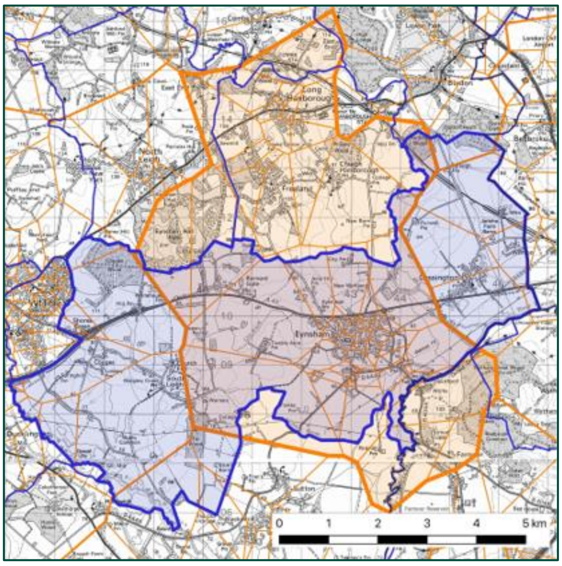
Oxfordshire Cotswolds Garden Village Energy Plan

MAY 2020



UNIVERSITY OF OXFORD

EDF ENERGY

OXFORDSHIRE COUNTY COUNCIL

Version	
1	Internal working draft
2	Draft for comment
3.0	Revised draft incorporating feedback from the Energy Plan working group
3.1	Revised draft for organisational sign off
4	Draft for circulation to LEO Partners
5	**Final report**

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With thanks to the Energy Plan Working Group for all their guidance and contributions:

- West Oxfordshire District Council
- Low Carbon Hub
- Green TEA
- Grosvenor Developments Ltd

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Executive Summary

This Energy Plan forms part of the evidence base developed to support the Oxfordshire Cotswolds Garden Village Area Action Plan. It responds to the local and national commitments to address climate change and provides a framework to aid the Garden Village development achieve net zero carbon emissions (taken here to mean emissions from operational energy use, including energy for heating and cooling, cooking, lighting and plug-loads). A set of principles and targets are established (set in the context of International, National, and Local Plan policies) to both formulate and guide subsequent energy master-planning by addressing building energy use and energy supply from the outset.

The Energy Plan sets out as its vision:

> *"The Oxfordshire Cotswolds Garden Village is an exemplar net zero carbon, energy positive development which meets the challenges of climate change head on.*
>
> *Successful collaboration between key stakeholders (including local community groups, Local Authorities, Developers) guides the development throughout planning, construction and lifetime of the site.*
>
> *Sustainable construction reduces embodied carbon throughout the Village, whilst best practice and use of innovative technologies minimise the energy needed to heat and power homes and businesses.*
>
> *Local renewable generation and smart energy management solutions meet the remaining energy demand and catalyse carbon reductions across the wider Eynsham area whilst contributing to the national decarbonisation and climate change response*."

To achieve this vision homes in the Garden Village should be designed to enable them to achieve net zero carbon in operation; measures to meet this requirement should follow the energy hierarchy. The following principles are established:

1. Minimising the operational energy demand of the buildings is a priority. All new homes should meet as a minimum, fabric specifications in line with those set out in the Future Homes Standard Consultation 2019 Impact Assessment (Table 4).
2. Fit for the future – no fossil fuels burnt on site for heat or power. This will be achieved through the use of low carbon heating systems. Heat pumps are recommended to ensure householders are not adversely impacted by the (current) higher unit cost of electricity.
3. Onsite renewable generation meets a minimum of 50% of the annual residential building energy demand, with use of rooftop solar maximised in line with Eynsham Neighbourhood Plan policy. Viability issues should be addressed through exploration

of innovative funding and supply models, including options to incorporate community energy. Opportunities to embed a smart local energy system within the Garden Village (with options to include the wider energy plan area) should be developed through continuing collaboration with Project LEO (Local Energy Oxfordshire).

4. Energy positive: Opportunities to extend local renewables to generate more energy on or close to the site than required in the Garden Village should be considered, offering an opportunity for income generation and to contribute to wider local and national decarbonisation. This recommendation – and opportunity - is based on the success of the county's thriving community energy sector spearheaded by the Low Carbon Hub and local community groups.
5. Where the carbon emission targets cannot be met through on-site measures any shortfall must be provided through off-site measures to be agreed with the District Council (this should be a cash in lieu contribution which can be ringfenced to deliver carbon savings for the benefit of the wider community). There are well developed systems for this approach in use in London valuing a tonne of carbon emissions for a local alternative offset.
6. Requirements for the long-term stewardship of the local energy system (including governance, monitoring and reporting) should be agreed at planning stage.

Energy modelling undertaken by the Energy & Power Group (University of Oxford) and EDF Energy R&D UK demonstrates that it is technically possible for onsite rooftop solar PV to meet the operational electricity (including electrified heat and transport) demand from the planned 2,200 homes on an annual basis. The model does not provide a complete assessment of the optimum strategy for integration of renewable generation at the development; additional options, both on and off site should be explored to go beyond this baseline scenario, increase generation diversity and enable deliverability at a range of scales, from site wide to property specific.

One of the biggest challenges identified in developing the energy plan is that current national policy and regulations do not yet reflect the legally binding national target to achieve net zero carbon emissions by 2050. The principles set out above aim to address this for the Garden Village, and evidence is presented to support West Oxfordshire District Council establish local policies to deliver a net zero carbon development (including examples of policies implemented by other authorities).

A cost benefit analysis prepared for the Committee for Climate Change indicates that delivering homes built to ultra-high energy efficiency standards and fitted with heat pumps costs between 1 to 4% more than one built to current specifications. Further analysis commissioned for this report suggests that costs to deliver a net zero carbon home are between 7.2% and 11.7% more than for a current standard build home. The range reflects the best and worst case scenarios and considers the following elements: timber vs standard construction and cost uplifts to meet improved fabric efficiency and building services (including mechanical ventilation and heat recovery; air source heat pumps; and solar PV). The majority of the uplift (4%) is a result of additional building services (mechanical ventilation and heat recovery and air source heat pumps) and photovoltaic (PV) systems (between 1.1-5.3% dependent on roof design and capacity installed), whilst fabric-related costs increase by just over 2%.

Ongoing collaboration will be required to explore finance models to deliver the energy infrastructure needed and to secure a model for long term management of the energy assets at the Garden Village. Community involvement will be key and options for community ownership of the renewable generation assets should be explored.

The Garden Village development provides a unique opportunity to be a national (and international) exemplar in overcoming both the technical and financial challenges highlighted thanks to wide collaboration and highly engaged local community-energy groups in the wider Eynsham area working alongside Project LEO, a world leading smart local energy system demonstrator project led by the DNO, SSEN.

1 Introduction

1.1 Purpose of this report

This Energy Plan has been prepared by Oxfordshire County Council, in collaboration with EDF Energy R&D UK and the Energy & Power Group (University of Oxford), on behalf of West Oxfordshire District Council and forms part of the evidence base to support the Oxfordshire Cotswolds Garden Village Area Action Plan (AAP).

This report should be read in conjunction with the Submission for Examination version of the AAP. Once adopted, the AAP will form part of the statutory development plan alongside the West Oxfordshire Local Plan 2031 and will be used as the basis for determining any future planning applications for the Garden Village site.

1.2 Background

Land to the north of the A40 near Eynsham has been allocated for development within the West Oxfordshire Local Plan 2031 under Policy EW1 a Strategic Location for Growth (SLG) comprising *"an exemplar development of the highest environmental and design standards based around a mix of compatible uses including housing, employment, transport, new schools and other community and leisure uses"*. One of 14 new villages supported by the Government under its Locally Led Garden Village, Town and City Programme, the Oxfordshire Cotswold Garden Village development will be led by an Area Action Plan (AAP) prepared by West Oxfordshire District Council.

The Garden Village development is likely to include approximately 2,200 dwellings, together with provision of about 40 hectares of business land (anticipated to comprise business space, land for a new Park & Ride, Primary School and community facilities) along with supporting ancillary services.

The Garden City principles set out by the Town and Country Planning Association (TCPA) will guide all aspects of the Oxfordshire Cotswolds Garden Village development and state that ***"New Garden Cities can be and must be exemplars of zero-carbon and energy-positive new development."***[1]

This is particularly pertinent in light of the growing calls for urgent action to address the Climate Emergency recognised nationally and locally following the publication of the

[1] TCPA, 2016. Practical Guides for Creating Successful New Communities Guide 4: Planning for Energy and Climate Change. https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=a5e9d5ae-2d96-41e3-8d66-06d8b699b76d

special report by the Intergovernmental Panel on Climate Change *'Global Warming of 1.5 degrees'* in October 2018[2].

- In June 2019, the UK became the first major economy to adopt a legally binding target to reach net zero carbon emissions by 2050[3]. The Committee on Climate Change states that achieving the net zero target will require full decarbonisation of buildings by 2050.[4]
- Locally, the Oxfordshire Energy Strategy, launched in November 2019, mirrors the national commitment to achieve net zero carbon countywide by 2050.
- All six Oxfordshire Local Authorities have made commitments to reduce emissions. West Oxfordshire District Council agreed a Council Motion in June 2019, stating that:

  "West Oxfordshire District Council recognises the serious and accelerating changes to the world caused by climate change and therefore declares a climate and ecological emergency.

  The Council is determined to be carbon neutral by 2030 and to encourage others in the District to follow its example."[5]

The Garden Village offers a unique and immediate opportunity to act on these climate change commitments, a point reflected in the Oxfordshire Garden Village Preferred Options Consultation paper, section 11 (Climate Change and resilience).

1.3 The Energy Plan

This Energy Plan was developed in collaboration with the Project LEO Consortium (see section 1.4) and a working group with representation from Local Authorities, the Eynsham community and Grosvenor (the land promoters for much of the Garden Village). This proposal was set out within '*Preferred Policy Approach 33 - Decentralised, Renewable and Low Carbon Energy'* of the Preferred Options AAP August 2019***:***

> *"to consider as part of Project LEO, the potential for an integrated, low carbon energy system...to maximise linkages with existing or proposed renewable and low carbon energy infrastructure in the locality."*[6]

The Plan responds to the need for action to meet climate change targets and provides a framework to aid the development at the Oxfordshire Cotswolds Garden Village

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[2] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C*

[3] UK Climate Change Act, 2008: http://www.legislation.gov.uk/ukpga/2008/27/contents

[4] Committee on Climate Change, 2018. Net Zero: The UK's contribution to stopping global warming

[5] West Oxfordshire Climate Emergency Motion, minutes of Council, June 2019. http://tinyurl.com/t94aglt

[6] Oxfordshire Cotswold Garden Village AAP Preferred Options https://www.westoxon.gov.uk/media/2036815/Garden-Village-APP-Preferred-Option-Paper-July-2019.pdf

embrace best practice and innovative solutions to achieve net zero carbon emissions (see Box 1). It establishes a set of principles and targets (set in the context of International, National, and Local Plan policies) to both formulate and guide subsequent energy masterplanning.

Energy modelling presented within this report has been undertaken by the University of Oxford and EDF Energy R&D team. It assesses potential energy demand based on the development scenario set out above; identifies the potential and scale of local renewable generation needed to meet the demand of the development; and offers a pathway to achieve net zero carbon emissions across the Garden Village.

The aim of the model is to demonstrate the feasibility of the targets set out in this Energy Plan. It is not intended be a full technical analysis, nor does it replace the energy modelling (using the standard assessment procedure) which will be required to inform a full energy masterplan for the development.

Box 1 Net Zero Carbon Development, definitions

The UK Green Building Council, working with businesses, trade associations and non-profit organisations, has set a framework to guide the delivery of buildings that are in line with the aims of the Paris Agreement – buildings which are net zero carbon across their life cycle. The framework offers definitions for the two components that make up whole life carbon: emissions from the construction process; and from in-use operational energy (the energy used for heating and cooling, cooking, lighting and plug-loads, but excluding commercial process loads and transport).

Net zero carbon – construction:

> *"When the amount of carbon emissions associated with a building's production and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."*

Net zero carbon – operational energy

> *"the amount of carbon emissions from building operational energy use on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."*

Developers aiming for net zero carbon in construction should also design the building to enable net zero carbon for operational energy.

1.4 Project LEO

Oxfordshire County Council, EDF Energy R&D and the University of Oxford are partners within Project LEO (Local Energy Oxfordshire), one of four national Smart Energy Demonstrator projects funded through the Government's Industrial Strategy Challenge Fund (ISCF) Prospering from the Energy Revolution. The Project is led by Scottish and Southern Electricity Networks (SSEN) and includes Low Carbon Hub, Oxford City Council, Oxford Brookes University, Piclo and Nuvve in addition to the partners listed above.

Project LEO will help lay the foundations to scale up low carbon generation across Oxfordshire by creating a local energy system which develops opportunities to better match local energy supply to local demand (through increased storage or shifting energy demand) and to make better use of the energy generated to free up capacity within the existing infrastructure to support electrification of transport and heat.

Project LEO includes a number of 'plug in projects' which will provide real world pilots across Oxfordshire to trial a range of flexibility and energy services relating to electrical power, transport and heat. Project LEO has identified the new Park and Ride site at the Garden Village development - with its planned solar generation and smart electric vehicle charging infrastructure – as a potential pilot project. The smart charging infrastructure will enable not only recharging of car batteries, but also for electrical energy stored in the electric vehicles to be fed back into the electricity grid to help supply energy at times of peak demand (vehicle to grid).

To make the most of this opportunity and to fully integrate the solar generation and the smart charging capability planned at the Park and Ride into the overall Oxfordshire Cotswold Garden Village development, the project identified a need to include an integrated energy planning study of the overall area. The initial outputs of the study inform this Energy Plan.

2 Structure of this Report

The Energy Plan is structured as follows.

The geographical scope of the study is defined in Section 3. Section 4 provides the global, national and local legislative and policy context for the Energy Plan.

Section 5 sets out the vision and principles for the Energy Plan; monitoring and reporting requirements to demonstrate compliance with targets are shown in Section 6.

Sections 7 to 9 provide evidence to support the vision and guiding principles and include a review of existing energy resources within the study area and key outputs from the energy modelling which informs this energy plan. Full details of the energy supply and demand modelling are included in Appendix 2 and 3.

Sections 10 and 11 consider the implications for design and viability, whilst section 12 focuses on long term delivery and stewardship of the Energy Plan.

3 Socio and Technical Boundary Definition of the Energy Plan

While the physical infrastructure which meets the energy needs of a particular area has a similar hierarchical structure to local government areas, the associated boundaries do not necessarily concur, or reflect established local community boundaries. As such, both the social and technical boundaries must be appreciated when considering the local energy system; for instance, a community may associate with a particular local generation asset which technically does not share a common point of connection to the high voltage (>11 kV) distribution network.

3.1 Social Boundary Definition

The proposed site for the Garden Village is situated on land north of Eynsham Village, adjacent to the A40. Eynsham is in the West Oxfordshire Local Authority district, one of five districts in the County of Oxfordshire. The proposed Garden Village development will be within the local electoral ward of Eynsham and Cassington; it is close to the neighbouring ward to the north of Freeland and Hanborough. There are two census Middle Layer Super Output Areas (MSOAs) associated with the Eynsham area: West Oxfordshire 006 and West Oxfordshire 011.

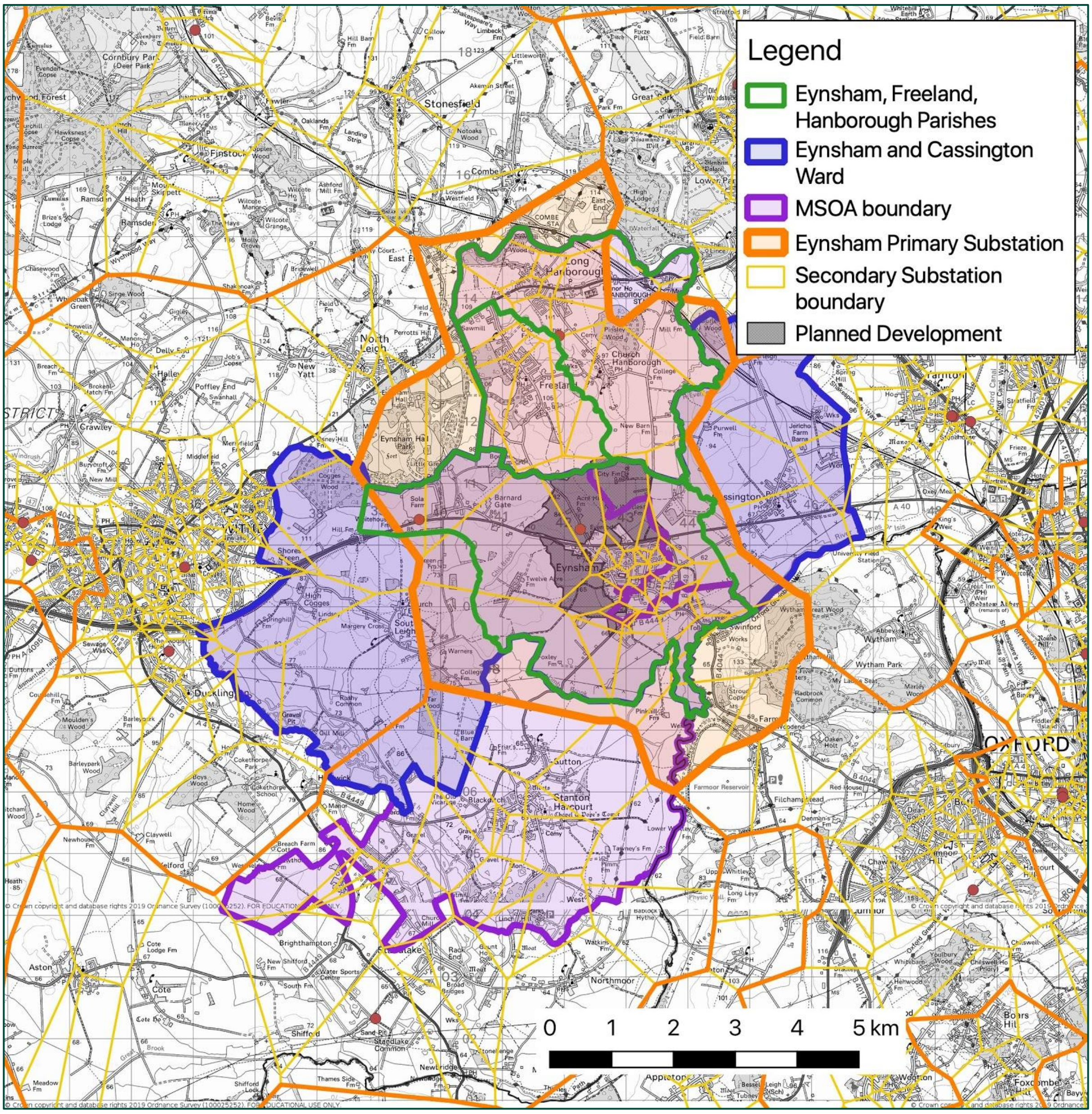
Discussions with representatives from the Eynsham Community have confirmed that residents most closely identify with the parish boundaries, showing in green on the map below (Figure 1). There are three key parishes associated with the Garden Village and Primary Substation Area, Eynsham, Freeland (northwest of Eynsham) and Hanborough (northeast of Eynsham).

3.2 Technical Boundary Definition

The primary substation (33kV/11kV) which serves Eynsham village is located on Cuckoo Lane, just north of the A40 and within the boundary of the proposed Garden Village development. The primary substation has 110 associated secondary substations; Figure 1 displays an estimate of the geographic area served by the primary substation based on closest associated secondary substation. Eynsham primary serves the central part of the Eynsham and Cassington ward, almost the entirety of Freeland and Hanborough, and small sections of North Leigh, Stonesfield and Tackley, Cumnor and part of South Leigh parish. Eynsham Primary is connected to Yarnton Bulk Supply Point (132kV/33kV), which is in turn connected to Cowley Grid Supply Point (400 kW/132kV) at which connection is made to the national transmission network.

Following discussions with the Energy Plan Working Group, the core area boundary of the Energy Plan will encompass the Garden Village development site and the wider technical Primary Substation Area.

