation potential in Crediton, with existing allocated areas for development (for legend see Figure 37).

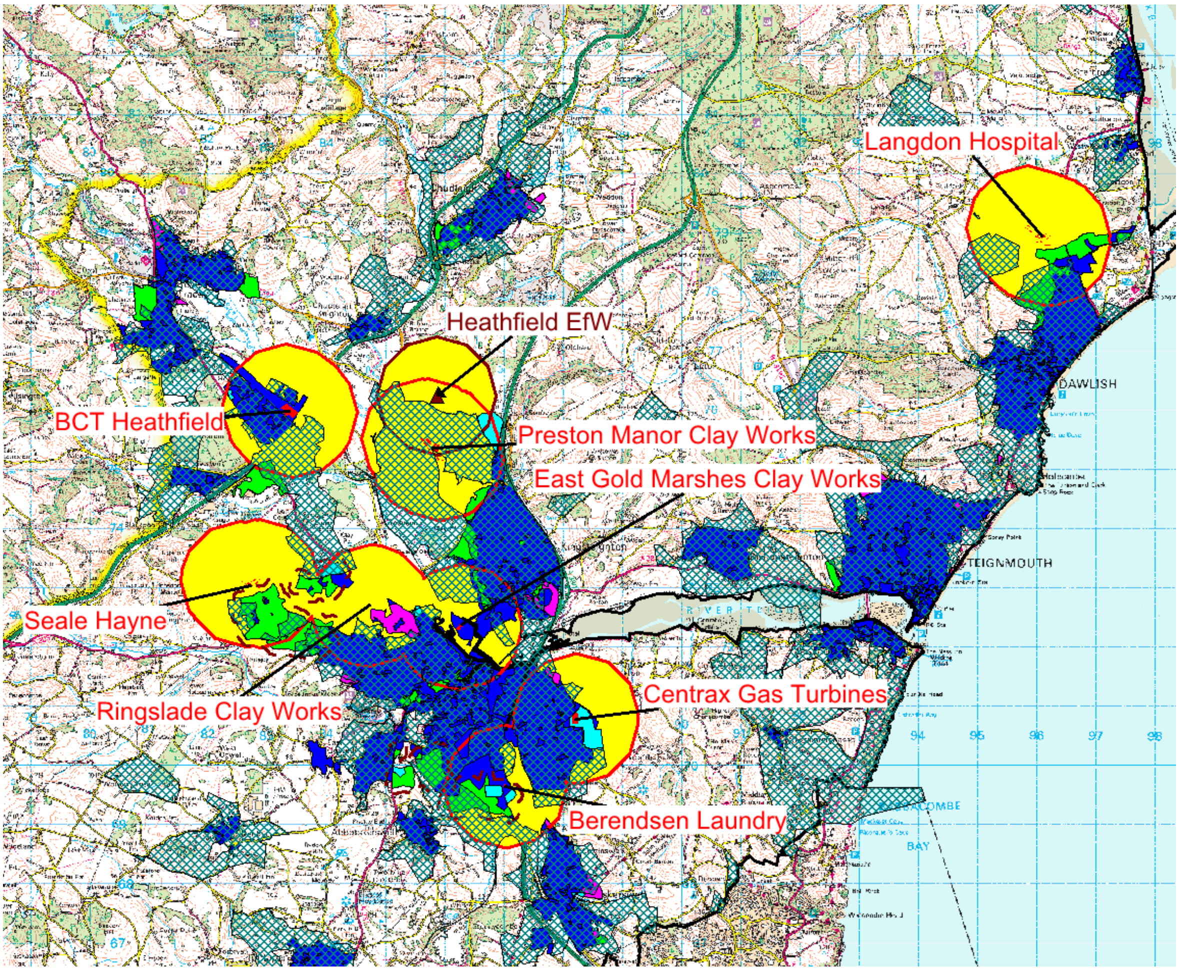

Figure 44. Identified sites with heat loads or heat generation potential in Newton Abbot and Dawlish, with existing allocated areas for development (for legend see Figure 37).

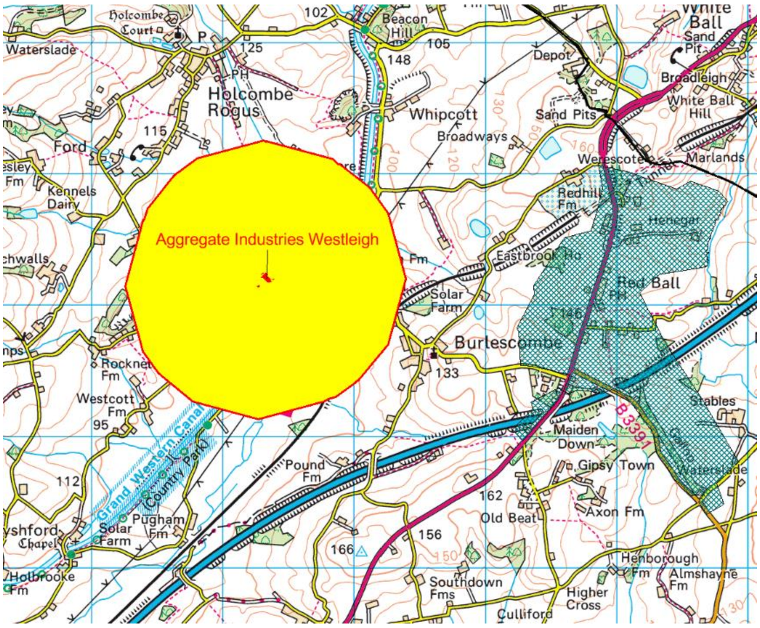

Figure 45. Identified sites with heat loads or heat generation potential north of Tiverton, with existing allocated areas for development (for legend see Figure 37).

