www.oxford.gov.uk

OXFORD CITY COUNCIL

Net Zero Carbon technical feasibility literature review (2026)

Oxford Local Plan 2045

1. Introduction 3
2. What do we mean by net zero carbon development? 4
3. General approaches to undertaking technical feasibility analysis of delivering net zero carbon new development 7
4. Results of technical feasibility analysis – what is feasible? 8
Limiting Space Heating energy demand 8
Limiting total Energy Use Intensity (EUI) 11
Meeting total energy needs through on-site generation 13
Low/Zero carbon heating technology (no fossil fuels) 15
Further considerations with non-residential development 16
5. Results of technical feasibility analysis – what may be more challenging/unfeasible? 17
Tall buildings 17
Energy intensive non-residential 18
6. Implications for Local Plan 2045 policy 18
Appendix 21

1. Introduction

1.1 This literature review compiles the findings of a range of technical feasibility studies into the delivery of net zero carbon buildings by comparable local authorities around England and also considers industry best practice recommendations. The research collates the findings from these studies in order to address the following:

- Is net zero carbon development technically achievable for the most regular building typologies expected to come forward in the city over the Local Plan period?
- Are there any typologies, or thresholds at which net zero carbon becomes unfeasible on site, and how could policy be formulated to address these scenarios?

1.2 The research drawn upon comes from technical studies completed as evidence bases for other local authorities' local plans, either adopted or emerging. These studies typically conduct analysis using a range of building typologies that are reflective of development that would be coming forward in these areas. To focus this review and ensure it is as relevant as possible to an Oxford context, the examples drawn out from them have been selected to be as reflective of development we might expect to come forward in Oxford over the period of the new Local Plan, wherever possible.

1.3 Before addressing the questions above, the report touches upon the components that we would generally expect to see applied within a net zero carbon development. The following sections then present the results of the literature review, framed around each of the key components of net zero design and looking at these through the lens of the different typologies. Finally, some conclusions are presented which are of relevance to the emerging policies of the Local Plan 2045.

1.4 For this literature review, evidence bases underpinning newly adopted or currently emerging Local Plans have been reviewed for seven local authority areas in detail. Where reference is made to a local authority in this document, it should be taken to mean their technical evidence base as a whole – links to the specific documents reviewed are included in Appendix A. The authorities and their associated evidence bases looked at in this review are as follows:

- Cornwall (Climate Emergency Development Plan Document adopted 21 February 2023)
- Bath and North East Somerset (BANES) (Local Plan Partial Update adopted 19 January 2023) (*note: this work relied upon the evidence base of Cornwall Council, along with some additional work produced by the West of England authorities*).
- Central Lincolnshire (Local Plan adopted 13 April 2023)
- Greater Cambridge (First proposals published Nov 2021 – preparing Reg 18 consultation for summer 2023)
- West Oxfordshire (Salt Cross Area Action Plan examination in 2021, main modifications in 2022) – (*note: this was an area action plan as opposed to a full local plan; whilst the carbon elements of the policy were determined to be in conflict with national policy at the time, the underpinning evidence on typology feasibility is considered relevant to this work).*
- Newham (Local Plan review – second reg 18 consultation published Jan 2023, currently preparing reg 19 submission plan)
- Essex Planning Officers Association/Essex Design Guide – (Net Zero Policy study 2023) - *note: this is a collective technical evidence base supporting local authorities writing carbon reduction policies in Essex County and beyond.*
- South Oxfordshire and Vale of White Horse (Local Plan 2041 currently under examination – Net Zero Carbon Study (2023)

1.5 The spread of evidence bases referred to in this study represent a fairly broad geographical spread across England. This selection helps to bolster the findings in terms of their applicability in other areas such as Oxford, as does the range of different building typologies that are used within each of these different studies, many of which are likely to be of a similar profile to those we can expect to see coming forward in the city over the Local Plan period.

1.6 In addition, the Council has reviewed emerging guidance relating to the UK Net Zero Carbon Buildings Standard (UKNZCBS), a pilot version of which was published in September 2024 and revised in April 2025. This guidance comprises of a range of technical standards recommended to deliver net zero buildings that can align with national decarbonisation targets.

1.7 Whilst the UKNZCBS remains in pilot testing and does not represent statutorily adopted guidance on how to deliver net zero buildings, its preparation has been informed by a wide-ranging collaboration from a cross-industry group of stakeholders from across the built environment. The new build performance targets it sets are science-led and data drive and build upon previous cross-industry guidance produced by bodies such as the Low Energy Transformation Initiative (LETI) and the UK Green Building Council (UKGBC).