Figure 1 Socio and Technical Boundaries within Eynsham and Wider Area.[7]



[7] Digital administrative boundaries source: Office for National Statistics licenced under the Open Government Licence V3.0. Base map: © Crown copyright and database rights 2020 Ordnance Survey (100025252).

4 Legislative and Planning Policy Context

The legislative and planning policy context guiding this Energy Plan is the global, national and local commitment to reducing greenhouse gas emissions. Relevant policies in place at the time of publishing are set out below. It is expected that this policy landscape will evolve over the next few years as measures are put in place nationally to meet the net zero emissions target set in national legislation earlier this year (see section 4.2.1). Relevant legislative or policy changes will need to be taken into consideration during delivery of the Garden Village.

4.1 Global Context

The UK is a signatory to the **Paris Climate Agreement, 2015**[8] under which governments have agreed a long-term goal of keeping the increase in global average temperature to **below 2°C above pre-industrial levels** and are legally bound to 'pursue domestic mitigation measures'.

The subsequent publication of the **IPCC Special Report** (October 2018)[9] sets out the likely impacts of global warming of 1.5°C above pre-industrial levels. Limiting global warming to 1.5°C with *'no or limited overshoot'* requires net global anthropogenic CO_2 emissions to fall by about 45% from 2010 levels by 2030 and reach net zero by around 2050. This will require "*rapid, far-reaching and unprecedented changes in all aspects of society"*.

4.2 National Context

4.2.1 Legislation

The **Climate Change Act, 2008** (2050 Target Amendment) Order 2019[10], sets a legally binding target for the UK to achieve net zero carbon emissions by 2050**.**

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8 United Nations (2015) Paris Climate Agreement; https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

9 IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland, 32 pp.*

10 UK Climate Change Act (2050 Target Amendment) https://www.legislation.gov.uk/ukdsi/2019/9780111187654

Section 19 (1A) of the **Planning and Compulsory Purchase Act 2004**[11] requires that:

> *'Development plan documents must (taken as a whole) include policies designed to secure that the development and use of land in the local planning authority's area contribute to the mitigation of, and adaptation to, climate change.'*

Through the above national legislation, there should be an assessment of the potential for local policy to achieve emission reductions over the plan period and that these reductions should reflect the targets set out in the UK Climate Change Act.

4.2.2 National Policy and Guidance

The **National Planning Policy Framework (NPPF) (2019)**[12] sets out the government's planning policies for England and must be taken into account in preparing local development plans. Three key paragraphs set out the guidance to address climate change:

- Para 148: *The planning system should support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change. It should help to: shape places in ways that contribute to radical reductions in greenhouse gas emissions, minimise vulnerability and improve resilience; encourage the reuse of existing resources, including the conversion of existing buildings; and support renewable and low carbon energy and associated infrastructure.*
- Para 149*: Plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures (in line with the objectives and provisions of the Climate Change Act 2008).*
- Para 150: *"New development should be planned for in ways that...can help to reduce greenhouse gas emissions, such as through its location, orientation and design. Any local requirements for the sustainability of buildings should reflect the Government's policy for national technical standards."*

As well as guiding the design and construction of housing, the NPPF also states that local plans should provide a positive strategy for the use and supply of renewable and low carbon energy and heat and should identify opportunities for a development to draw its energy supply from decentralised, renewable or low carbon energy supply systems

[11]Planning and Compulsory Purchase Act 2004 https://www.legislation.gov.uk/ukpga/2004/5/contents

[12]National Planning Policy Framework, 2019: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf

and for co-locating potential heat customers and suppliers. The relevant Local Plan policies are set out in Section 4.3.

4.2.3 Building Regulations

Technical standards for the energy performance of new (and existing) buildings are set out in Part L of the **Building Regulations**[13]**.** Under the current provisions (and clarified in the 2019 update of the NPPF) "*LPAs (*Local Planning Authorities) *now can require energy efficiency improvements on Building Regulations with no limit stated, to pursue the target of halving emissions from new buildings by 2030.*" An uplift is included in numerous adopted Local Plans, including the London Plan 2016, Reading Borough Local Plan, 2019 (see Section 7.2).

At the time of writing, the Ministry for Housing, Communities and Local Government is consulting on a proposed **Future Homes Standard** (FHS)[14] which is expected to see a significant uplift in Part L requirements for domestic buildings. The new standard, announced in the Chancellor's 2019 Spring Statement, follows recommendations made by the Committee on Climate Change that new build homes should deliver ultra-high levels of energy efficiency by 2025 at the latest (consistent with a space heat demand of 15-20 kWh/m^2/year) and that the connection of new homes to the gas grid should end by the same date.[15]

The consultation paper indicates that an average home built to the Future Homes Standard will produce 75-80% less carbon emissions than one built to current Part L requirements. This is likely to be achieved through very high fabric standards (triple glazing and standards for walls, floors and roof that significantly limit any heat loss) and low carbon heating systems. Whilst other technologies, such as hydrogen may have a role to play in heating systems of the future, the consultation anticipates that heat pumps (primarily air to air or air to water) are the most likely solution. Heat networks are also included in the 'formula', whilst direct electric heat may play a small role, for example, where the home is built to highest fabric standards and heat demand is therefore very low.

By 2025 all new dwellings will be required to meet this standard; an initial uplift in current building regulations is expected to be introduced in 2020.

A consultation on energy efficiency standards for non-residential buildings is expected during 2020.

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[13] Conservation of fuel and power: Approved Document L https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l
[14] MHCLG, Future Homes Standard consultation, 2019: https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings#history
[15] UK Committee on Climate Change, 2018. https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/

4.3 Local Policy Context

4.3.1 West Oxfordshire Local Plan, 2031

The West Oxfordshire Local Plan[16], adopted in September 2018, provides the overarching framework to guide and deliver development in the District.

POLICY OS3 requires that all development proposals *show consideration of the* ***efficient and prudent use and management of natural resources.*** The following points refer to energy demand:

- ***minimising use of non-renewable resources, including land and energy****, and maximising opportunities for travel by sustainable means*
- ***minimising energy demands and energy loss through design, layout, orientation, landscaping, materials and the use of technology****;*
- ***minimising summer solar gain, maximising passive winter solar heating, lighting, natural ventilation, energy and water efficiency and reuse of materials****;*
- *using recycled and energy efficient materials.*

Policy EH6 sets out the conditions under which renewable and low-carbon energy developments (including battery storage) in the district will be considered, and states that:

- *The use of decentralised energy systems….. will be encouraged in all developments.*
- *Developments that are led by or meet the needs of local communities will receive particular support when considering the merits of renewable energy developments.*

Policy EH6 also sets a requirement for an **energy feasibility assessment or strategy which assesses viability and practicability for decentralised energy systems for proposals on strategic development areas (SDAs), all residential development for 100 dwellings or more**, all residential developments in off-gas areas for 50 dwellings or more, and all non-domestic developments above 1000m^2 floorspace.

Where feasibility assessments demonstrate that decentralised energy systems are practicable and viable, such systems will be required as part of the development, unless an alternative solution would deliver the same or increased energy benefits.

This Energy Plan provides evidence and recommendations to support policy development for the Garden Village Area Action Plan. The site developer will be required to provide a detailed energy masterplan.

[16] West Oxfordshire Local Plan, 2031: https://www.westoxon.gov.uk/localplan2031

4.3.2 Garden Village Area Action Plan

Development at the Garden Village Strategic Location for Growth will be guided by an Area Action Plan (AAP). West Oxfordshire District Council set out the Garden Village preferred options paper for public consultation between August to October 2019. It notes that the AAP has a key role to play in setting standards required of developers and the measures they will need to deploy to minimise the carbon footprint of the development. It includes as a core objective:

- ***GV37*** *To adopt an ambitious approach towards low and zero carbon energy - maximising opportunities to draw energy from decentralised, renewable or low carbon energy supply systems.*

WODC commits to "*exploring through the AAP, the scope to which new buildings are able to achieve zero carbon standards in terms of their energy efficiency, design and construction"* indicating that they could require all new buildings to be built to zero carbon standards and where, for good reasons, this is not feasible use allowable solutions to address any remaining emissions. This is set out in Preferred Policy Approach 32 – Sustainable Construction:

> ***Preferred Policy Approach 32 – Sustainable Construction***
> *To include within the AAP, a policy setting out the sustainable construction requirements that will be applied to residential and non-residential buildings at the garden village.*
>
> *Subject to further consideration regarding viability and practical delivery, the intention is to achieve zero-carbon standards for both residential and non-residential buildings, whilst allowing for carbon-offsetting where this is demonstrably shown to be impractical.*

The Preferred Options paper draws on Local Plan policy EH6 and the Eynsham Neighbourhood Plan (see below) to commit to developing in the AAP an ambitious approach at the Garden Village in respect of energy generation from sustainable sources:

> **Preferred Policy Approach 33 – Decentralised, Renewable and Low Carbon Energy**
>
> *To include within the AAP, a requirement for development of the garden village to be underpinned by an ambitious and pro-active approach to decentralised, renewable and low carbon energy at a range of different scales from site-wide to property specific.*
>
> *In accordance with the Local Plan, the developer will be required to prepare an energy feasibility assessment or strategy to assess the viability and practicability of a decentralised energy system within the garden village.*

To also include a requirement to consider as part of Project LEO, the potential for an integrated, low carbon energy system within the garden village and to maximise linkages with existing or proposed renewable and low carbon energy infrastructure in the locality.

4.3.3 Eynsham Neighbourhood Plan

The **Eynsham Neighbourhood Plan 2018 to 2031** (December 2018)[17] was formally made part of West Oxfordshire District Council's development plan on 6 February 2020. Following the formal decision statement required by the Neighbourhood Planning Regulations, West Oxfordshire District Council will now use the Eynsham Neighbourhood Plan to help decide planning applications within Eynsham Parish.

The Plan includes policies which will guide development at the Garden Village. These include Policy ENP5 (Sustainability: Climate Change) which states that "*Particular support will be given for proposals that help meet the intentions of the Climate Change Act 2008 including development that makes the most efficient use of land and materials and maximises the opportunities for the use of renewable and low-carbon forms of energy in accordance with WOLP policy".*

The Parish Council state that they will seek to encourage developers to adopt the highest practical standards of energy efficiency and resource conservation, and consider the following requirements as "*the minimum needed to make the transition to a low carbon future a reality while ensuring that home owners have good value and properly sustainable homes*:

- *All homes should be constructed with a very high but achievable standard of insulation and air-tightness and be fitted with the internal ducting necessary for Mechanical Heat Recovery Ventilation.*
- *Combined Heat and Power schemes should be implemented where practical and viable.*
- *All homes on a development site shall have an average of 3 kW PV generation capability.*
- *New homes should at least have the capability of adding a charging point suitable for different types of electric vehicles.*
- *New homes should have water-saving fittings as standard for toilets and showers.*
- *Other measures to mitigate the effects of climate change will be supported."*

[17] Eynsham Neighbourhood Plan (referendum version)

4.3.4 Countywide plans and strategies

The **Oxfordshire Energy Strategy**[18], published by the Oxfordshire Local Enterprise Partnership in 2018, sets the strategic framework to secure a smart, clean energy infrastructure across the county and to drive countywide decarbonisation. The Strategy seeks to:

> *"Lead nationally and internationally to reduce countywide emissions by 50% compared with 2008 levels by 2030 and set a pathway to achieve zero carbon growth by 2050. We will realise the economic benefits of this low carbon transition by supporting:*
>
> - *ambitious and innovative clean generation projects across the county, both in urban and rural areas, and in growth locations;*
> - *projects that reduce energy demand and increase energy efficiency for domestic, industrial, commercial buildings and transport"*

The Energy Strategy highlights the need to minimise additional energy demand arising from new developments, and at the same time to scale up deployment of decentralised low carbon energy generation to meet at least 50% of the county's power demand by 2030.

The Local Industrial Strategy (LIS), 2019[19] sets out the ambitions for local employment growth. It highlights the potential limitations for Oxfordshire's energy network to support future growth and increasing local low carbon generation. Energy infrastructure needs to respond to changing requirements and next generation needs of energy-intensive science and technology assets. It notes that "*the emerging Oxfordshire Cotswold Garden Village, provide[s] the opportunity to develop new and innovative energy solutions to begin addressing these challenges*."

The LIS also highlights the role for Oxfordshire as a test bed to bring forward new and innovative solutions through 'Living Labs'. The key building blocks for world leading Living Labs already exist in Oxfordshire with partners collaborating across local authorities, universities and local businesses, to deliver innovative projects that demonstrate the Living Lab concept.

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[18] Oxfordshire Energy Strategy, 2018. https://www.oxfordshirelep.com/sites/default/files/uploads/Oxfordshire%20Energy%20Strategy%20-%20published%202019.pdf

[19] Oxfordshire Local Industrial Strategy https://www.oxfordshirelep.com/sites/default/files/uploads/Oxfordshire%20Local%20Industrial%20Strategy_0.pdf

The **Oxfordshire Plan 2050 - Emerging Joint Statutory Spatial Plan**[20] sets out the spatial strategy for Oxfordshire and identifies energy supply and demand as a key issue to be addressed. The initial consultation document identifies that:

> '*opportunities must be sought to improve the energy efficiency of homes and reduce energy demands of households. It will be important for new developments to maximise energy efficiency whilst integrating renewable and smart energy technologies in order to minimise energy demand'*.

The Emerging Plan highlights the use of sustainable design and construction methods to reduce emissions throughout construction and the lifetime of a development. It also sets out a requirement to reduce the need to travel, and where cars are needed, to support the shift to electric vehicles.

4.4 Planning for the future

Whilst the Climate Change Act amendment order setting the target for net zero emissions by 2050 was adopted into legislation in June 2019, national and local policies to enable this target to be met have yet to follow. For example, we expect the national Future Homes Standards (see Section 4.2.3) to come into force in 2025 with a phased implementation from late 2020. Changes in the building regulations for new non-residential developments are also anticipated.

At a local level, a number of Planning Authorities have already set a precedent with zero carbon targets embedded in adopted policies. For example, the recently adopted Reading Borough Local Plan, requires that "*All major new-build residential development should be designed to achieve zero carbon homes"* (Policy H5, *Standards for New Housing)* (see also section 7.2).

By planning to meet these standards and align with national commitments made through the Paris Agreement, the Oxfordshire Cotswold Garden Village will stand out as an exemplar development, leading the way to deliver benefits to residents and developers alike.

[20] Oxfordshire Plan 2050 https://oxfordshireplan.org/

5 Vision and Guiding Principles for the Energy Plan

The vision and principles set out in this section have been developed in conjunction with the Energy Plan Working Group and are informed by feedback from the Garden Village public consultations (carried out by West Oxfordshire District Council and Grosvenor) and by energy modelling carried out by the University of Oxford and EDF Energy R&D UK (see Section 9). Further evidence to support the requirements established by the principles is presented in Section 7.

5.1 Vision

The Oxfordshire Cotswold Garden Village Area Action Plan Preferred Options paper set out for consultation the following vision:

> *'By 2031, the Oxfordshire Cotswolds Garden Village will be established as a thriving and inclusive community, epitomising all that is good about West Oxfordshire but with its own strong and distinctive character, form and identity.*
>
> *The Garden Village will be* ***known for its emphasis on the environment, quality and innovation*** *and will* ***tackle the challenges presented by climate change 'head-on'****, providing a model example of how to plan a new community for the 21st century in a logical, organic and sustainable way. The perfect setting for wildlife and people to flourish together.*
>
> *Those who live there will enjoy* ***a healthy, high quality of life****, with* ***affordable, attractive and energy efficient homes*** *set within leafy, walkable village neighbourhoods closely integrated with extensive green space including a new countryside park and supported by a range of facilities including schools, community space, leisure and recreation and local shopping opportunities.*
>
> *Those who work there will be drawn by a broad range of exciting employment and training opportunities with high quality business space in an attractive rural setting, reliable and integrated public transport choices and 'future proofed' infrastructure including digital connectivity to enable and encourage high rates of home and remote working.*
>
> *Those who visit will experience a strong sense of place, will be able to easily and safely find their way around, enjoy a broad range of different activities and opportunities and leave wanting to return time and time again'.*

Community engagement by West Oxfordshire District Council and Grosvenor has identified best practice energy efficiency construction and use of renewable energy as priorities to deliver a sustainable development. Numerous responses emphasise the need for the Garden Village to be net zero carbon and energy positive[21].

[21] https://www.westoxon.gov.uk/gardenvillage and https://oxongv.co.uk/

This Energy Plan draws on the overall vision, along with feedback from the public consultations and from the Energy Plan Working Group, to set out the following vision and principles to guide delivery of a net zero carbon development without the need to retrofit and which responds to the local and national ambition to address climate change.

> *"The Oxfordshire Cotswolds Garden Village is an exemplar net zero carbon, energy positive development which meets the challenges of climate change head on.*
>
> *Successful collaboration between key stakeholders (including local community groups, Local Authorities, Developers) guides the development throughout planning, construction and lifetime of the site.*
>
> *Sustainable construction reduces embodied carbon throughout the Village, whilst best practice and use of innovative technologies minimise the energy needed to heat and power homes and businesses.*
>
> *Local renewable generation and smart energy management solutions meet the remaining energy demand and catalyse carbon reductions across the wider Eynsham area whilst contributing to the national decarbonisation and climate change response*."

5.2 Principles

The principles set out below provide the framework to achieve net zero carbon emissions from operational energy across the Garden Village development, defined by the UK Green Building Council as:

> ***"the amount of carbon emissions from building operational energy use on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."*** [22]

Operational energy use includes both that covered by building regulations (space heating, hot water, cooling, ventilation and lighting systems) and equipment used in the building (fridges, washing machines, cooking etc). Section 1 (Box 1) provides further detail.

Homes in the Garden Village should be designed and built to be net zero carbon in operation. Whilst aiming to deliver the net zero carbon target, developers should achieve at least a 75-80% improvement on Part L 2013 target emissions rate (TER) in line with the indicative figures set out in the Future Homes Standard consultation (or any

[22] UK Green Building Council, *Net Zero Carbon Buildings: A Framework Definition*. April 2019. https://www.ukgbc.org/ukgbc-work/net-zero-carbon-buildings-a-framework-definition/

more stringent requirements which may be set in future policy) and based on SAP10.1 (or subsequent) methodology.

Measures adopted to achieve the net zero operational carbon target should follow the energy hierarchy as set out in the West Oxfordshire Local Plan (paragraph 4.6):

- **Lean** – *using less energy, by the use of sustainable design and construction measures;*
- **Clean** – *supplying energy efficiently, giving priority to decentralised energy supply;*
- **Green** – *using renewable energy.*[23]

Principle 1. Minimise energy demand

Sustainable construction methods are used to reduce embodied carbon**.**

Measures to minimise the operational energy demand of the buildings are a priority. New homes should meet as a minimum the fabric specifications shown in Table 1 below based on those set out in Future Homes Standard, 2019 Consultation Impact Assessment (or subsequent revisions).

Table 1 Fabric Specifications

Fabric Specification	Part L 2020 (Option 1)
External Wall U-value (W/m^2K)	0.15
Corridor Wall U-value (W/m^2K)	0.18
Party Wall U-value (W/m^2K)	0
Roof U-value (W/m^2K)	0.11
Floor U-value (W/m^2K)	0.11
Window U-value (W/m^2K)	0.8
Window g-value	0.57
Door U-value (W/m^2K)	1.0

Source: Future Homes Standard, 2019 Consultation. Impact Assessment (Table 4)[24]

Non-residential buildings should incorporate best practice fabric energy efficiency standards.

[23] West Oxfordshire Local Plan 2031

[24] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/836925/REQUEST.pdf

Principle 2. Fit for the future - no fossil fuels burnt on site for heat or power

Decarbonisation of heating and hot water systems is critical to achieving the net zero operational carbon target (see Section 9.1). **Low carbon heating systems** need to be planned for from the outset in line with the government's commitment for no new homes to be connected to the gas grid from 2025. The technology selected should be in line with the requirement to minimise building energy demand. Heat pumps are recommended to ensure householders are not adversely impacted by the (current) higher unit cost of electricity.