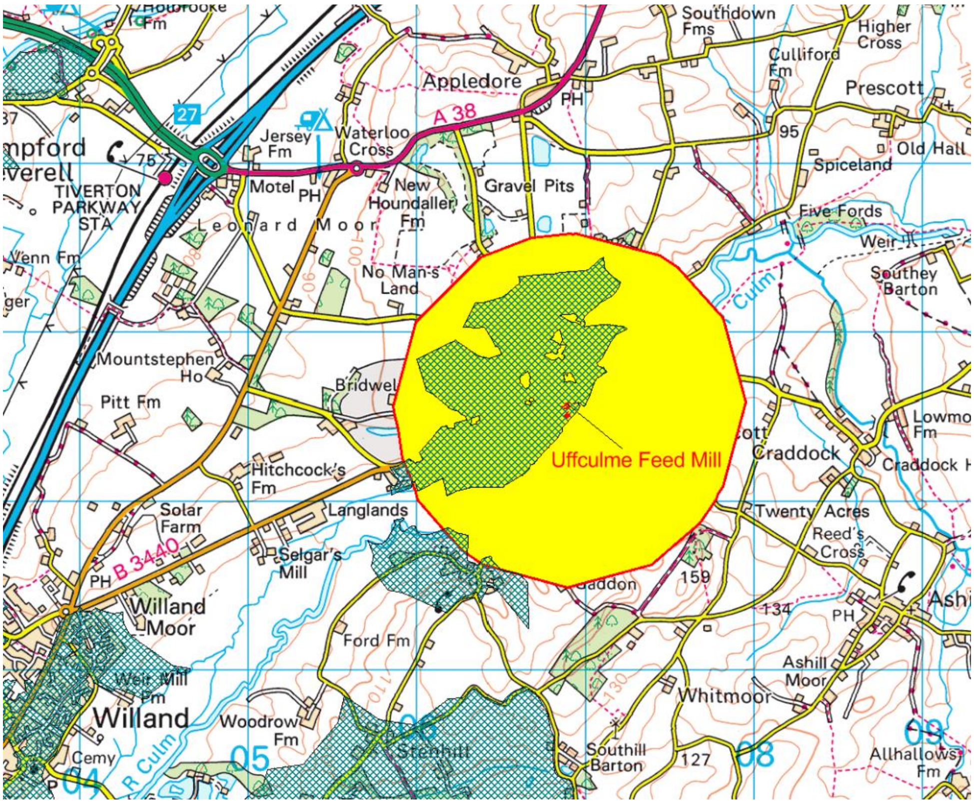

Figure 46. Identified sites with heat loads or heat generation potential in Uffculme, with existing allocated areas for development (for legend see Figure 37).

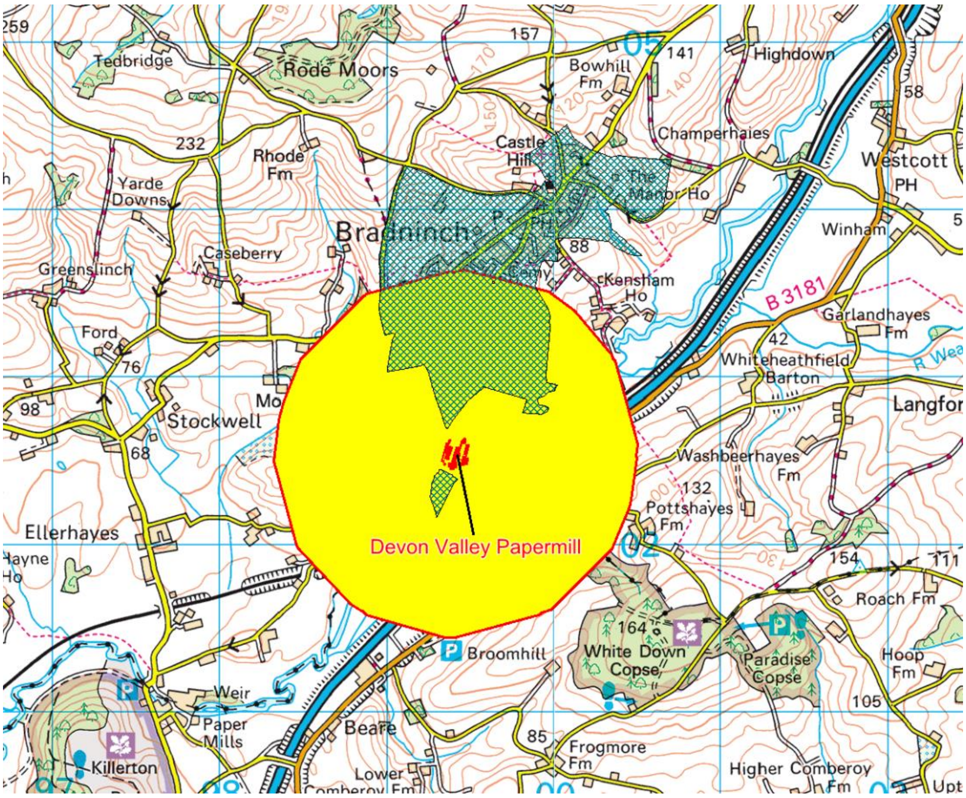

Figure 47. Identified sites with heat loads or heat generation potential in Hele and Bradninch, with existing allocated areas for development (for legend see Figure 37).

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.