2. What do we mean by net zero carbon development?

2.1 There are a variety of definitions for what net zero carbon development in operation should look like in new buildings, and the topic of what net zero carbon development means in practice is discussed in greater detail in the Carbon Reduction and Climate Resilient Design Background Paper (008). The Council has previously agreed a motion that adopts the UKGBC definition for net zero development, which has two parts, dealing with operational energy and the construction process. The operational energy definition reads as:

> *When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance, after all efforts have been otherwise made, offset.*

2.2 Ultimately, the avoidance of fossil fuel energy systems, coupled with an ability to meet all energy needs of the development through onsite renewable generation are the key metrics in determining if the building is net zero in operation (Figure 2.1).

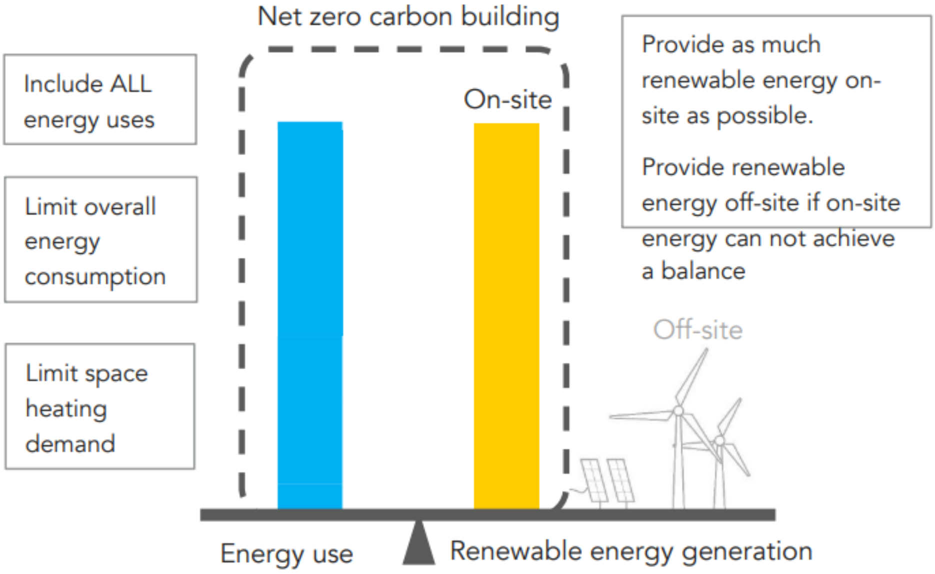

Figure 2.1 – A net zero carbon building meets all energy needs through renewable sources, ideally on-site generation in first instance – source: extracted from Newham Council Operational Energy and Carbon Evidence Base (2022)

2.3 However, significant work by a range of bodies such as Royal Institute of British Architects (RIBA), the Committee on Climate Change (CCC), the UK Green Building Council (UKGBC), and the Low Energy Transformation Initiative (LETI) has been undertaken to inform what net zero in operation looks like in practice. The work of LETI in particular has previously provided a breakdown of different aspects of what a net zero building should look like[1] and has been referred to regularly across the industry, including being utilised in the majority of the local authority evidence bases that have been reviewed for this piece of work. The LETI net zero carbon definition can be looked at as similar to the UKGBC definition but with some added detail, utilising more specific targets and standards for the various components of net zero design. The guidance set out in the new UKNZCBS effectively builds upon these definitions and further fleshes out or updates the various recommended targets and standards for a wider range of elements of new buildings and for a more comprehensive list of typologies of buildings, though as it is relatively new it is yet to have begun to be incorporated into wider local authorities' work.

2.4 The general approach to these different pieces of best practice guidance in relation to net zero carbon design in operation is the focus on energy use performance of the building (measured as Energy Use Intensity/EUI, which is the total amount of energy used in a building in a year divided by its floor area). In practice, this means setting limits on total energy use and space heating, which helps to ensure more efficient buildings, and subsequently reduce the amount of onsite renewables needed. Encouraging on-site renewable energy generation is also important not only in avoiding emissions from grid electricity (in advance of national grid net zero carbon targets) but also because this can improve resilience of the energy network by reducing demands on the national grid system which will be under increasing pressure as we shift to greater reliance on electricity (e.g. through decarbonising heating systems and shifting to electric vehicles).

2.5 Whilst there are various recommendations and emerging targets being set, the local authority feasibility studies reviewed typically break down energy performance in their

[1] https://www.leti.uk/cedg

analysis into performance against a number of metrics, which are detailed in Table 1 below. The table also includes discussion about the updated best practice recommendations emerging from the new UKNZCBS as revised in 2025.