Principle 3. Use of onsite renewable generation is maximised

Onsite renewable generation should be maximised and meet at least 50% of annual building energy demand (residential and non-residential). Use of solar PV on residential buildings should be maximised; the Eynsham Neighbourhood Plan sets a requirement for an average of 3kW PV generation capability on all new homes.

Viability issues should be addressed through exploration of innovative funding and supply models, including options to incorporate community energy (see also Principle 5).

At the same time, opportunities to embed a smart local energy system to manage peak and seasonal variation in both demand and generation within the Garden Village and to develop a local energy market (with options to include the wider energy plan area) should be explored through continuing collaboration with Project LEO throughout the development of the Garden Village.

Principle 4. Energy positive

The government's Community Energy Strategy highlights that *"new garden cities can and should use community owned energy systems benefitting from longer term revenue they generate and jobs they create whilst safeguarding bills for householders and businesses*. *This should include options for local community investment"*[25].

Opportunities to invest in and extend local renewables to generate more energy on or close to the site than required in the Garden Village should be considered, offering an opportunity for income generation and to contribute to wider local and national decarbonisation.

The District Council should explore options with the Eynsham community and the Low Carbon Hub, an Oxford-based social enterprise and community interest company, to embed such a community energy model into the Oxfordshire Cotswold Garden Village development.

[25] BEIS, 2014. *The Community Energy Strategy*

Principle 5. Allowable solutions

If shown and independently verified that it is not possible to meet the net zero emissions target through on-site measures, any shortfall should be provided through agreed off-site measures. West Oxfordshire District Council should consider a cash in lieu contribution which could be ringfenced and used to deliver carbon savings for the benefit of the wider community, for example for local energy efficiency projects within the wider energy plan boundary.

Principle 6. Long term stewardship

A long term monitoring and management plan with agreed resourcing and reporting governance is required to measure success and ensure the elements of the local energy system are managed, maintained and developed over time for the benefit of the whole community. Recommended monitoring requirements are set out in the following section.

6 Monitoring and reporting

Recommendations for monitoring and reporting throughout the development and lifetime of the site are set out below. These should be reviewed periodically to ensure they remain current and relevant.

1. Construction

For a true net zero carbon development (as defined in Section 1 Box 1), embodied carbon would also demonstrate net zero, however there is recognition that further work needs to be done to reach this goal nationally. We recommend that West Oxfordshire District Council consider the standards suggested in the LETI Climate Emergency Design Guide (40% reduction on baseline by 2025 and 65% by 2030)[26].

Developers should provide a statement of embodied carbon to inform any future offsetting requirements which West Oxfordshire District Council might consider.

In line with the proposals in the Future Homes Standard, West Oxfordshire District Council should require a compliance report setting out as built performance and including evidence of the materials used on site to meet specified fabric standards.

2. Householder affordability rating

Householder affordability ratings should be provided in line with the requirements likely to be included in the FHS (or alternative metric specified by the Local Authority) to ensure that householders are not adversely affected by the use of non-gas based heating systems. The consultation document proposes using a minimum Energy Efficiency Rating (as calculated for Energy Performance Certificates and which includes the theoretical costs of heating and hot water for the dwelling) as a possible measure.

3. Annual reporting: key performance indicators

We recommend that West Oxfordshire District Council require a process for the developer to report annually on the following key performance indicators (KPIs) for the Garden Village development and the outputs compared to design standard predictions.

The requirements assume that smart metering is installed throughout the development and temporal (electricity generation/load profiles) data made available for reporting (household data aggregated to ensure anonymity).

i. Greenhouse gas emissions (tonnes CO_2e / year)*
ii. Total electrical energy consumption (kWh/year) (to include breakdown by residential vs non-residential properties).

[26] London Energy Transformation Initiative, 2020. Climate Emergency Design Guide: How new buildings can meet UK climate change targets. https://www.leti.london/ecp

iii. Peak electrical demand

*Calculation of net emissions will take account of:
(a) emissions associated with the use of locally produced energy
(b) emissions associated with production of energy imported from centralised energy networks, taking account of the carbon intensity of those imports as set out in the Government's Standard Assessment Procedure, and
(c) emissions displaced by exports of locally produced energy to centralised energy networks where that energy is produced from sources whose primary purpose is to support the needs of the Garden Village.

7 Supporting evidence

The vision and guiding principles for the Energy Plan are set against the developing Climate Emergency responses at both a local and national level and within the international, national and local policy context (section 4). They are supported by the energy modelling presented in Section 9 (and in detail in Appendix 3) which demonstrates that, based on the quantum of housing set out in the proposals for the Garden Village, it is technically feasible to achieve annual net zero carbon emissions for operational energy use in the residential development.

Further evidence in support of the principles and recommendations made in Section 6 is set out below.

7.1 Embodied carbon

Around two thirds (67%) of the annual carbon emissions associated with a medium-sized residential dwelling (built to current standards) arise from ongoing operational energy use. The remaining third relate to embodied carbon: 21% to the building products and materials; 2% to transportation to / from the development; 9% to impact of construction; and around 1% to construction and end of life disposal.

Considering construction processes and materials during the design stage will help reduce embodied carbon across the development and minimise the need for any future offset requirements which will be needed if the development were to achieve whole life net zero carbon emissions at a later date. Recommended targets (included in Section 6.1) and best practice guidance is set out in the recently published Climate Emergency Design Guide produced by the London Energy Transformation Initiative (LETI). [27]

[27] London Energy Transformation Initiative, 2020. Climate Emergency Design Guide: How new buildings can meet UK climate change targets. https://www.leti.london/ecp

7.2 Beyond Part L 2013

Clarification through the revised National Planning Policy Framework (NPPF) published in 2018, advised that under current policies local planning authorities are able to set emission reduction targets beyond those achieved through current Building Regulations (part L 2013). There are numerous examples where this is already demonstrated in adopted Local Plans (see Table 2). Most set a requirement for emission reductions of 19% beyond Part L 2013 (equivalent to that set in the Code for Sustainable Homes Level 4), whilst a number have gone beyond that. Most recently, Policy H4 in the Reading Borough Local Plan, adopted in November 2019 requires that: ***All major new-build residential development should be designed to achieve zero carbon homes.***

The Plan goes on to state that this will mean: "*as a minimum a 35% improvement in the dwelling emission rate over the 2013 Building Regulations".*

Similarly, the London Plan Policy S12 requires that *"development proposals should make the fullest contribution to minimising carbon dioxide emissions in accordance with the following energy hierarchy: 1. Be lean: use less energy; 2. Be clean: supply energy efficiently; 3.. Be green: use renewable energy"*
The Plan sets a zero carbon target for all major developments and requires a minimum on-site emissions reduction of at least 35% beyond Building Regulations, of which at least 10% should be achieved for residential developments through energy efficiency measures. [28]

Locally, the Oxford City Local Plan consultation draft sets phased targets to zero carbon by 2030:

> *"Carbon reduction in new-build residential developments (other than householder applications): Planning permission will only be granted for new build residential and student accommodation developments (or 25 student rooms or more)* ***which achieve at least a 40% reduction in the carbon emissions from a code compliant base case*****. This reduction is to be secured through on-site renewable energy and other low carbon technologies (this would be broadly equivalent to 25% of all energy used) and/or energy efficiency measures.* ***The requirement will increase from 2026 to at least 50% reduction in carbon emissions****.* ***After 31 March 2030*** *planning permission will only be granted for residential and student accommodation (25 or more non self-contained student rooms)* ***development that is Zero Carbon.***
>
> *(where the Code compliant base case is the amount of reduction in carbon emissions (from regulated energy) beyond Part L of the 2013 Building Regulations or equivalent future legislation.* ***The current code compliant base case means***

[28] https://www.london.gov.uk/sites/default/files/new_london_plan_december_2017.pdf

that the developer has to demonstrate 19% less carbon emissions than Part L of the 2013 Building Regulations.[29]

7.3 Ultra-high efficiency housing

The principles set out in the previous section follow the energy hierarchy to prioritise reducing building energy demand (and therefore emissions) through fabric energy efficiency measures. Whilst the Future Homes Standard consultation document indicates an interim standard may require an incremental uplift in fabric efficiency, we have recommended as a minimum the immediate implementation of the standard expected to be introduced in 2025. This draws on evidence provided to the Committee on Climate Change ('Fit for the future[30]) that demonstrates it is more cost-effective to introduce ultra-high efficiency housing than to make smaller improvements on current regulatory requirements, for example tightening to 20-30 kWh/m^2/year of space heat demand. This reflects a significant (up to c.£3,300) saving in the capital cost of the radiators and heating distribution system which helps offset some of the additional costs associated with the most energy efficient fabric specifications.

Reducing the operational energy use of buildings will make it easier to meet electricity demand from onsite generation (Principle 2) and will also minimise additional demand on the local electricity grid helping reduce the extent and capital cost of reinforcement.

7.4 Low carbon heat

The Committee for Climate Change report also shows that use of cost-effective low carbon heat (via an air source heat pump) reduces regulated operational carbon emissions over 60 years of a home built in 2020 by more than 90% compared with an otherwise equivalent gas-heated home for a capital cost uplift of around 1-2% (see also Section 11). Savings of nearly 80% were identified for a naturally ventilated office and of 30% for an air-conditioned office.

Combining more stringent fabric energy standards alongside low carbon heat provides additional benefits:

- achieves further savings in running costs (around £30-£40 relative to installing a heat pump alone) and improves the quality of the internal environment;
- reduces energy consumption and therefore the quantity of low-carbon energy required to meet demand;
- helps reduce or avoid peaks in energy demand associated with space heating;

[29] http://www.oxford.gov.uk/downloads/download/1041/001_csd_-_core_submission_documents

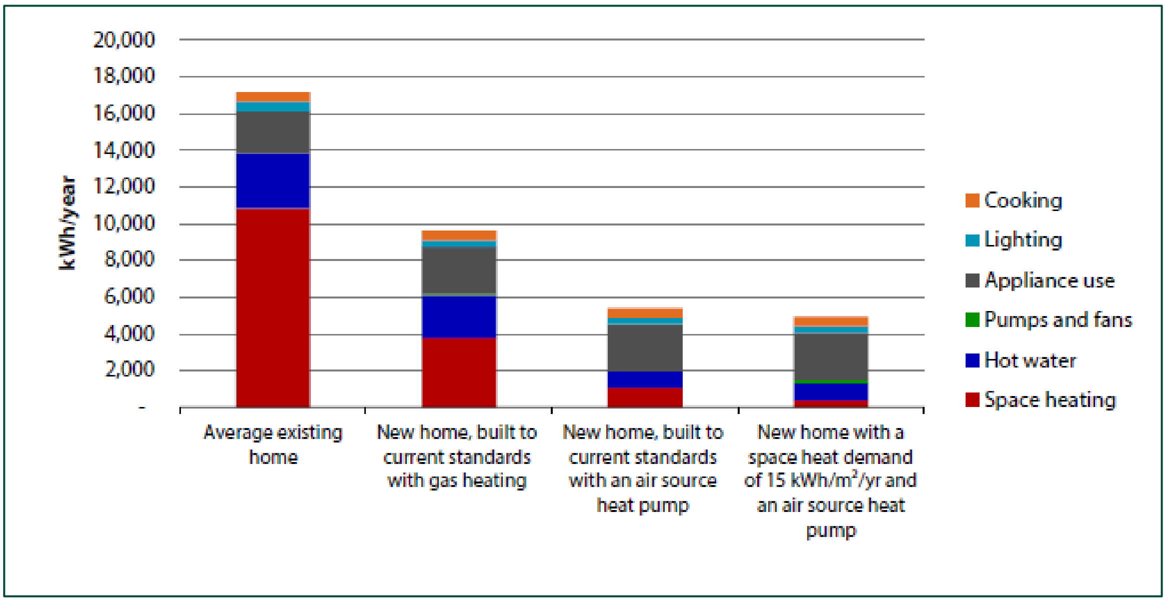
[30] UK Housing: Fit for the future? Committee on Climate Change, 2019. https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/

- offers potential for fewer radiators and reduced heating distribution system, freeing up internal wall space, saving associated capital and maintenance costs.[31]

Figure 2 compares energy consumption in homes built to current and extended standards and with or without gas boilers or heat pumps. (See also Section 11, Implications for Viability.)

The results of the energy demand model for the Garden Village also clearly demonstrates the benefits of heat pumps (Section 8.2).

Figure 2 Comparison of energy consumption in existing and new homes



Source: Committee for Climate Change, Fit for the Future: BEIS (2018) Energy Consumption in the UK; Currie & Brown and Aecom for the CCC (2019) The costs and benefits of tighter standards for new buildings.

[31] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings. https://www.theccc.org.uk/wp-content/uploads/2019/07/The-costs-and-benefits-of-tighter-standards-for-new-buildings-Currie-Brown-and-AECOM.pdf*

7.5 Renewable generation

To explore the potential for on-site renewable electricity generation, the available capacity for roof top solar PV generation at the Garden Village is considered in Section 8.1 and demonstrates that with roof top solar PV alone, sufficient capacity could be installed to meet the modelled energy demand for the development. The model used here is intended to inform a baseline of what is technically possible from the simplest source of generation; it is not a complete assessment of the optimum strategy for integration of renewable generation at the development. Whilst the development should maximise solar PV on roof spaces (an approach set out in the London Plan Energy Assessment Planning Guidance), it should also aspire to explore additional options, both on and off site, to go beyond this baseline scenario, increase generation diversity and enable deliverability at a range of scales, from site wide to property specific.

This approach is supported by the West Oxfordshire District Council Local Plan policy which supports the use of other options for decentralised, renewable and low carbon generation and Local Plan Policy EH6 requires that developers consider this in their detailed energy strategy.

Renewable generation to meet Garden Village requirements could be delivered in a number of ways, for example, the opportunity to benefit from the thriving community energy in Oxfordshire is highlighted in Principle 5. Spearheaded by the Low Carbon Hub and local community groups, latest figures show 69 community-owned renewable energy installations already in place across the county, generating 858 GWh each year (66 solar PV installations with an installed capacity of 13 MW, 2 hydro installations with an installed capacity of 499 kW and one wind farm of 5 turbines and installed capacity of 6.5 MW).

The Low Carbon Hub is actively seeking opportunities to expand local renewable generation and smart grid technologies. As a key partner in Project LEO, the LCH is developing projects to trial and demonstrate the added benefits of locally installed renewables integrated in smart local energy systems. Collaboration with Project LEO throughout the development of the garden village offers opportunities to further explore how a smart local energy system could be developed at the Garden Village and enable innovative community energy models to be instigated along with access to additional local energy markets.

The Milton Keynes Local Plan, adopted in March 2019 sets a precedent for integration of community energy schemes: Policy SC1 requires provision of on-site renewable energy generation, or connection to a renewable or low carbon community energy scheme, to contribute to residual carbon emissions from a development.[32]

[32] Milton Keynes Local Plan, 2019

7.6 Allowable solutions

WODC has indicated in the Garden Village AAP Preferred Options paper, that they would consider the use of allowable solutions to address any remaining emissions to achieve carbon reduction targets which could not be achieved on-site. This follows precedent set by the Greater London Authority and most recently by Reading Borough Council. As well as setting 35% uplift on the current Part L target emission rate (to include at least 10% delivered through energy efficiency measures), the Reading Borough Local Plan requires that where zero carbon cannot be achieved on site, remaining emissions are subject to "*a contribution of £1,800 per tonne towards carbon offsetting within Reading (calculated as £60 per tonne over a 30 year period).*[33] The contributions (to be managed by Reading Borough Council) are expected to be used for energy efficiency projects in the Borough, for example to retrofit existing homes.

This reflects the approach taken in London since 2016. An overall price per tonne of carbon is fixed for the Greater London area, each Borough collects and manages its carbon contributions (see also Table 2).

Table 2 Building emission reduction and energy policy requirements in Local Plans

Local authority	Policy summary	Link	Status
Reading Borough Council	Policy H4: All major new-build residential development should be designed to achieve **zero carbon homes.** As a minimum a **35% improvement in the dwelling emission rate over the 2013 Building Regulations**. **Contribution of £1,800 per tonne towards carbon offsetting** within Reading (calculated as £60 per tonne over a 30 year period)	Reading Borough Local Plan	**Adopted, November 2019**
Milton Keynes Council	SC1 Sustainable Design and Construction - 4.a. Achieve a **19% carbon reduction improvement upon the requirements within Building Regulations Approved Document Part L 2013**. 4.b. Provide **on-site renewable energy generation**, **or connection to a renewable or low carbon community energy scheme**, that **contributes to a further 20% reduction in the residual carbon emissions** subsequent to a) above. 4.c. Make financial **contributions to the Council's carbon offset fund** to enable the residual carbon emissions subsequent to the a) and b) above to be offset by other local initiatives.	Milton Keynes Local Plan	**Adopted March 2019**

[33] Reading Borough Council Local Plan, 2019

Local authority	Policy summary	Link	Status
Cambridge City Council	In order to ensure that the growth of Cambridge supports the achievement of national carbon reduction targets...all new development will be required to meet the following minimum standards of sustainable construction...unless it can be demonstrated that such provision is not technically or economically viable: On-site reduction of regulated carbon emissions of 44% relative to Part L 2006. (This is equivalent to 19% reduction on 2013 Edition).	Cambridge Local Plan 2018	**Adopted October 2018**
Brighton and Hove City Council	CP8 Sustainable Buildings -All development will be required to achieve the minimum standards as set out below unless superseded by national policy or legislation…Residential (New Build) Energy Performance 19% carbon reduction improvement against Part L 2013	Brighton and Hove City Plan Part One; Brighton and Hove's City Councils Development Plan	**Adopted March 2016**
Greater London Authority	Policy S12 C: Major development should be **net zero-carbon**…In meeting the zero-carbon target a **minimum on-site reduction of at least 35 per cent beyond Building Regulations** is expected. Residential development should aim to achieve 10 per cent, and non-residential development should aim to achieve 15 per cent through energy efficiency measures. Where it is clearly demonstrated that the zero-carbon target cannot be fully achieved on-site, any shortfall should be provided, in agreement with the borough, either: 1) through a cash in lieu contribution to the borough's carbon offset fund, or 2) off-site provided that an alternative proposal is identified and delivery is certain.	New London Plan	Emerging
Oxford City Council	At least a 40% reduction in the carbon emissions from a code compliant base case. Increasing from 2026 to at least 50% reduction in carbon emissions and from 31 March 2030 to Zero Carbon.	Oxford Local Plan 2036 Proposed Submission Draft	Emerging
Greater Manchester Combined Authority	GM –S 2 Carbon and Energy –a. Be zero carbon from 2028 by following the energy hierarch (with any residual emissions offset)…With an interim requirement that all new dwellings should seek a 19% carbon reduction against Part L of the 2013 Building Regulations…Achieve a minimum of 20% reduction in carbon emissions (based on the Dwelling Emission or Building Emission Rates) through the use of on site or nearby renewable and/or low carbon technologies…	Greater Manchester's Plan for Homes, Jobs and the Environment (spatial framework)	Emerging

7.7 Existing developments

There are already examples of developments across the country which are leading the way to deliver energy efficiency and carbon reductions – some achieving (or close to achieving) the ambition set out in this plan. For example:

North West Bicester is a 6,000-home extension to the market town of Bicester. The exemplar phase is nearing completion with 393 zero carbon homes built to Code for Sustainable Homes level 5, incorporating triple glazing and average 34 m^2 of solar PV per roof. The development achieved a 30% carbon reduction during the build process through reduction in embodied carbon of materials and use of local sources.[34]

Eddington, NW Cambridgeshire will provide 1,500 homes for university and college staff, 1,500 private homes for sale, and accommodation for 2,000 postgraduates. The first phase of the development includes 700 homes for university staff and 700 market homes. All buildings are designed and built to Code for Sustainable Homes level 5 and BREEAM Excellent, with extensive use of roof top PV.[35]

Graylingwell Park is an award-winning development in Chichester, West Sussex. The development has transformed a derelict former hospital site to provide 792 mixed tenure new build and refurbished homes. All new homes were built to Code for Sustainable Homes Level 4 standards (and Code Level 6 energy performance). The homes also have mechanical ventilation with heat recovery and photovoltaic panels to further reduce the carbon emissions. Feedback from the first phase of the development was that the PV was saving residents between £1,100 and £1,350 per customer per year.

With the main focus of the development on carbon reduction, it is considered to be the UK's largest carbon neutral development. Around 60% of the carbon reduction comes from on-site actions, with the remainder from off-site renewables investment.[36]

Hungate is a development of approximately 1,100 homes within the old city walls of York. The development is being delivered in phases and is due to complete in 2022. The sustainability standards across the scheme have improved as the phases have progressed. City of York Council originally required EcoHomes for phase 1 and then Code for Sustainable Homes Level 3 as standards progressed. However, the latest

[34] http://growingbicester.co.uk/
[35] https://eddington-cambridge.co.uk/
[36] https://www.ukgbc.org/wp-content/uploads/2018/09/The-Policy-Playbook-v.-June-2019-final.pdf

phases exceed the energy and carbon requirements for Code for Sustainable Homes Level 4.

- **Trumpington Meadows** (a Grosvenor / Barratts development in Cambridgeshire): homes achieve Code for Sustainable Homes level 3 with later phases achieving level 4. Rooftop PV is included as an option.[37]

7.8 Cost of retrofit

The vision and principles identified for the Garden Village guide the delivery of a net zero carbon development to avoid the need for retrofit. Enhanced fabric efficiencies are difficult and costly to retrofit. Energiesprong trials in Nottingham show that the cost to bring existing homes to zero carbon can be as high as £75,000[38] per home.

[37] https://www.grosvenor.com/our-properties-and-places/trumpington-meadows and https://www.trumpingtonmeadows.com/environment/sustainability.aspx
[38] https://energiesprong.org/green-alliance-champions-the-uk-to-go-dutch-with-the-energiesprong-approach/

8 Review of Existing Energy Resources

This section of the Energy Plan reviews the existing energy resources (including both generation and demand) within the Energy Plan area, as defined in Section 3.

8.1 Generation

The amount of embedded generation is estimated from assets registered through the Feed-in Tariff (FiT) and Renewable Obligation (RO) schemes as of April 2019. For the 7 core Lower Super Output Areas (LSOAs) which make up the majority of the primary substation area, 11.1 MW of embedded low-carbon generation capacity is present. Assuming typical capacity factors for the generation technologies present, further detailed in Section 13.1 of Appendix 2, this corresponds to approximately 11.7 GWh annually. The 10 MW Eynsham Solar Farm included in this (at Barnard Gate), is connected to its own primary substation. Therefore, the estimated generation connected at the Eynsham Primary Substation is **1.1 MW**, generating an estimated **1.2 GWh** annually. Taking into account any LSOA which intersects the primary substation area, this increases to 2.1 MW generating 2.3 GWh annually.

8.2 Demand

The Department for Business, Energy and Industrial Strategy (BEIS) provides statistics for both electricity and gas consumption estimated at sub-national (LSOA and MSOA) level; the latest estimates are for 2017[39]. Analysing the data for the 7 core LSOA areas, and 2 core MSOA areas associated with Eynsham shows that 90% of meters are domestic with an associated mean annual consumption of **4.16 MWh/meter;** 10% are non-domestic meters with a mean annual consumption of **8.87 MWh/meter**. There are currently **4328** electricity customers connected to the Eynsham Primary Substation as reported by SSEN[40]. Using the ratio of meters typical for the area, this equates to an estimated **20 GWh** annual electricity demand.

For Gas demand, 99% of meters are domestic gas meters with a mean annual consumption of **15.5 MWh/meter**, while the 1% of non-domestic meters have a mean annual consumption of **175.6 MWh/meter.** This corresponds to a total annual gas consumption of **72.5 GWh** for the 2 MSOAs associated with Eynsham for which both domestic and non-domestic meter numbers are known.

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39 https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-electricity-consumption and https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-gas-consumption

40 SSEN Contracted Demand Information; URL: https://www.ssen.co.uk/ContractedDemandMap/?mapareaid=1. Accessed: Sept 2019

8.3 Electricity Network

The distribution network operator (DNO), Scottish and Southern Electricity Networks (SSEN) openly provide indicative network data under licence for purposes of assessing capability to connect large-scale developments to major substations. Further details can be found in the appendices. As of September 2019, Eynsham Primary Substation has a nameplate rating of 24.0 MVA, with a minimum load recorded of 4.24 MW and a maximum recorded load of 12.05 MW. Available generation headroom capacity is 28.24 MVA. This is calculated using the reverse power flow capability of the substation, nameplate rating, firm demand and may include accepted but not yet connected generation and quoted generation figures; therefore, it can regularly change.

In a previous feasibility study by SSEN reported in the Eynsham Area Infrastructure Delivery Plan section 5.7 (May 2019), it was concluded that their estimate of an additional 9 MVA load from the garden village could be supported without reinforcement at the Eynsham Primary Substation and on the 33 kV section of the network. However, it would trigger reinforcement of a 2.1 km stretch of 132 kV cable between Headington and Yarnton which would likely be funded by SSEN. A second assessment should be undertaken based on the current network condition and updated garden village demand based on the principles defined herein.

9 Energy Modelling

In order to develop ambitious yet achievable principles around energy use and generation on the Garden Village development site, basic empirical energy modelling has been undertaken. The demand scenarios presented below are examples of possible load conditions based on different building efficiency standards and technology options. They are not intended as strict design criteria which must be adhered to; rather to be used to ensure the principles established within this Energy Plan for the Garden Village have been developed through an evidence-based approach and show that they are achievable from a purely energy technology perspective. Future Developers of the Garden Village Site are free to explore alternative approaches which meet the principles and aspirations of this Energy Plan.

A detailed methodology and results of the modelling undertaken are provided in Appendix 3: Energy Modelling. The key findings are presented below.

9.1 Energy demand

To estimate future energy demand for the garden village site, a bottom-up empirical approach was used based on real customer load profiles for the various building types (residential, school, health centre and science park).

Five scenarios were compared to show the impact of the key factors influencing delivery of net zero carbon homes (fabric efficiency and heating system):

1. Homes built to current standards, heating provided by gas boiler (base scenario)
2. Homes built to current standards, heating provided by electric boilers
3. Homes built to current standards, heating provided by air source heat pumps
4. High quality fabric buildings with space heating demand ≤ 15 kWh/m2/year (net zero scenario)
5. 50% of homes built with high quality fabric (as scenario 4) and 50% homes built to current standards but with heat pumps installed.

Scenarios 2 to 5 assume that the grid will be fully decarbonised within a few years. Further details on the assumptions made for each of the scenarios (including building fabric specifications) are presented in Appendix 3, Section 15.1.1.

Table 3 Results for the residential area scenarios: energy consumption

	Current building standards			High quality fabric buildings	Mix 50% High quality fabric buildings + 50% current standards with Heat Pumps
	Gas Boilers	Electric Boilers	Heat pumps		
Annual heating energy consumption (GWh)	30.34	25.30	8.43	2.81	5.62
Annual total electricity consumption (GWh)	9.18	39.80	22.93	17.30	20.12
Peak Load (MW)	2.63	17.02	9.03	6.37	7.70
Average annual electricity consumption (kwh/m^2/year)	49.11	212.82	122.62	92.52	107.57

The results highlight the impact of space heating demand on average annual electricity consumption: lowest consumption is achieved in homes with high fabric energy efficiency (scenario 4); heat pumps are shown to significantly reduce electricity consumption in homes built to Part L 2013 standard (scenario 3 compared with scenario 2).

Scenario 5 is included for illustrative purposes and shows that an intermediate delivery solution (heat pumps are used throughout the development, but half of the homes are built to current standards (Part L 2013) and half to the proposed high quality fabric standard) could achieve a reasonable reduction in average electricity consumption.

A summary of modelled energy demand from other building types and from electric vehicle charging within the development (excluding the Park & Ride) is given in Table 4 and shows an estimated total annual energy demand of 48.6 GWh. Details of the assumptions made for each building type are provided in the technical appendices (Section 15.1.3).

Table 4 Summary of electricity demand and maximum peak load for the whole area (excluding the Park & Ride)

	Residential with high quality fabric buildings	School	Hospital	Science Park	50% EVs*	Total
Annual Electricity demand (GWh)	17.30	1.59	0.24	23.48	6.04	**48.64**
Maximum Peak load (MW)	6.37	0.52	0.07	3.74	6.60	**17.30**

illustrates electricity demand in a scenario where half of the homes have electric vehicles)

In addition to the above, energy supply and demand at the proposed Park & Ride was modelled separately and considered the site to have the following components influencing its energy profile: solar PV canopy; smart electric vehicle charge points; load for an on-site café. The results indicate that there is likely to be a net surplus of energy generated onsite in the summer and a shortfall during the winter months. The excess generation could potentially be exported to meet energy needs away from the P&R or stored in batteries for use at a later time. Full details are provided in the Appendix 3, 15.2.

9.2 Energy generation

Solar PV is seen as the major renewable generation technology for Oxfordshire; the opportunities for onshore wind generation are geographically limited (due to the presence of numerous MoD air bases in the county and limited wind speeds) and is not currently supported by national policies; therefore, the following analysis only considers solar PV. As new technology develops and policy adapts, additional generation opportunities such as small-scale wind, hydrogen or ammonia-fuelled fuel cells may become feasible and should be considered throughout the development. The analysis uses the residential high-quality fabric buildings with 50% EV penetration scenario presented above for representative electrical demand. As with generation, alternative demand technologies such as heat pumps or improvements in household device efficiency, will reduce the demand further, reducing the amount of generation required to achieve net zero. Further detailed analysis is presented in Appendix 2, sections 14 and 15.

As a simple starting point, the estimated total annual site demand is 48.6 GWh (excluding the Park & Ride which is treated separately). For an annual solar capacity factor of 12%, 46.2 MWp of solar generation would be required to achieve net zero energy annually; this approximately corresponds to 11% of the total area of the garden village. Only considering the residential site (domestic buildings, school, hospital and EV loads), annual demand is 25.2 GWh, requiring 24.0 MWp of solar PV; this corresponds to approximately 8% of the residential site area.

Rooftop PV is a common, well understood technology which requires no additional land to be set aside for generation. To assess the potential of rooftop PV in meeting net zero ambitions, a simple bottom-up model is presented. The model is intended as a baseline of what is technically possible, not a complete technical and financial assessment for the development. Two scenarios are investigated, a moderate scenario which uses typical design and efficiency parameters, and an aspirational (still feasible in 2020) scenario which aims to demonstrate how certain design decisions within a development, under an aspirational approach, could increase the ability of achieving net zero.

The total on-site rooftop PV capacity for the two modelled scenarios is summarised in the table below.

Table 5 Summary of modelled on-site solar capacity and annual electricity generation

	Moderate		**Aspirational case**	
	Total Capacity (MW)	**Annual Generation (GWh)**	**Total Capacity (MW)**	**Annual Generation (GWh)**
Domestic	11.75	11.46	23.94	26.01
School	0.49	0.50	0.61	0.62
Hospital	0.13	0.13	0.16	0.17
Science Park	4.87	4.97	6.09	6.21
Total	**17.24**	**17.06**	**30.80**	**33.01**

Under the moderate generation scenario, a total annual generation figure of 17.06 GWh is **35%** of the estimated annual demand (highest efficiency building fabric standards and 50% EVs) for the entire garden village site. Looking only at the residential area of the development, excluding demand and generation potential of the science park, annual generation is **12.09 GWh**. This corresponds to **48%** of the 25.2 GWh estimated annual demand.

Under the aspirational generation scenario, increased generation capability comes from higher efficiency PV panels and the use of mono-pitched, south-facing roofs. The total annual generation potential of 33.01 GWh is **68%** of the estimated annual demand (highest efficiency fabric standards and 50% EVs) for the entire garden village site. Only considering the residential area of the development, annual generation potential for the aspirational case is **26.8 GWh**. This corresponds to **106%** of the estimated 25.2 GWh annual demand, indicating a net-zero, even energy positive, residential development is possible with current (2019) best practice building efficiencies, high PV module efficiencies and optimal building layout. This is just one simple example scenario, additional on-site generation in the form of ground mount solar or canopies could be explored to allow more practical building layouts or cheaper, lower efficiency technology.

10 Implications for Design

Achieving a net zero carbon development requires planning for sustainable design from the outset. Guidance set out in the following sources should be applied to the design of the Garden Village.

Site layout needs to maximise renewable generation potential and construction needs to make best use of resources, minimise waste and maximise housing energy efficiency. This approach is set out in the NPPF and in the National design Guide published by the Ministry for Housing, Communities and Local Government, October 2019. [41]

NPPF paragraph 148 highlights that planning should: support transition to low carbon future; shape places that contribute to radical reductions in greenhouse gas emissions, minimise vulnerability and improve resilience to climate change; and support renewable and low carbon energy and associated infrastructure.

NPPF paragraph 149 requires a proactive approach to mitigating and adapting to climate change (guidance notes set out that this should be in line with the objectives and provisions in the Climate Change Act), whilst paragraph 150 states that we need to plan new development to reduce greenhouse gas emissions, for example through location, orientation and design. Local requirements should reflect the government's policy for national technical standards (see Section 4.2.1).

The newly published National Design Guide (paragraphs 135 to 145) highlights that:

> *"Well-designed places and buildings conserve natural resources including land, water, energy and materials. Their design responds to the impacts of climate change. It identifies measures to achieve: mitigation, primarily by reducing greenhouse gas*

[41] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/843468/National_Design_Guide.pdf

emissions and minimising embodied energy; and adaptation to anticipated events, such as rising temperatures and the increasing risk of flooding.

A compact and walkable neighbourhood with a mix of uses and facilities reduces demand for energy and supports health and well-being. It uses land efficiently so helps adaptation by increasing the ability for CO_2 absorption, sustaining natural ecosystems, minimising flood risk and the potential impact of flooding, and reducing overheating and air pollution.

Well-designed places: have a layout, form and mix of uses that reduces their resource requirement, including for land, energy and water; are fit for purpose and adaptable over time, reducing the need for redevelopment and unnecessary waste; use materials and adopt technologies to minimise their environmental impact.

Section R1 emphasises the use of the energy hierarchy and states that : *the development should also maximise the contributions of natural resources, for example passive measures for light, temperature, ventilation and heat. Good developments minimise cost of running buildings and are easy and affordable to use and manage.*

Use of materials

The guide goes on to set out the importance of materials and type of construction in determining the energy efficiency of a building or place, and how much embodied carbon it contains. Materials should be selected to reduce their environmental impact, for example, through the use of locally sourced materials, high thermal or solar performance

"New construction techniques may contribute toward improving energy efficiency, productivity and quality of new homes. Include off-site manufacture of buildings and components"

Locally, the draft Oxfordshire County Council Developer Guide to Infrastructure Delivery and Contributions (January 2019), states that:

"*All development proposals should seek to minimise their carbon emissions to meet local carbon targets and national target set out in the Climate Change Act 2008. The local targets are:*

- *Oxford - reduce carbon emissions by 40% by 2020*
- *Oxfordshire - reduce carbon emissions by 30% by 2030 [from 2008 base]*"

In addition to the policy guidance highlighted above, the recently published Climate Emergency Design Guide produced by the London Energy Transformation Initiative (LETI) outlines the requirements of new buildings to ensure that climate change targets are met and provides a clear route map to achieve net zero carbon buildings.[42]

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[42] LETI, February 2020. Climate Emergency Design Guide. https://www.leti.london/cedg

11 Implications for Viability

A cost benefit analysis of improved building fabric together with low carbon heat sources by Currie & Brown and Aecom on behalf of the Committee on Climate Change (CCC)[43] shows that the use of ultra-high energy efficiency standards, installed alongside an air source heat pump, represents a 1 - 4% uplift on build costs relative to a home built to current regulations.

The figures also show that it is more cost-effective to introduce ultra-high efficiency housing with a space heating demand <20 kWh/m^2/year than to make smaller improvements on current regulatory requirements, eg to 20-30 kWh/m^2/year of space heat demand. This reflects a significant (up to c.£3,300) saving in the capital cost of the radiators and heating distribution system which helps offset some of the additional costs associated with the most energy efficient fabric specifications.

11.1 Costs to achieve a net zero carbon residential development

Bioregional, an international sustainability charity with a base at NW Bicester, was commissioned to further evaluate costs for each of the elements needed to deliver a net zero carbon residential development at the Garden Village compared with one built to current UK Building Regulations Part L 2013. The zero-carbon definition used for this work is:

> *That all energy use [both regulated and unregulated energy] is offset on site, over the duration of a year.*

The study considered:

1. The cost of basic timber frame vs traditional build scenarios built to comply with Building Regulations UK Part L 2013 (fabric and building services).
2. The cost of enhanced timber frame and traditional build scenarios (fabric and building services) able to reach net zero carbon over the duration of a year.
3. The scale of uplift to reach net zero carbon and where these costs sit (by element).

Based on the assumed mix of homes at the Oxfordshire Cotswolds Garden Village (see Modelled scenarios included both traditional and timber frame constructions and are based on the SPONS 2019 cost catalogue and supplier quotes.
The enhanced specification was modelled to comply with option 1 in the 2020 Future Homes Standard consultation to align with the Energy Plan principles. This option is expected to form the basis of a Future Homes Standard 2025. Details are set out in Table 7.

[43] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings. https://www.theccc.org.uk/wp-content/uploads/2019/07/The-costs-and-benefits-of-tighter-standards-for-new-buildings-Currie-Brown-and-AECOM.pdf*

PV capacity was based on a blend of two options:

Option 1 - 30-degree mono pitch roofs facing due south

Option 2 - 45-degree duo pitch roofs facing due south
Full details of the assumptions can be found in the Bioregional report accompanying this Energy Plan.
Table 6 below) and preferred roof design set out in the generation model informing this energy plan (see section 9), Bioregional created an idealised dwelling at a gross internal area of 107m². The costs for this idealised type can be scaled up as required to work out whole development level costings (with further modest cost savings above a contract value of £4,250,000 through economies of scale).

Modelled scenarios included both traditional and timber frame constructions and are based on the SPONS 2019 cost catalogue and supplier quotes.

The enhanced specification was modelled to comply with option 1 in the 2020 Future Homes Standard consultation[44] to align with the Energy Plan principles. This option is expected to form the basis of a Future Homes Standard 2025. Details are set out in Table 7.

PV capacity was based on a blend of two options:

- Option 1 - 30-degree mono pitch roofs facing due south
- Option 2 - 45-degree duo pitch roofs facing due south

Full details of the assumptions can be found in the Bioregional report accompanying this Energy Plan.

Table 6 Assumed housing mix at the development (size and types).

Type	GV Distribution (%)	Floor area - GIA (m²)	Footprint (m²)	Idealised GIA (m²)
Detached	35%	147	74	51
Semi-Detached	32%	96	48	31
Terraced	11%	101	51	11
	12%	64	32	8
Flats	10%	61	61	6
Idealised total				**107**

Table 7 Base and enhanced performance specification details.

[44]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/852605/Future_Homes_Standard_2019_Consultation.pdf

Element	Base or compliance specification	Enhanced specification (ZC)
Roof u-value (W/m²K)	0.13	0.11
External wall u-value (W/m²K)	0.18	0.15
Floor u-value (W/m²K)	0.13	0.11
Window u-value (W/m²K)	1.4	0.8
Airtightness (m³/m²h@50Pa)	5	1
Ventilation	Natural with intermittent extract	MVHR
Heat source	Gas combi boiler, 24 KW	ASHP, 5 KW
Heating	Regular radiators	Oversized radiators
PV	None	4.8 KWp

Bioregional's high-level assessment found a cost range of £11,768 to £19,034 over and above the base cost to deliver a net zero carbon home. This is equivalent to between **7.2% and 11.7% uplift**. The cost uplifts to meet net zero carbon are distributed as follows:

- Fabric related cost uplift of £3,405 - £3,913 (2.1-2.4%)
- Building services related cost uplift of £8,363 (4%)
- Renewable energy (PV) cost uplift £1,873 - £8,632 (1.1-5.3%)

The likely lowest and highest cost scenarios were considered to provide a realistic range, depending on the final build system, roof design and PV specification. Details are shown in Table 8 and Table 9.

The costs are influenced by a range of factors such as the roof design and the build or system specification. The majority of the uplift is a result of additional building services (mechanical ventilation and heat recovery and air source heat pumps) and photovoltaic (PV) systems.

i. **Improved building fabric** results in a very small cost uplift (2%), as a majority of structural elements remain unchanged, with only the insulation thickness (therefore quantity) increasing. The majority of fabric costs are in the primary elements such as triple glazed windows and doors. It could also be argued that those fabric costs are not a true uplift, as the enhanced fabric specification (or similar performance level) is likely to be required as standard at latest in the 2025 Future Homes Standard.

ii. **Building services costs.** The Bioregional model considered a building services specification able to meet zero carbon requirements through an air source heat pump (ASHP), oversized low temperature radiators, mechanical ventilation with heat recovery (MVHR) and 4.8KWp PV. This resulted in an estimated total cost uplift of £11,525 (per dwelling), equivalent to a 7.1% uplift (over base cost). They note that Communal low or ambient temperature heat (pump) networks could provide further efficiencies.

A **majority of building services costs sit within on-site energy generation**, specifically PV systems. The exact cost of these measures will depend on panel type, efficiency and sizing. An integrated PV system can produce small savings in avoided roof tiles which are factored into this assessment. Bioregional note that PV also accounts for the largest cost uncertainty due to limited specification at feasibility stage. A range of options are assessed in the report.

The **second largest cost element is the heat source**, in our example an ASHP. Not requiring a gas connection to site can lead to further small build cost savings. Further savings from say the renewable heat incentive (live until March 2021), have not been factored here but are possible for rented stock.

Other large cost elements are mechanical ventilation (MVHR in this case) and oversized radiators. These are both a requirement for the low airtightness levels and the heat pump technology specified.

Bioregional also note that electrically led solutions make best use of rapid grid decarbonisation in the UK. Although further savings on build costs could be achieved from use of direct electric systems, only heat pump solutions also guarantee affordability for homeowners since the unit price of gas is currently 2 to 3 times less than that of electricity.

Table 8 Lowest cost to achieve net zero carbon

Element	Cost uplift per dwelling (£)	Percentage of base cost (%)
Fabric - traditional	£3,405	102.1%
Building services (excluding PV; including gas connection saving)	£8,363	104.0%
1.65 KWp PV* (including roof tile saving from integrated PV)	£1,873	101.1%
Total uplift		**£11,768**
Percentage of base build cost		**107.2%**

*NB: Likely not enough yield to offset both regulated and unregulated energy (i.e. not ZC)

Table 9 Worst case (highest) cost to achieve net zero carbon

Element	Cost uplift per dwelling (£)	Percentage of base cost (%)
Fabric – timber frame	£3,913	102.4%
Building services (excluding PV; including gas connection saving)	£8,363	104.0%
8.4 KWp PV* (including roof tile saving from integrated PV)	£8,632	105.3%
Total uplift		**£19,034**
Percentage of base build cost		**111.7%**

A further study by Currie and Brown[45] commissioned to inform the West of England Joint Spatial Plan considers a range of options to achieve carbon savings in new housing and the associated costs. Policy options considered included setting minimum levels of energy efficiency, onsite carbon reduction measures and achieving net zero carbon standards for (a) regulated emissions and (b) regulated & unregulated emissions. Allowable solutions at a cost of £95 per tonne to meet a zero carbon target were also considered.

Results indicated that it is possible to achieve net zero regulated emissions from a combination of energy efficiency, onsite carbon savings and allowable solutions for an additional capital cost of 5-7% for homes and non-domestic buildings. Achieving net zero regulated and unregulated emissions is likely to result in a cost impact of 7-11% for homes, consistent with the findings set out in the previous section.

The study also highlights that the cost of achieving these standards is likely to fall over time both due to reducing cost of technology and due to the reducing carbon intensity of grid electricity which means that carbon emissions of new homes will be lower than the level estimated by current regulatory compliance methods.

West Oxfordshire District Council may also wish to reference the viability assessment provided alongside the recently adopted Reading Borough Local Plan[46]. Whilst focus is given to sustainable construction methods (and find cost parity with traditional methods), consideration is also given to uplift on Part L 2013. Similar evidence is available in

[45] Currie & Brown (2018). *Cost of carbon reduction in new buildings*
[46] Reading Borough Local Plan, https://www.reading.gov.uk/media/9748/EC030-Additional-Information-on-Viability-Assessment/pdf/EC030_Additional_Information_on_Viability_Assessment.pdf

both the Milton Keynes[47] and Ipswich[48] Whole Plan Viability Assessments. Both adopted plans incorporate an uplift on Part L 2013 regulations.

Whilst the improved build standards and low carbon heat requirements may introduce an increase in build costs (estimated 1 - 4% uplift), anecdotal evidence suggests that homes built to better energy efficiency standards sell more quickly than standard homes in the same area (the example referenced Passivhaus). This provides a quick return on investment for developers helping offset the small additional outlays required to build.

12 Long term stewardship

Ongoing collaboration will be required to secure a model for long term management of the energy assets at the Garden Village. Community involvement will be key, and we recommend that options for community ownership of the assets be explored.

A monitoring and reporting regime will be required to ensure that buildings across the development achieve annual net zero carbon emissions. Resourcing and reporting governance to secure ongoing monitoring at the development (including annual reporting as set out in Section 6) should be agreed at the planning stage. Responsibility and penalties for failure to meet the target should be agreed at an early stage (for example cost per tCO_2e payable to the District Council).

[47] Whole Plan Viability Study 2017 - Milton Keynes Council
[48] https://www.ipswich.gov.uk/sites/default/files/ipswich_viability_testing_for_dev_plan_accompanying_note_dec_14.pdf and https://www.ipswich.gov.uk/sites/default/files/adopted_core_strategy_and_policies_dpd_review_1_march.pdf

13 Further work

This Energy Plan sets a framework for the Garden Village development. We strongly recommend that the site promoter, developers, local authorities and other key stakeholders in the local community continue to collaborate throughout the site planning process and beyond to explore existing funding models or develop new business models to deliver the energy efficiency standards and local generation solutions to enable a net zero carbon Garden Village.

In addition, Project LEO, in collaboration with key stakeholders, including the local community, and will develop a more detailed energy model to explore the elements of a local energy system. Whilst centred on the Garden Village this should also consider interactions and integration with the wider Eynsham area.

The Garden Village development provides a unique opportunity to be a national (and international) exemplar in overcoming both the technical and financial challenges highlighted thanks to highly engaged local community-energy groups in the wider Eynsham area working alongside Project LEO, a world leading smart local energy system demonstrator project led by the DNO, SSEN.

Appendix 1 Abbreviations and Glossary

AAP	Area Action Plan	Planning document prepared by West Oxfordshire District Council to guide development at the Garden Village. The AAP will establish an agreed vision for the garden village together with an overall framework for development and a series of objectives and policies against which any future planning applications will be judged.
BEIS	Department for Business, Energy and Industrial Strategy	Government department with responsibility for climate change, energy & clean growth
CCC	Committee for Climate Change	Independent, statutory body established under the Climate Change Act 2008 to advise the UK and devolved governments on emissions targets and to report to Parliament on progress made in reducing greenhouse gas emissions and preparing for and adapting to the impacts of climate change.
COP	Coefficient of Performance	Ratio of power input to power output used to describe the efficiency of a system. The higher the number, the more efficient the system.
FHS	Future Homes Standard	New building standard proposed for implementation across the UK from 2025 (with interim standard from 2020) to replace requirements set in Part L of current Building Regulations (2013).
FiT	Feed in Tariff	Government programme designed to promote the uptake of renewable and low-carbon electricity generation technologies, introduced in 2010, closed to new applicants from April 2019
IPCC	International Panel on Climate Change	UN body for assessing the science related to climate change
KPI	Key Performance Indicators	Measures used to monitor delivery and effectiveness of projects
LEO	Local Energy Oxfordshire	National demonstrator project funded by Innovate UK through the Prospering from the Energy Revolution fund.
LCH	Low Carbon Hub	Social enterprise at forefront of community energy, based in Oxford and a partner in Project LEO

LPA	Local Planning Authority	Public **authority** whose duty it is to carry out specific **planning** functions for a particular area.
LSOA	Lower Super Output Area	Statistical area defined by the Office for National Statistics. Each LSOA has a minimum population of 1000 and the mean is 1500.
MSOA	Middle Layer Super Output Area	Geospatial statistical unit created by ONS with a population between 5000 and 7200
MVA	Megavolt amperes	Unit used for measuring apparent power, the total current and voltage in an **electrical** circuit
NPPF	National Planning Policy Framework	Sets out government's planning policies for England and how these are expected to be applied.
OCC	Oxfordshire County Council	Partner in Project LEO
PSS	Primary Substation	Part of an electrical generation, transmission, and distribution system
SAP	Standard Assessment Procedure	Methodology used by the Government to assess and compare the energy and environmental performance of dwellings
SDA	Strategic Development Area	Area identified for development in the Local Plan
SLG	Strategic Location for Growth	Area to the north of Eynsham identified in the West Oxfordshire Local Plan which will form the Oxfordshire Cotswold Garden Village
T&CPA	Town & Country Planning Association	Charity campaigning for the reform of the UK's planning system to make it more responsive to people's needs and aspirations and to promote sustainable development
TER	Target Emissions Rate	A minimum allowable standard for the energy performance of a building, expressed in annual kg of CO_2 per square metre
UKGBC	UK Green Building Council	Charity catalysing sustainability in the built environment
UoO	University of Oxford	Partner in Project LEO
WODC	West Oxfordshire District Council	Local Planning Authority for West Oxfordshire district

Eynsham Energy Plan Technical Appendices

Appendix 2: Review of Resources

14.1 Generation

Determining the exact amount of embedded generation within an area can be difficult due to the lack of a single database, requirements for registration differing for size and installation type, lack of accurate and maintained records where they do exist and geospatial/network tagging of assets. As an estimate, the Feed-in-Tariff (FiT), Renewable Obligation (RO) and Renewable Energy Guarantees Origin (REGO) databases (available through Ofgem) as of April 2019, have been combined and assigned to the LSOA in which they are located (using the postcode to LSOA lookup available through ONS). Annual generation is estimated by using a typical capacity factor for each technology type. 0.12 and 0.29 was used for PV and Wind respectively.

Table 10 Core LSOAs (within Eynsham Primary Substation area)

LSOA code	Installations	Declared net capacity (kW)	Estimated Annual Generation (kWh)
E01028785	36	95	99,486
E01028786	44	176	184,875
E01028787	107	10317	1,084,4852
E01028788	46	151	158,868
E01028789	31	104	108,925
E01028790	52	155	163,378
E01028791	48	140	147,305
Total	**364**	**11,137**	**11,707,687**
Eynsham Solar Farm (ESF)	1	9,990	10,501,488
Total (exc. ESF)	**363**	**1,147**	**1,206,199**

Table 11 Wider LSOAs (overlapping with Eynsham primary substation area)

LSOA	installations	Declared net capacity (kW)	Estimated Annual Generation (kWh)
E01028708	31	100	105,204
E01028742	14	145	151,972
E01028785	36	95	99,486
E01028786	44	176	184,875
E01028787	107	10317	10,844,852
E01028788	46	151	158,868
E01028789	31	104	108,925
E01028790	52	155	163,378
E01028791	48	140	147,305
E01028799	67	184	193,263
E01028800	52	220	231,748
E01028804	38	179	187,839
E01028825	34	157	214,364
Total	**600**	**12122**	**12,792,077**
Eynsham Solar Farm	1	9990	10,501,488
Total (exc. ESF)	**599**	**2132**	**2290589**

14.2 Demand

14.2.1 Electricity

The mix of meter types as reported by BEIS in the 2017 sub-national electricity and gas consumption data for core LSOAs and MSOAs associated with the Eynsham area suggest about 90% of meters are domestic meters, and 10% are non-domestic meters[49]. However, non-domestic meters account for 32% of the area's electricity demand. The mean annual consumption for a domestic meter is **4.16 MWh** and **8.87 MWh** for a non-domestic meter. There are **4328** electricity customers currently connected to the Eynsham Primary Substation.[50]

Table 12 Electricity Meters and consumption

Electricity	Domestic meters	Non-domestic meters	Total annual consumption (GWh)	Mean annual domestic consumption (kWh)	Mean annual non-domestic consumption (kWh)
Core LSOAs	4,564	N/A	18.9	4160.2	N/A
Core MSOAs	5,182	575	34.3	4514.5	8871.5
Eynsham Primary Substation	4,328		31.3	7232.0	

49 BEIS 2017 Sub-national electricity consumption; URL: https://www.gov.uk/government/collections/sub-national-electricity-consumption-data. Accessed: Sept 2019
BEIS 2017 Sub-national gas consumption; URL: https://www.gov.uk/government/collections/sub-national-gas-consumption-data. Accessed: Sept 2019

50 SSEN Network Loading and Capacity Information; URL: https://www.ssen.co.uk/NetworkCapacityInformation/. Accessed: June 2019

14.2.2 Gas

Domestic gas meters account for 99% of gas meters within the Eynsham MSOA area. The mean annual domestic gas consumption is **15.5 MWh**, this is much higher for the few non-domestic meters at **175.6 MWh**, but collectively still only accounts for 11% of the area's gas consumption.

Table 13 Gas Meters and consumption

Gas	Domestic meters	Non-domestic meters	Total Annual consumption (GWh)	Mean annual domestic consumption (kWh)	Mean annual non-domestic consumption (kWh)
Core LSOAs	4,177	N/A	64.6	15,513.6	N/A
Core MSOAs	4,178	45	72.5	15,275.5	175,609.0

14.3 Electricity Network

The tables below summarise data made openly available under licence as an indication of the network capacity only.

Table 14 Demand Availability Data [51]

Primary Substation Name	Voltage (kV)	Latitude	Longitude	Nameplate rating (MVA)	Minimum Load (MW)	Maximum Load (MW)
Eynsham	33/11	51.789495	-1.388416	24.00	3.30	11.50

Table 15 Generation Availability Data [52]

Primary Substation Name	Corresponding Bulk Supply Point	Break Fault level vs Rating (kA)	Transformer Nameplate Rating (MVA)	Sum of Quoted Generation (MVA)	Minimum Load (MW)	Maximum Load (MW)	Contracted Generation (MVA)	Available Headroom Capacity (MVA)	Reverse Powerflow Capability (%)
Eynsham	Yarnton	9.18 / 25	24	0	4.24	12.05	0	28.24	50

Table 16 Network Capacity information [53]

Primary NRN (3 / 4)	Primary Substation Name	Primary Substation Customers	Primary Transformer Rating ((MVA)	Primary Substation Peak Demand (MVA)	Fault Level (kA)
4614	EYNSHAM	4328	24	11.13	25

[51] SSEN Contracted Demand Information; URL: https://www.ssen.co.uk/ContractedDemandMap/?mapareaid=1. Accessed: Sept 2019

[52] SSEN Generation Availability Information; URL: https://www.ssen.co.uk/generationavailability/. Accessed: Sept 2019

[53] SSEN Network Loading and Capacity Information; URL: https://www.ssen.co.uk/NetworkCapacityInformation/. Accessed: June 2019

Appendix 3: Energy Modelling

15.1 Demand

To estimate future demand for the garden village site, a bottom-up empirical approach is taken where real customer load profiles for the various building types, social demographics and technologies are combined to create a site profile at half-hourly resolution. The load is broken down into 6 separate contributions:

i. Residential heating, hot water and (non-EV) household electricity use for 2200 dwellings
ii. Residential EV charging
iii. Science park for a 40 ha site with a footprint for building of 4.096ha
iv. A School to accommodate over 1030 pupils
v. Health centre/small hospital
vi. Neighbouring park and ride development (treated separately)

15.1.1 Demand Model Inputs

15.1.1.1 Residential

Five scenarios were considered to evaluate the total energy consumption of the residential area (based on the distribution of housing types set out in Table 17).

Table 17 House type distribution

House type	GV Distribution[54] (%)
Detached	35
Semi-Detached	32
Terraced	23
Flat	10

[54] Based on assumptions for the Garden Village

Table 18 Residential energy demand scenarios

Scenario 1 Homes built to 2013 Part L standards: Gas heating

A base scenario assuming homes built to 2013 part L standards and with a gas boiler was created using real customers' load profiles averaged from several iterations from 2200 randomly picked household based in the Oxfordshire area. An average gas boiler efficiency of 0.83 was assumed[55].

From this scenario several assumptions (described below) were made to model four low carbon scenarios. To compare the space heating energy demand from other energy use we assumed that 79% of gas usage[56] was for space heating and 21% for water heating and cooking.

Scenario 2 Homes built to current Part L standards; heating provided by Electric Boilers

Assumptions as Scenario 1 but heating provided by electric boiler; efficiency 0.99 assumed

Scenario 3 Homes built to current Part L standards; heating provided by Heat Pumps

Heat pumps with an average coefficient of performance (COP) of 3 varying from 2.5 for the coldest days to 3.5 for the warmest days were considered.

Scenario 4 High quality fabric buildings (space heating demand ≤15 kWh/m^2/year)

This scenario was based on the space heating demand achieved in buildings designed to Passivhaus standards[57] (*space heating demand ≤ 15 kWh/m^2/yr; primary energy total demand ≤ 120 kWh/m^2/yr)*.

Assuming that the electricity grid will be fully decarbonised in some years a primary factor of one was applied. This means that primary energy demand equals final energy demand. This scenario targets mainly the quality and efficiency of the fabric. Any carbon free heating type can be considered as long as the space heating demand targets are reached.

The following criteria enable a space heating demand of less than 15kWh/m^2/year[58]:

Exterior walls to achieve a U-value of less than 0.15

Windows: U-values less than 0.8

Airtightness: Less than 0.6 air changes/hour at 50Pa (Pascal)

Ventilation: Over 80% heat recovery from ventilation exhaust air

Scenario 5 Mix of 50% high quality fabric buildings + 50% regular new build with heat pumps

This intermediate scenario assumes that 50% of houses are built with high quality fabric to achieve a space heating requirement of ≤ 15 kWh/m^2/year and 50% houses are built to current Part L standards but equipped with heat pumps.

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55 Calculated from the BRE boiler database - https://www.ncm-pcdb.org.uk/sap/pcdbsearch.jsp?pid=26

56 ECUK: End uses data tables

57 UK Passivhaus standards https://passivhaustrust.org.uk/what_is_passivhaus.php

58 https://www.homebuilding.co.uk/passivhaus-what-is-it/

15.1.1.2 Home EV chargers - energy demand

Three electric vehicle (EV) penetration scenarios were considered, each assuming use of 7kW chargers:

- 2% of homes with EV (44 charge points)
- 50% of homes with EV (1100 charge points)
- 100% of homes with EV (2200 charge points)

The 100% EV scenario each home has a charge point and assumes only one EV per home.

15.1.1.3 Science park demand

Begbroke Science Park energy demand was used to indicate energy demand at the proposed Garden Village science park area. Begbroke has a building footprint of 1.2 ha. The load curve for the Eynsham development was scaled to the footprint size of the new science park which is expected to be 4.096ha.

15.1.1.4 School demand

The energy demand of an existing 600 pupil school in Oxford was used and the load curve scaled for a school accommodating 1030 pupils, the maximum planned for the Garden Village area. Alternative building fabric scenarios were not modelled.

15.1.1.5 Hospital demand

The demand from a small hospital in Oxfordshire with a footprint size of 2320 m^2 was used and scaled to the footprint of the maximum planned size for the hospital at the Garden Village: 1083 m^2

15.1.2 Demand Model Outputs

The results of the energy demand modelling are set out in the tables and charts below.

Figure 3 Residential heating scenarios: daily heating energy use (MWh)

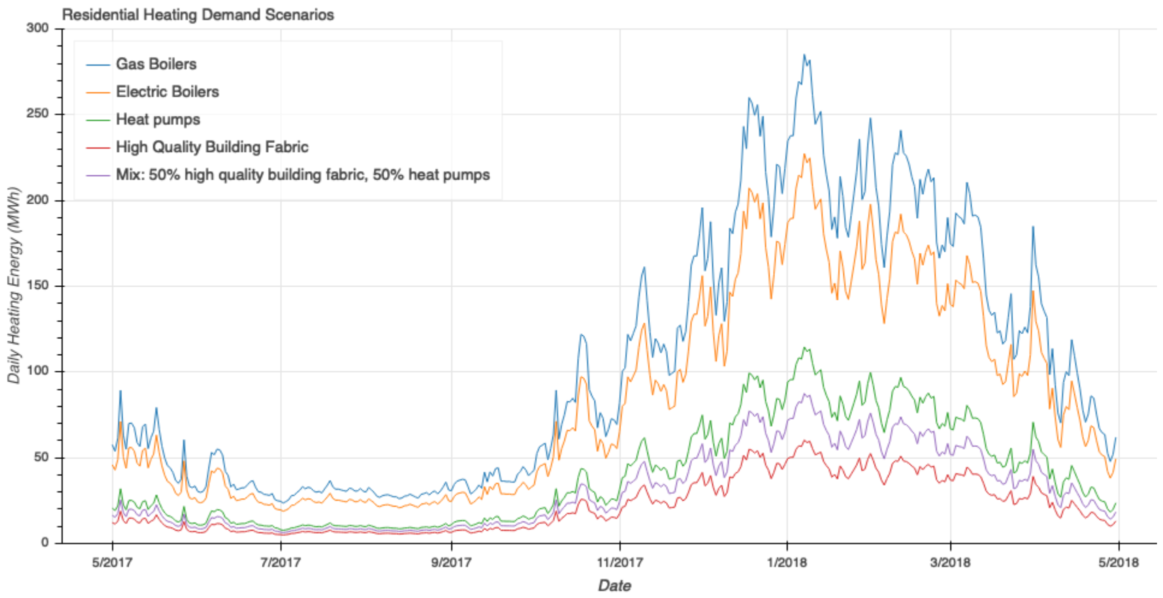


Table 19 Residential heating scenarios: summary results

	Current building standards			High quality fabric buildings	Mix 50% High quality fabric buildings + 50% current standards with Heat Pumps
	Gas Boilers	Electric Boilers	Heat pumps		
Yearly Consumption (GWh)	30.34	25.30	8.43	2.80	5.62
Average annual heating energy consumption (kWh/m^2/year)	162.24	135.30	45.10	15.00	30.05

Heating homes with electric boilers is slightly more energy efficient and, assuming that the electricity comes from decarbonised sources, has a lower carbon impact than using gas boilers. However, with the unit cost of electricity currently around three times higher than that of gas, may not be affordable for householders.

The use of heat pumps (scenario 3) significantly reduces heating energy consumption. Building houses with high quality fabric enables the energy demand for space heating to be minimised.

This table also shows that it is possible to achieve reasonable results (a low average annual energy demand) with a mix of 50% of the houses built under high quality fabric standards and 50% of the houses built under regular standards but equipped with heat pumps.

Figure 4 Total Residential electrical demand scenarios

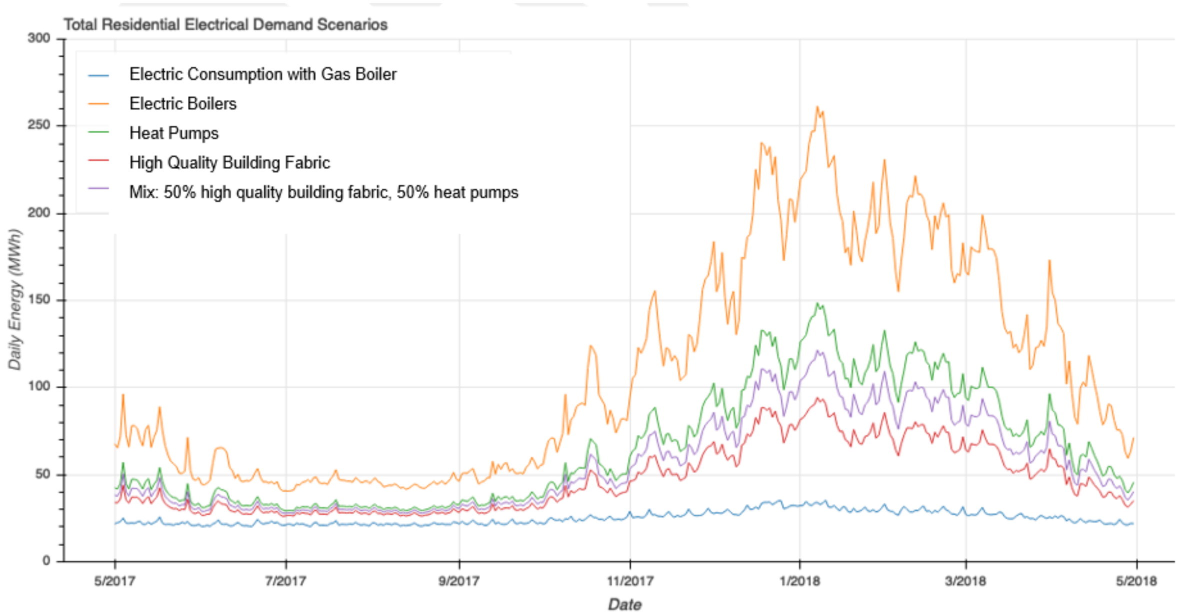


Table 20 Total residential electrical demand scenarios summary

	Current building standards			High quality fabric buildings	Mix 50% High quality fabric buildings - 50%Heat Pumps
	Gas boilers	Electric boilers	Heat pumps		
yearly electricity consumption (GWh)	9.18	39.80	22.93	17.30	20.12
Peak Load (MW)	2.63	17.02	9.03	6.37	7.70
average electricity consumption (kWh/m2/year)	49.11	212.82	122.62	92.52	107.57

Figure 5 Daily electricity consumption for EV scenarios

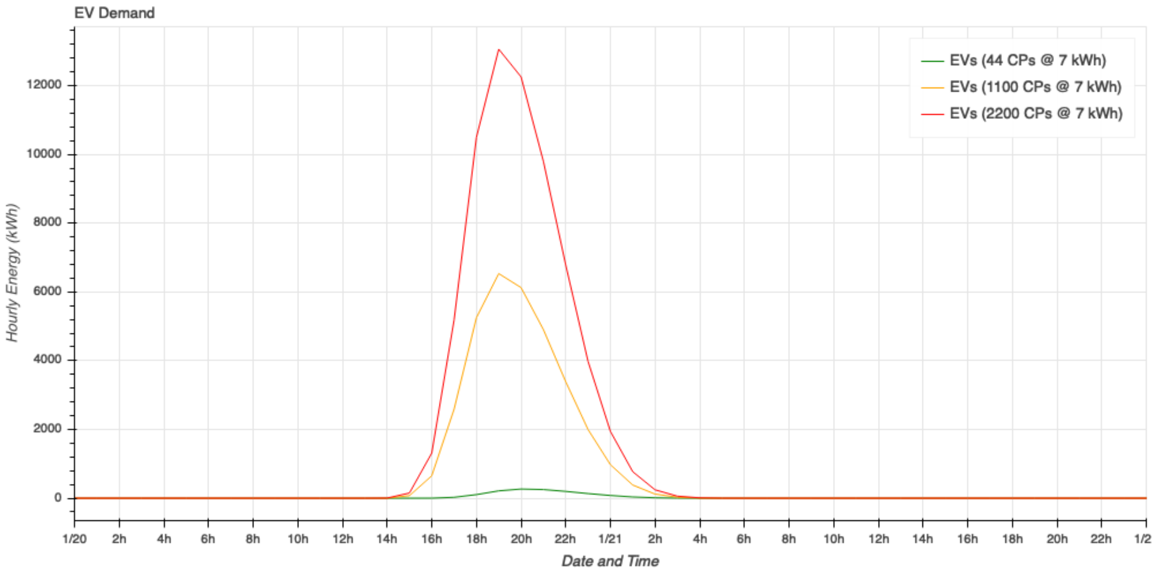
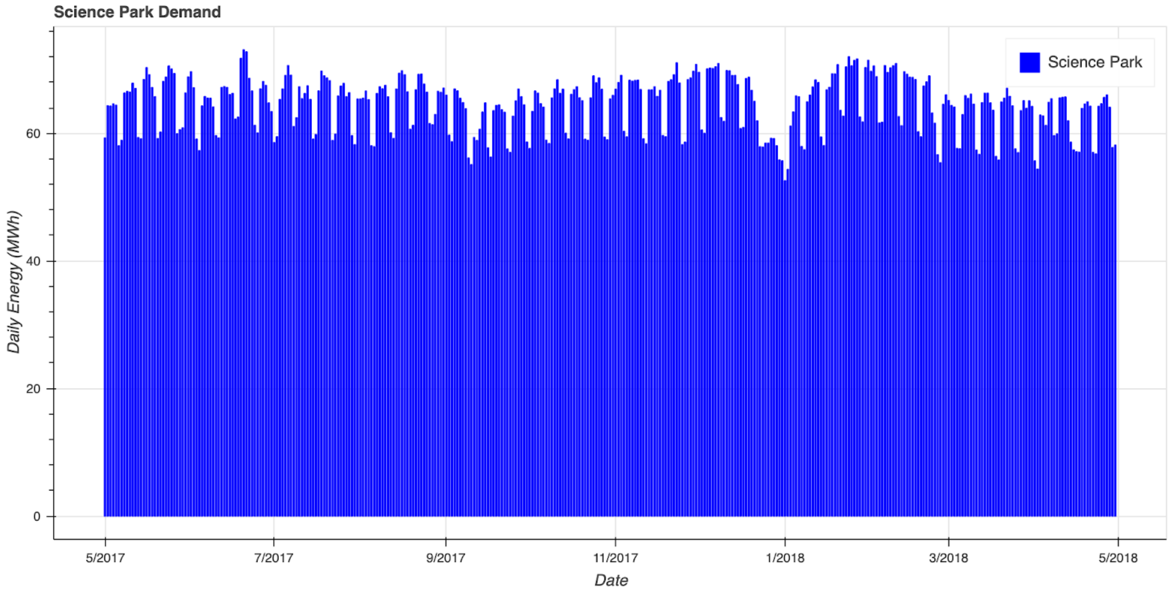


Table 21 Yearly electricity consumption summary for the 3 EV scenarios

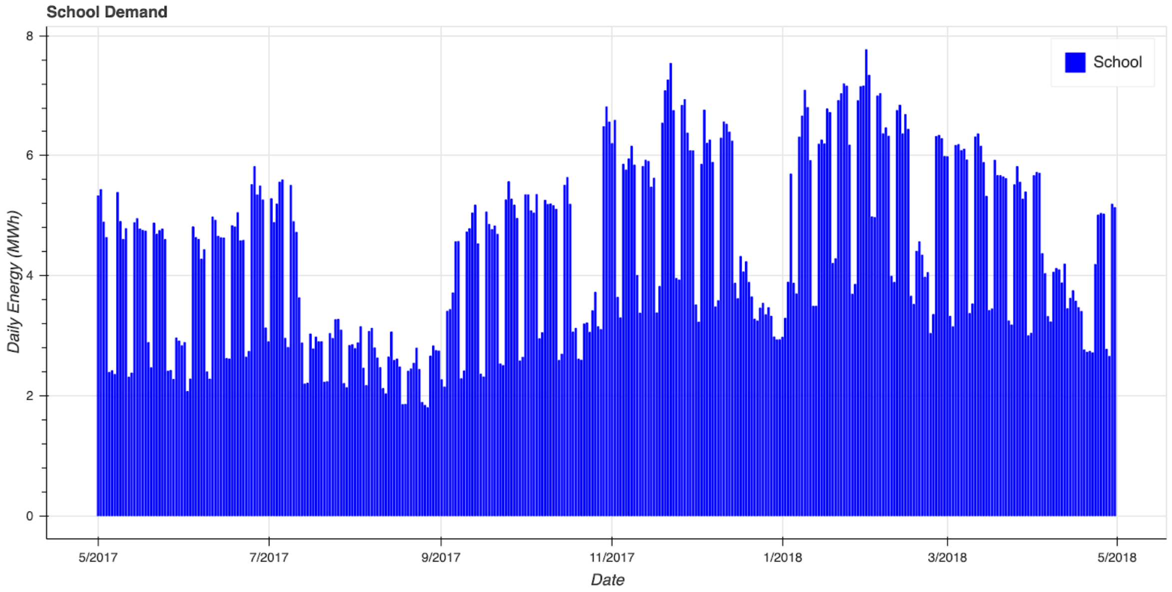
	44 CPs @ 7 kW	1100 CPs @ 7 kW	2200 CPs @ 7 kW
Yearly Consumption (GWh)	0.24	6.04	12.08
Peak Load (MW)	0.27	6.60	13.20

Figure 6 Science Park Energy Demand



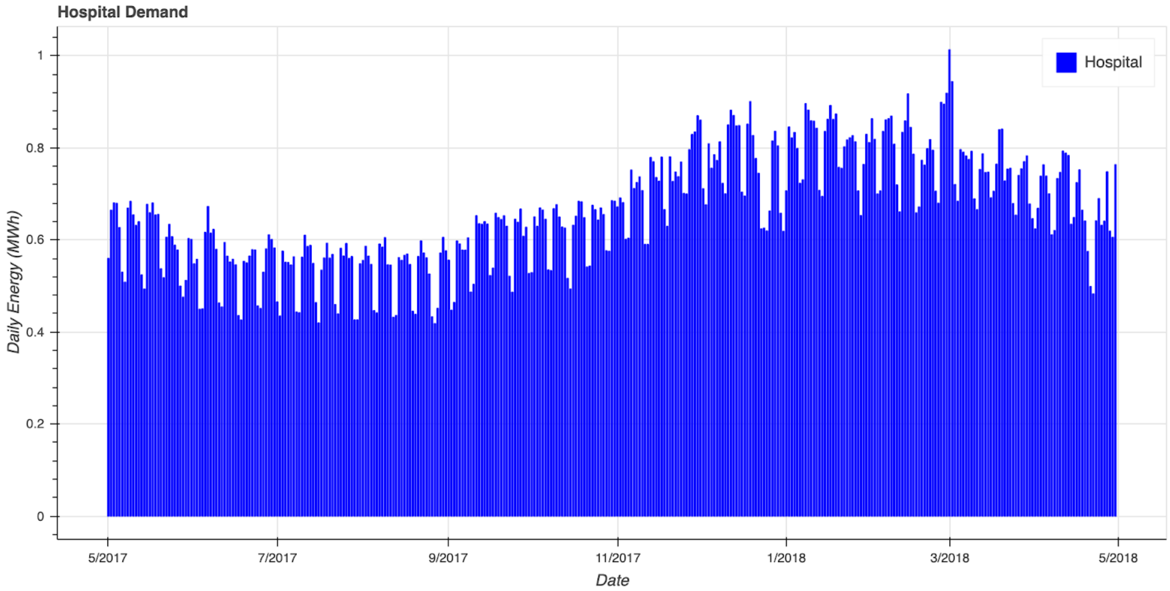
Yearly Consumption (GWh)	23.50
Peak Load (MW)	3.74

Figure 7 School energy demand



Yearly Consumption (GWh)	1.59
Peak Load (MW)	0.52

Figure 8 Hospital Energy Demand



Yearly Consumption (GWh)	0.24
Peak Load (MW)	0.07

15.1.3 Total Garden Village Demand Scenarios

Total electricity demand and maximum peak load for the different residential and EV scenarios for the whole area were estimated.

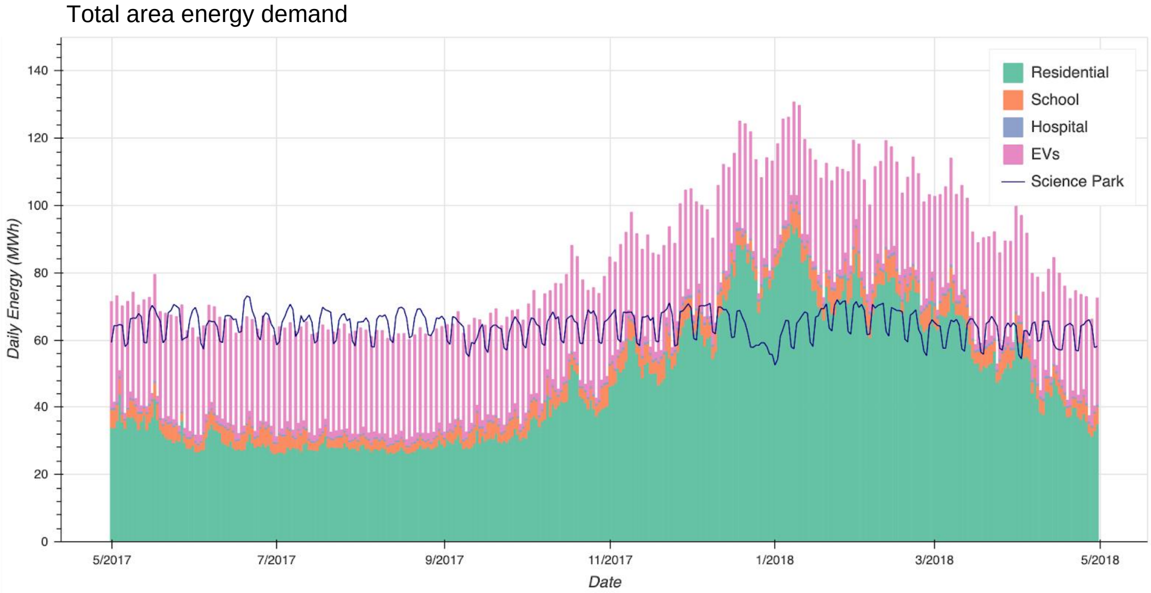
Table 22 Total electricity demand and peak load scenarios

2% EV scenario	Current build standards			High quality fabric buildings	Mix 50% High quality fabric buildings - 50%Heat Pumps
	Gas heating	Electric Boilers	Heat pumps		
Total electricity demand for the whole area (GWh)	34.73	65.34	49.40	42.84	46.12
Maximum Peak load (MW)	7.24	21.63	14.44	10.97	12.70

50% EV scenario	Current build standards			High quality fabric buildings	Mix 50% High quality fabric buildings - 50%Heat Pumps
	Gas heating - current houses	Electric Boilers	Heat pumps		
Total electricity demand for the whole area (GWh)	40.526	71.142	55.205	48.645	51.925
Maximum Peak load (MW)	13.572	27.961	20.770	17.304	19.037

100% EV scenario	Current build standards			High quality fabric buildings	Mix 50% High quality fabric buildings - 50%Heat Pumps
	Gas heating - current houses	Electric Boilers	Heat pumps		
Total electricity demand for the whole area (GWh)	46.568	77.184	61.246	54.687	57.967
Maximum Peak load (MW)	20.170	34.559	27.367	23.901	25.634

Figure 9 Modelled total annual electricity demand for Garden Village (all building types, high quality fabric homes, 50% with EVs)



15.2 Park & Ride

15.2.1 Inputs

The Park & Ride will have three major components with regards to its energy profile. These are the solar canopy, the EV charging points and the local load of the on-site café that serves the drivers arriving in the morning. Planning documents indicate that the Park & Ride will have 1,000 spaces and 45 charge points.

The local load is assumed to follow a restaurant-like profile, which is scaled to match the small size of the café and time-shifted to match the early arrival of the drivers. From available MPAN data, 10 daily load curves of a restaurant are averaged, scaled and time-shifted to give an indicative average load of a café.

For the solar canopy, the estimations use UK-averaged, hourly capacity factors which are then multiplied by the power rating of the canopy to get an estimated power output. To get both the maximum and minimum power outputs, data from the last 10 summer solstices are averaged to give an estimated capacity factor profile for the longest day of the year. The same is done with the winter solstices from the last 10 years to get an estimated capacity factor profile for the shortest day of the year. Both of these profiles are then averaged together to get an average profile representing the whole year. The capacity factors data are sourced from Renewables Ninja[59].

The EV charge points provide energy to their connected vehicles. They are assumed to be “dumb” chargers that begin providing energy from the moment they are connected to the moment the battery has reached its final charge or the vehicle

[59] https://www.renewables.ninja/

disconnects (no smart charging scenarios). According to the planning permission documents submitted for the Park & Ride, there will be 45 charge points on-site. Depending on the scenario, the simulations use different mixes of charger power ratings (7, 22, 50kW).

The load of the EV chargers depends heavily on the behaviours of the drivers: the studies conducted in the planning of the Park & Ride indicate estimated peak arrival times and peak departure times, shown in the following table. In the model, the arrival times of the EVs have been estimated and distributed along the predicted morning peak and the average and variance for the durations of stay have been adjusted to match these peaks.

The peak load and net energy consumption/production of the Park & Ride are estimated in the next section. This is done for each of the three scenarios presented earlier: Business As Usual 2020, EV+PV, EV+PV+Fast charging.

Table 23 Assumed distribution of vehicle arrival and departure evaluation

Year	AM Peak (0800-0900)		PM Peak (1700-1800)	
	In	Out	In	Out
2021	135	6	8	139
2031	224	14	14	193

15.2.2 Results

The next sets of graphs present the outcomes of the energy modelling for the park and ride.

Figure 10 shows the projected load for charging the vehicles over the course of a day in each of the three scenarios. Each case has 45 chargers with the proportion of types following the definitions set within the scenario table. As shown, incorporating chargers of higher power into the car park will result in a higher peak load early in the morning with a smaller tail end later in the day, though there is likely to be some sort of charging load until late afternoon regardless of the scenario.

Figure 11 represents all the relevant power curves (both consumption of local demand and total demand of EV chargers and seasonal production of the solar canopy). There is a significant difference in the PV production between peak summer and peak winter. Unfortunately, there is a strong likelihood that the peak charging power does not coincide with the peak solar panel power output meaning that the self-consumption of the site is wanting. One can also note that the local load from the on-site café is negligible in every case when compared to the EV charging load. It is also important to note that these curves represent “typical” days but PV production varies significantly according to weather conditions, and there are a small number of chargers meaning that the EV load curve is susceptible to a high level of randomness.

Figure 12 summarises the net energy profile of the Park & Ride. In the scenario with 500 kWp of PV capacity, even in the best case, the system will still need to import energy in order to meet the peak demand of the chargers. For the scenario with 1 MWp of PV, the system should be able to mostly meet the demand of the chargers in the summer, but will need to supplement its supply, especially on days with less irradiation. The PV does nonetheless reduce how much power should be imported. Installing solar panels onto the Park & Ride will allow a net export of energy to be possible at times, but energy will have to be imported in order to meet the peak demand of the EV chargers, especially in winter. Smart Charging could allow better self-consumption, but methods for use in public applications are still being trialled.

As shown in the daily summary in Figure 13, by including PV, there will be a net surplus of energy in the Summer and a reduced shortage in the Winter. Depending on the demand or supply on the rest of the grid, this energy could potentially be exported to meet energy needs off-site or stored in batteries for use at a later time.

Figure 10 EV Charging Load Profile

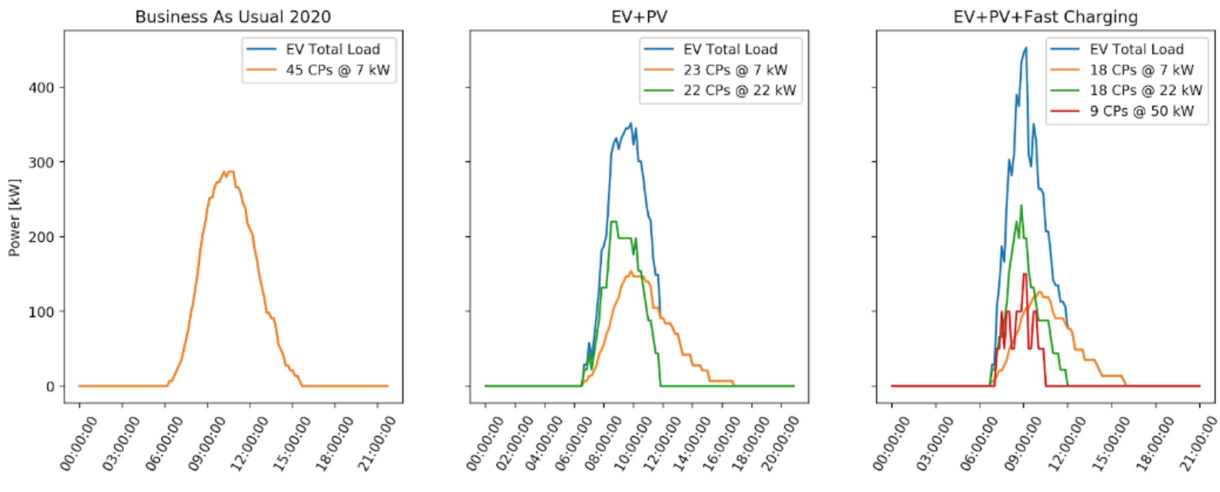


Figure 11 PV Generation

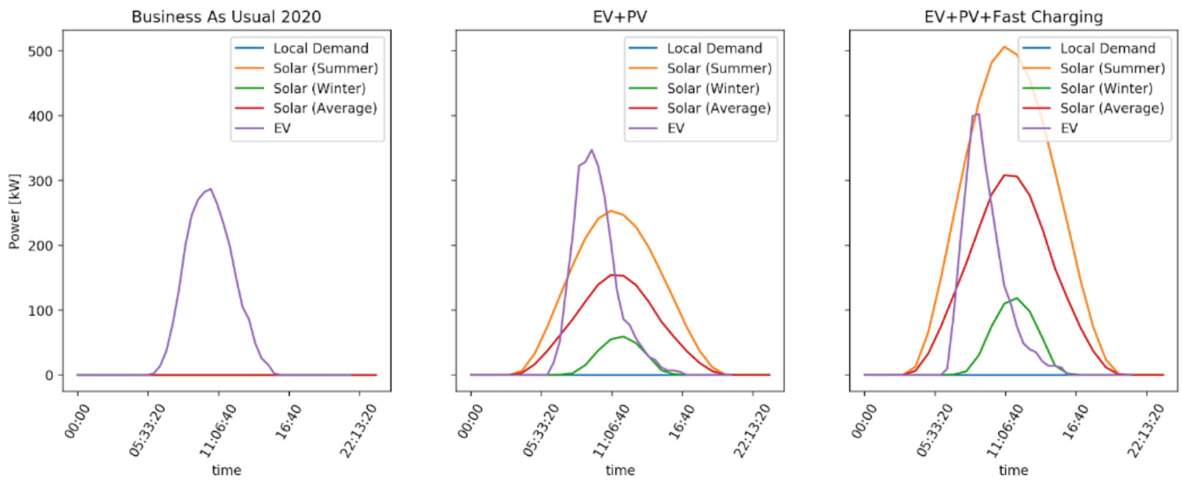


Figure 12 Net Power Profile for Park & Ride (positive signifies excess power)

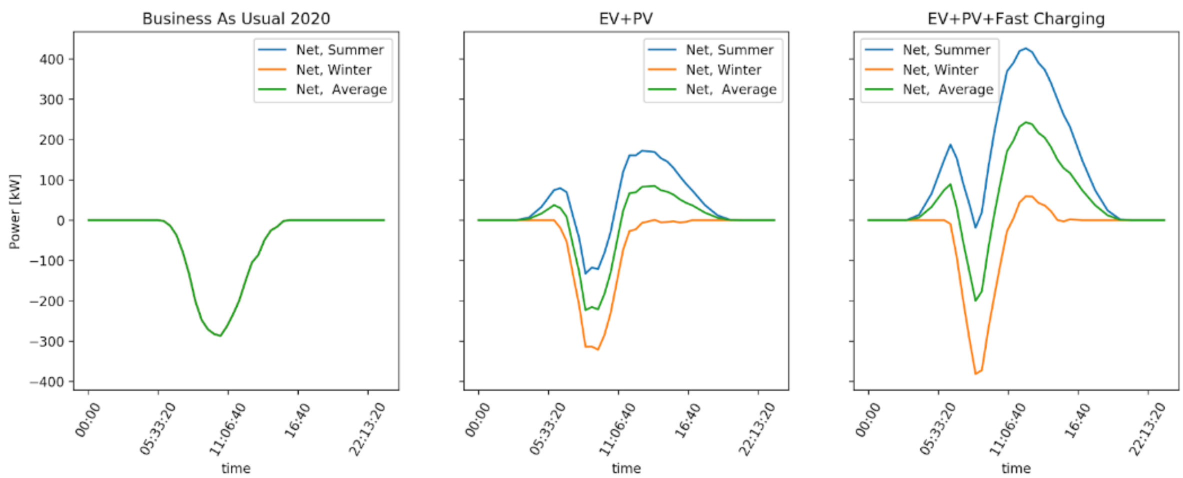
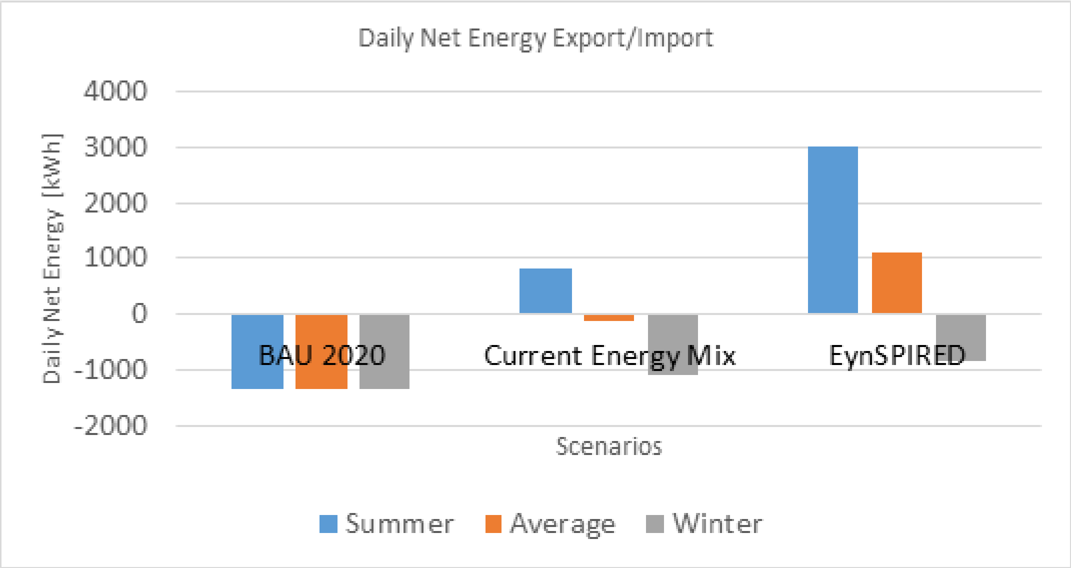


Figure 13 Daily Net Electricity for Park & Ride



15.3 Required PV area for annual net zero

The following analysis uses the residential high-quality fabric buildings with 50% EV penetration scenario presented above for representative electrical demand. The estimated total annual site demand is 48.6 GWh. Solar PV is seen as a major generation technology in Oxfordshire due to the lack of national support for onshore wind and the numerous MoD air bases located in the county. For an annual solar capacity factor of 12%, this would require 46.2 MWp of solar generation to achieve net zero energy annually. Assuming a figure of 0.160 kW/m^2 for a typical PV module, this will require an area of approximately 2.89×10^5 m^2. At a tilt of 40° and 90% ground utilisation, this corresponds to a floor area of about 2.46×10^5 m^2 or **24.6 ha.** This could range from 18 ha to 34 ha depending on the efficiency of the PV modules used and the space assumed between panels. The total area of the garden village development is 215 ha. Therefore, this corresponds to **11.4 %** of the total site. If only considering the residential site, ignoring both the park and ride demand and the science park demand, the annual demand figure becomes 25.2 GWh. This will require 12.8×10^5 m^2 or **12.8 ha.** This corresponds to **7.7 %** of the residential site area (167 ha). If high efficiency modules of 0.20 kW/m^2 are considered, this required area drops to 9.2 ha, or 5.5% of the residential site area.

Table 24 Solar PV generation assumptions

		Demand (GWh)	CF	PV capacity (MWp)	Module efficiency (kW/m^2)	Solar farm space efficiency	PV module area (m^2)	Tilt	Ground area (m^2)	Ground area (ha)
Total Site	Average	48.6	0.12	46.2	0.16	0.90	288955.5	40.0	245947.5	24.6
	Low	48.6	0.12	46.2	0.13	0.80	355637.5	40.0	340542.7	34.1
	High	48.6	0.12	46.2	0.20	1.00	231164.4	40.0	177082.2	17.7
Residential Site (ex. science park)	Average	25.2	0.12	24.0	0.16	0.90	149828.8	40.0	127528.3	12.8
	Low	25.2	0.12	24.0	0.13	0.80	184404.6	40.0	176577.7	17.7
	High	25.2	0.12	24.0	0.20	1.00	119863.0	40.0	91820.4	9.2

Site	Area (ha)
Residential	167
Science Park	40
Park and Ride	8
Total Garden Village	215

15.4 On-site Generation

A simple energy balance model has been developed, presented below, to assess the potential of achieving a net-zero development. It is not a presentation of the optimal solution, but rather a demonstration of what's technically possible considering a moderate and aspirational (but feasible in 2020) scenarios. It is based on solar PV as the prime generation source; but other generation options which could include small-scale wind, hydrogen or ammonia-fuelled fuel cells and CHPs, should be considered by the developers to go beyond what's presented here.

15.5 Domestic rooftop potential

Firstly, the potential for domestic rooftop solar is modelled according to the following methodology.

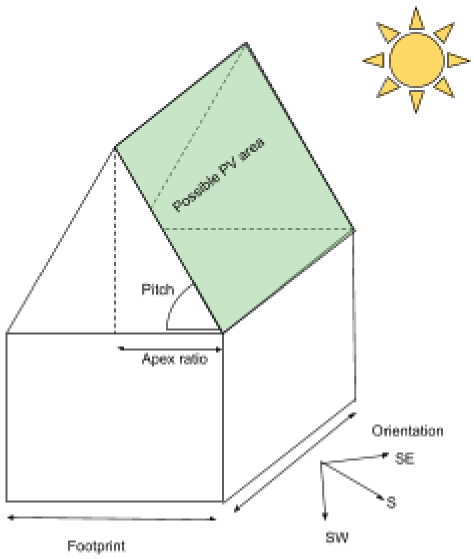
Model Parameters

Assumed values for the model parameters are listed below:

- **Number of houses with PV panels**: All **2200** planned houses within the garden village development are considered to have PV panels.
- **Pitch of house roof:** The pitch of the roof defines the tilt of the installed rooftop PV. For the moderate scenario, **45º** has been used across all buildings. For the aspirational scenario, an angle of **30º** is used, more practical for a mono-pitched roof.
- **Panel orientation:** This is based on building orientation. For the moderate scenario, each house is assigned a random orientation from a set of **9 orientations (**E, ESE,SE, SSE, S, SSW, SW, WSW, W); for the aspirational scenario, every building has a south facing roof.
- **House type**: Each house is randomly assigned a house type based on the weighted distribution of house types expected for the development. An average floor area is defined for each house type, and the footprint is assumed to be half this based on 2 storey houses. For a flat, a share of the block of flats footprint was estimated based on a 3 storey block. This is summarised in the table below.

Type	GV Distribution (%)	Floor area (m^2)	Footprint (m^2)
Detached	35	147	74
Semi-Detached	32	96	48
Large Terraced	11	101	51
Small Terraced	12	64	32
Flat	10	61	20

- **Apex position:** This defines the position of the apex of a gable style roof, which influences the area of the side available for solar. **0.5** (apex central to the building) is used for all buildings in the moderate scenario. **1** indicates a mono-pitched roof and is used for the aspirational scenario.
- **Module efficiency:** The PV module efficiency. **16%** is used for the moderate scenario, this corresponds to **0.16 kW/m**^{2}. **21%** is used for the aspirational scenario, this corresponds to **0.21 kW/m**^{2}.
- **Area utilisation:** The percentage of roof area which can be covered in panels. **90%** was used for domestic houses.



15.5.1 Method

The potential solar capacity for each house roof was calculated using the following equation:

$$PV_{cap} = \left(\frac{\alpha \times F}{\cos\theta}\right) \times \gamma \times \eta$$

Where α is the roof apex position, θ is the pitch of the roof, F is the footprint area, γ is the area utilised and η is the module efficiency.

The total solar capacity for each orientation (and tilt) was determined by grouping the houses by orientation and summing each associated rooftop installation. An hourly solar generation profile was acquired for each orientation from Renewables.ninja which uses historic weather reanalysis to simulate solar output based on the previously published methods and scaled for the capacity of each orientation and tilt.[60] Generation for 2017 was modelled.

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[60] Pfenninger, Stefan and Staffell, Iain (2016). Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, pp. 1251-1265. doi: 10.1016/j.energy.2016.08.060

15.5.2 Domestic Capacity

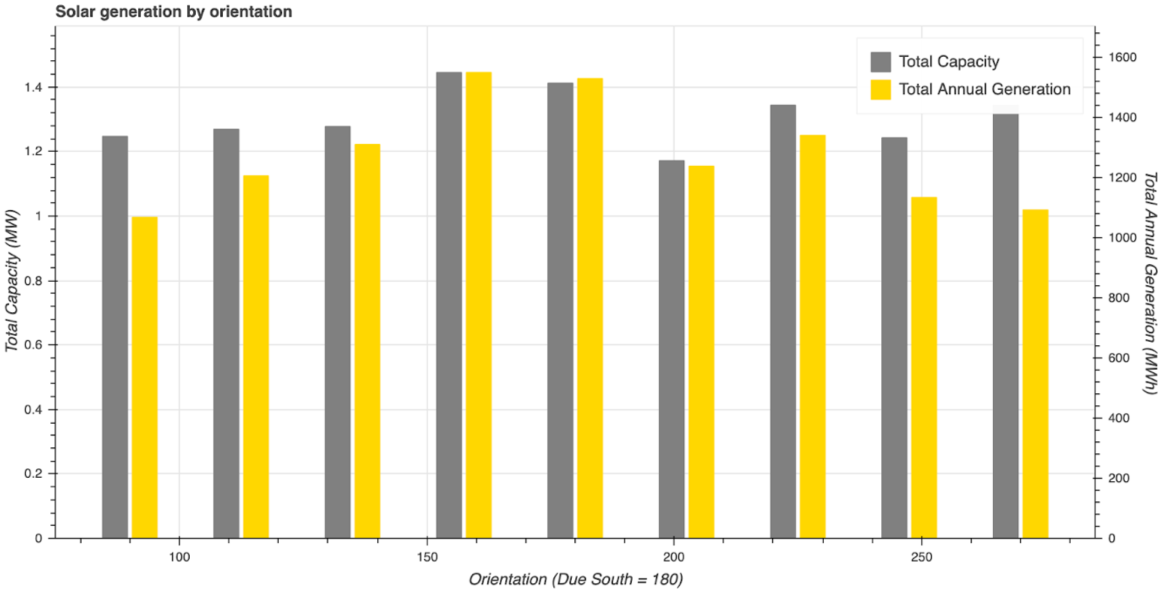
The total domestic rooftop PV capacity for the moderate scenario is **12 MW** and is expected to generate **11.46 GWh** annually. The rooftop PV modelled as a function of orientation is summarised in the table and graph below.

Table 25 Rooftop PV capacity and generation by orientation

Orientation	Number of houses	Total Capacity (kW)	Annual Generation (kWh)
90	226	1247	1,067,332
112.5	234	1269	1,205,336
135	238	1277	1,309,467
157.5	270	1445	1,548,884
180	262	1412	1,528,746
202.5	229	1172	1,237,731
225	247	1344	1,339,999
247.5	238	1243	1,133,558
270	256	1343	1,092,181
Total	**2200**	**11751**	**11,463,234**

Staffell, Iain and Pfenninger, Stefan (2016). Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output. Energy 114, pp. 1224-1239. doi: 10.1016/j.energy.2016.08.068
Renewables.ninja. URL: www.renewables.ninja. Accessed: Sept 2019.

Figure 14 Solar generation by orientation



For the aspirational scenario which assumes higher efficiency modules and south facing mono-pitched roofs to maximise available roof area, the PV capacity is on the order of **24 MW**, generating **26 GWh** of energy annually.

15.6 Non-domestic rooftop potential

There are a number of non-domestic buildings planned for the garden village site. Following on from the demand modelling the following buildings have been considered: a school for 1030 pupils with a footprint of 4000 m^2, a hospital of 1083 m^2 and a science park with a building footprint of 40000 m^2.

15.6.1 Model Parameters

The model parameters which differ from the domestic model are:

- **Number of buildings**: 1 building is assumed to represent each of the school, hospital and science park opportunities.
- **Pitch of roof:** The roof is assumed to be a flat roof for non-domestic buildings, a tilt of **10º** is used for the PV**,** which is common for a flat roof as additional planning permission isn't required.
- **Panel orientation:** All non-domestic PV is assumed to be south facing, 180°.
- **Apex position:** This isn't applicable to a flat roof, a default value of 1 is used.
- **Area utilisation:** To take into consideration the use of non-domestic roof space for HVAC systems, the percentage of roof area which can be covered in panels is reduced to **75%**.

15.6.2 Method

The same method is used as for domestic generation.

15.6.3 Non-domestic Capacity

The total non-domestic capacity is **5.49 MW** which will produce approximately **5.6 GWh** of solar generation annually for the moderate scenario. Excluding the science park, these figures are 0.62 MW and 0.63 GWh respectively. For the aspirational scenario where the only difference is 20% module efficiency, the non-domestic capacity is **6.86 MW**, producing approximately **7.0 GWh**. Excluding the science park, these figures are 0.77 MW and 0.79 GWh.

15.7 Total on-site capacity

The total on-site solar capacity potential, based on the model presented, and estimated annual energy generation is summarised in the table below.

Table 26 Total on-site solar capacity potential

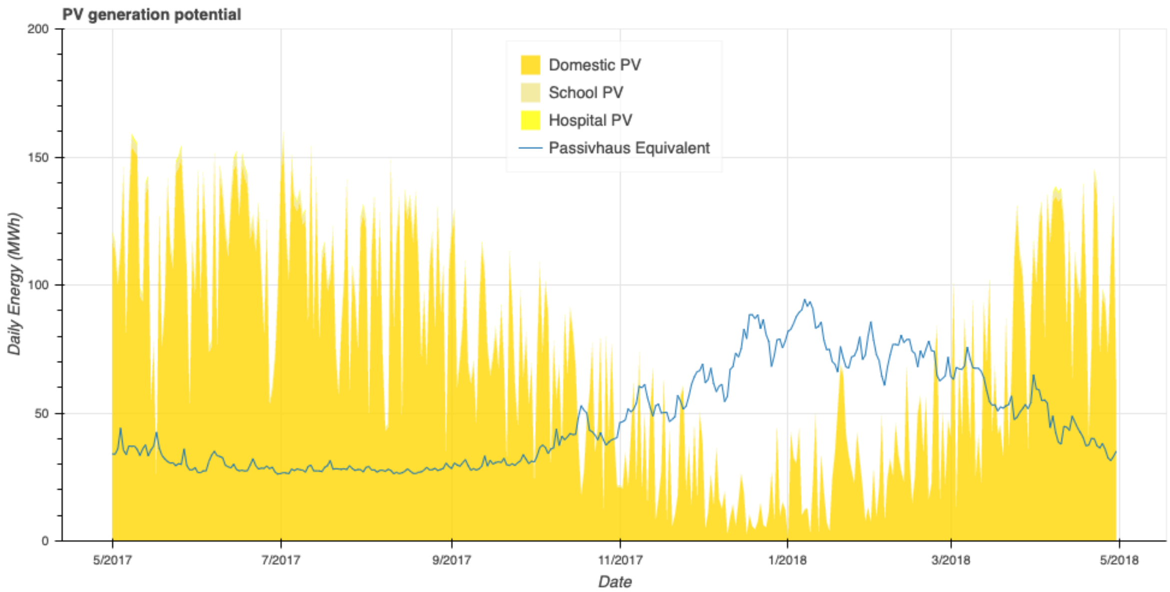
	Moderate		Aspirational	
	Total Capacity (MW)	**Annual Generation (GWh)**	**Total Capacity (MW)**	**Annual Generation (GWh)**
Domestic	11.75	11.46	23.94	26.01
School	0.49	0.50	0.61	0.62
Hospital	0.13	0.13	0.16	0.17
Science Park	4.87	4.97	6.09	6.21
Total	**17.24**	**17.06**	**30.80**	**33.01**

Under the moderate generation scenario with the highest efficiency standards, a total annual generation figure of 17.06 GWh is **35%** of the estimated annual demand for the entire garden village site. Looking only at the residential area of the development, excluding demand and generation potential of the science park, annual generation is **12.09 GWh**. This corresponds to **48%** of the 25.2 GWh estimated annual demand.

Under the aspirational generation scenario and highest building efficiency standards, the total annual generation figure of 33.01 GWh is **68%** of the estimated annual demand for the entire garden village site. Only considering the residential area of the development, annual generation is **26.8 GWh**. This corresponds to **106%** of the estimated 25.2 GWh annual demand, indicating a net-zero, even energy positive, residential development is possible with current (2019) best practice building efficiencies and PV module efficiencies.

The graph below shows daily energy generation under the aspirational scenario in comparison to high quality building fabric equivalent residential demand as shown previously. Although net-zero annually, a development based entirely on solar would not be net zero at all times of the year due to the seasonal variations in solar and demand. In winter months, demand will be greater than generation, while the opposite will be true in summer. It should also be noted, this analysis has considered the development as a collective. A net-zero site does not necessarily translate to every building being net-zero in its energy use. A local energy market should be considered to ensure all residents are able to benefit from the site's generation potential.

Figure 15 Daily energy generation (aspirational scenario) vs residential demand (high quality fabric)



15.8 Additional on-site options

The above modelling only considers the potential from utilisation of rooftop solar. There are many additional opportunities which future developers could explore to increase the on-site solar capacity beyond just rooftop PV. This might include garage rooftop space, solar canopies for driveways and pavements and solar thermal technologies which meet heat demand directly with efficiencies in excess of 70%. Also, as further solar technology innovation occurs, new solar use cases are expected to come through along with efficiency improvements; perovskite PV being one such promising solar development which has demonstrated up to 29.1% with lab devices (compared to 21% used in the aspirational scenario).[61] As mentioned before, there are also alternative non-solar zero-carbon generation options which could be considered. Therefore, the figures presented in the modelling above represent just one possibility which is achievable today, any future development should consider numerous options (which go beyond that presented), with full financial consideration of the various scenarios, including the cost savings expected for residents.

[61] NREL Best Research-Cell Efficiencies. URL: https://www.nrel.gov/pv/cell-efficiency.html; Accessed: Feb 2020

16 System Modelling

16.1 System definition

To better understand how the development's energy system will operate, a higher fidelity system model was developed to analyse the energy balance at an hourly resolution over the entire year. This will help to better appreciate the more intricate challenges associated with a highly solar based local energy system and begin to understand the impact the development will have on the wider electricity system to help inform further system analysis regarding network upgrades.

Due to lack of certainty over commercial/science park site use requirements and therefore the size of the high demand (which may require new/separate network infrastructure), only the residential site is considered.

16.2 Model

Hourly profiles are combined for the demand of domestic housing, the school, the hospital and domestic EV charging: $D = D_{dom} + D_{sch} + D_{hosp}$. Likewise, generation combines the domestic rooftop PV, school PV and hospital PV: $G = G_{dom} + G_{sch} + G_{hosp}$. The net hourly power demand is calculated from the difference between demand and generation: $P_{net} = D - G$. To test the impact storage can have on the system, a basic storage model is applied whereby the storage charges if there is excess generation and the storage is not fully charged, and discharges if there is unmet demand and energy is available within the storage. A financial assessment is not within the scope of this study.

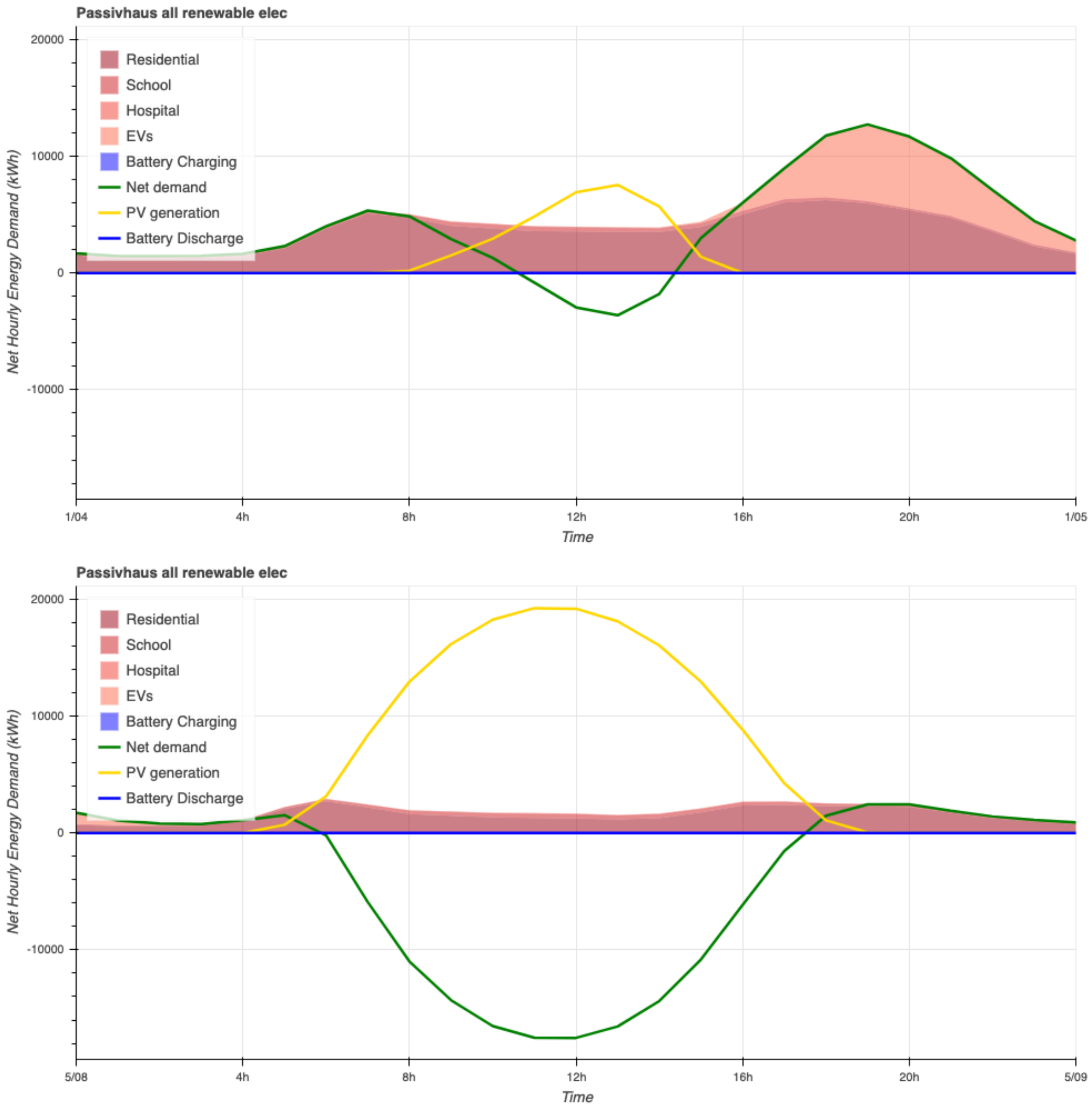
16.3 CO_2 emissions

Associated CO_2 emissions have been calculated on both imported and exported electricity from the grid, using the current UK government grid carbon intensity conversion factor. This means if net-zero demand is achieved, it follows that emissions will also be net-zero. This assumption does not take into account embedded emissions in the technology, or the temporal variability in grid carbon intensity.

16.4 Results

The figures below show hourly energy profiles for the winter and summer days which have the maximum hourly net import and export respectively for the aspirational net-zero scenario.

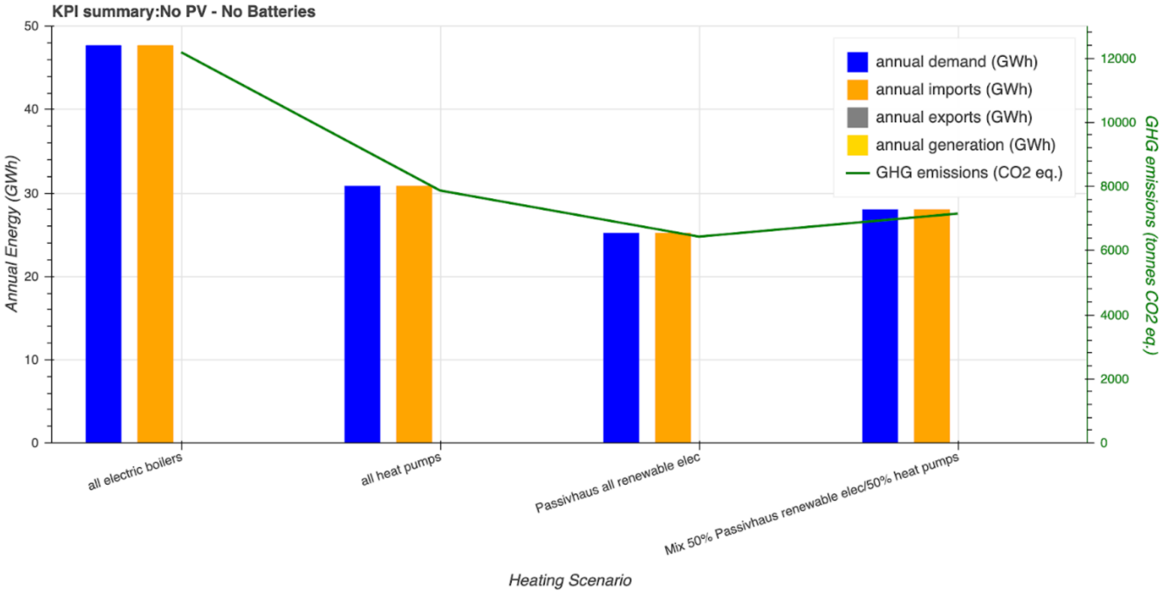
Figure 16   Hourly energy profiles for winter and summer

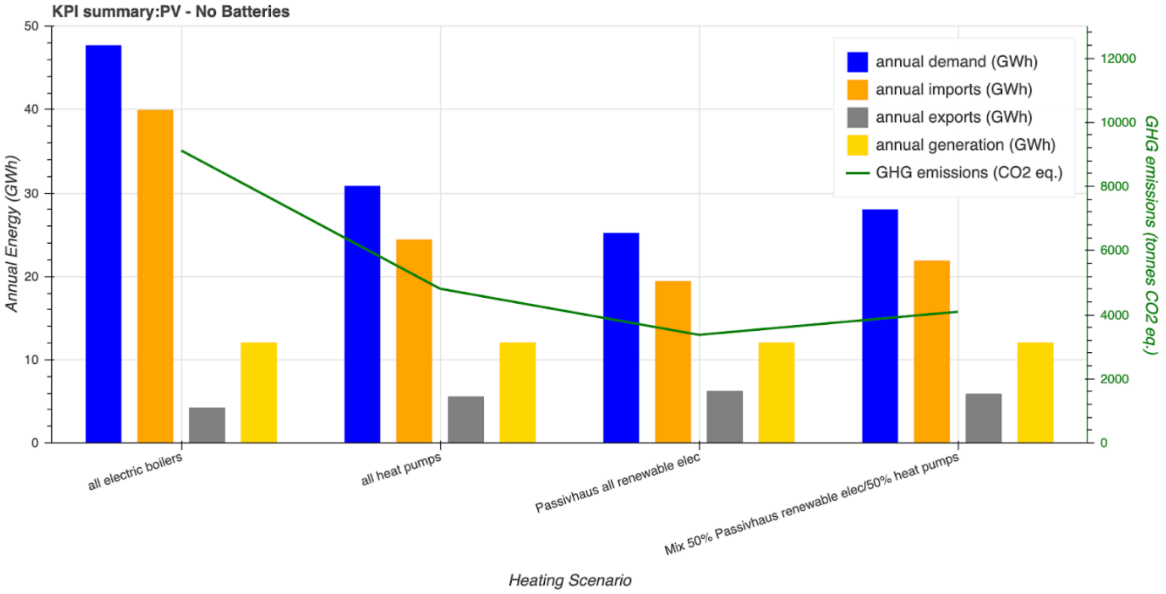


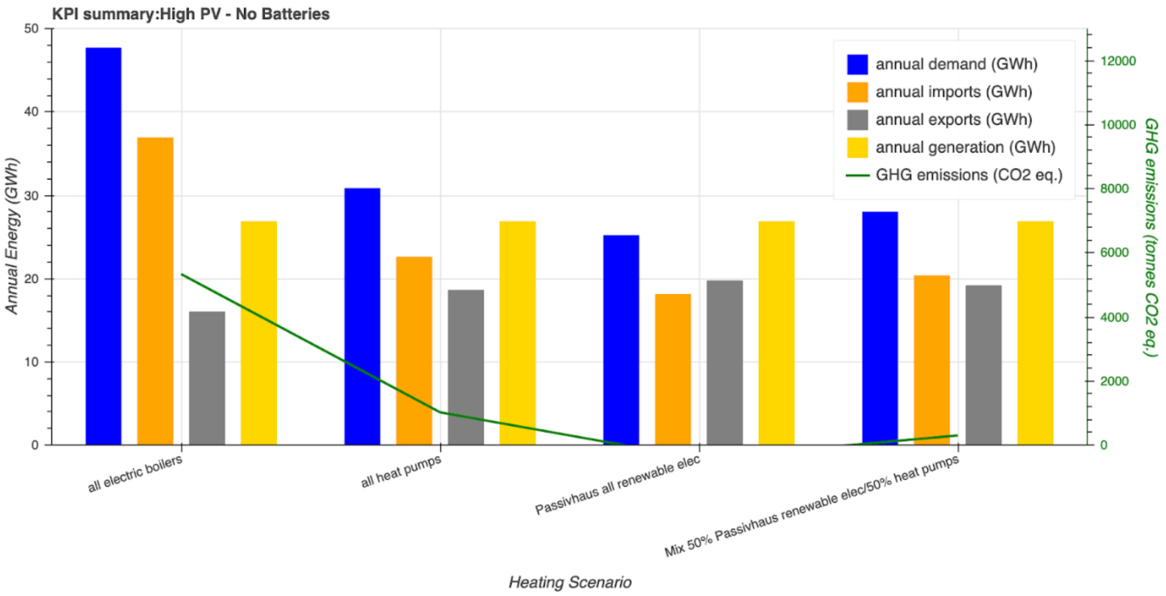
The maximum import in the winter is due to the highest heating demand combined with an evening peak in EV charging based on the non-smart charging profile used. The summer profile demonstrates the extent to which there will be excess generation in the summer months. On the summer day above, the peak solar generation is more than 6 times that of the peak demand.

The following three graphs track 5 key performance indicators (KPIs) (Annual demand, annual grid imports, annual grid exports, annual generation and greenhouse gas emissions) for a scenario with no PV generation and the two generation scenarios.

Figure 17 KPI summaries







As seen previously, it’s possible to achieve annual net-zero in the high building fabric and high generation scenario. However, due to the variable nature of solar and mismatch between generation and demand, a significant amount of energy is still exchanged with the grid. Adding additional PV generation to the system doesn’t increase diversity, it increases the imbalance. This is seen when comparing the two PV scenarios; increasing PV capacity from 12.4 MW to 24.7 MW (99% increase) only reduces imported electricity from 19.3 GWh to 18.1 GWh (6% decrease) while the exported electricity increases from 6.2 GWh to 19.7 GWh (318% increase). This will have both a technical impact on local grid infrastructure capacity that will need further consideration by the DNO regarding network upgrades, taking into account the wider Eynsham energy system and expected planned growth, but also a financial one. If the mismatch in price for exported and imported energy remains as it is today, the financial incentives for residents from savings on their energy bills may not be great enough to justify the uplift in housing costs which may result from the high PV scenario.

Under such circumstances, aggregated battery storage within homes or a single larger site installation should be investigated further. Storage will help with both reducing impact on the network through flexibility and the ability to peak shave, while also providing the ability to self-consume more of the solar electricity generated on site.

The garden village development provides a unique opportunity to be a national (and international) exemplar in overcoming both the technical and financial challenges highlighted thanks to a highly engaged local community-energy groups in the wider Eynsham area working alongside Project LEO, a world leading smart local energy system demonstrator project led by the DNO, SSEN.