Table 1: General metrics used for assessing performance of net zero carbon buildings in operation and commentary on best practice in relation to these metrics.

Metric	General recommendations in relation to this metric
Limiting space heating energy demand	• Limits on space heating help to ensure buildings are designed efficiently and that overall energy demand is not dominated by energy needed to heat/cool the building (which can be significant otherwise). • The new UKNZCBS 2025 has identified targets for some typologies (mainly residential inc flats and houses, commercial residential and some culture/entertainment venues), others are subject to further work. These targets range between 15-20 kwh/m^2/yr. • Other work previously, includes the Committee on Climate Change who recommended that energy use for heating be limited to between 15-20 kwh/m^2/yr (UK Housing Fit for the Future, 2019[2]). Bodies such as LETI and Passivhaus have generally pushed for the lower end of this range (15 kwh/m2/yr).
Limiting total Energy Use Intensity (EUI) for the development (which includes space heating within it)	• Limits on overall energy use for the building, which covers all energy demands and is essentially the energy use as measured at the meter. Important for efficiency, reducing energy bills, strain on the grid. • The UKNZCBS includes unique targets aligned to more than 25 different typologies of residential and non-residential typologies. These range from 45 or 40 kwh/m2/yr for homes and flats built in 2025, to higher targets for non-resi uses like 64 to 80 kwh/m2/yr for general offices, and more than 200 kwh/m2/yr for some higher energy uses like science and tech, some sports/leisure uses, and food and beverage with catering. The targets generally step down and tighten year on year from 2025 and 2050. • Previous guidance has generally been more limited in the amount of typologies addressed, particularly in relation to non-residential uses that are more varied in form/function and challenging to specify. LETI for example recommend net zero carbon residential to be no more than 35 kwh/m2/yr; non-residential varies between 55-65 kwh/m2/yr.
Including enough on-site energy generating capacity to match total EUI	• The best practice guidance across the different standards generally advises that to be net zero carbon in operation, ideally on-site energy generation should match total EUI. • Sometimes a target is set for a certain proportion of energy to be derived from onsite renewable per m2 of the roofspace, as has been incorporated into the UKNZCBS e.g. , a minimum of 65 kWh/m2 building footprint / year for Single Family Homes and a minimum of 40 kWh/m2 building footprint / year for other building types.
Low/Zero carbon heating technology (no fossil fuels)	• The key target here is not to rely on direct fossil fuel burning (e.g. gas boilers) to heat the building and instead to rely on other forms of electrically powered heating such as heat pumps.

[2] https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/

3. General approaches to undertaking technical feasibility analysis of delivering net zero carbon new development

3.1 The authorities that have been reviewed as part of this research have applied their feasibility analysis to different selections of building typologies, some exclusively residential, others including a mix of residential and non-residential. The authorities typically developed their building typologies from case studies seen in their local area, many of which would be applicable to what we would expect to see in Oxford. Table 2 sets out a summary of the range of typologies assessed. The main focus is usually residential, which is easier to predict and model, as there is typically less variation in the profile of these types of development compared to non-residential (which could cover anything from schools to offices, commercial or industrial uses). But of the authorities that looked mainly at residential in detail, most did try to consider non-residential to varying degrees of detail.

Table 2: Summary of building typologies assessed across the local authorities' studies reviewed in this report

Local Authority	**Typologies of residential development tested**	**Typologies of non-residential development tested**
Cornwall (and relied upon by BANES)	• S house (2 bed/GIA 84m2) • Bungalo emi-detached house (3 bed/GIA 93m2) • Terraced w (3 bed/GIA108m2) • Detached house (4 bed/GIA 142m2) • Low rise flats (7 units/GIA 641m2) • Medium rise flats (20 unit/GIA 1,590m2)	N/A
Central Lincs	• Semi-detached house (3 bed/GIA 100m2) • Bungalow (3 bed/GIA 134m2) • Detached house (4 bed/GIA 142 m2)	• Light industrial unit (9 individual units/GIA 977m2) • School (GIA 3,280m2) • *Other typologies reviewed at high level: Offices; Multi-residential blocks; Student Accom; Small Retail Units; Leisure Centres; Research facilities*
Greater Cambridge	• Semi-detached house with dormer window, 3 storeys including room in pitched roof • Terraced house, 2 storeys plus pitched roof, no dormer window • Block of 40 flats, 4 storeys	• School – based on Darwin Green Primary School. • *Other typologies reviewed at high level: Offcies; Tall block of flats; Student blocks; Retail unitys; Light industrial; Leisure centres; Research*
Newham	• 3 bed townhouse (GIA 116m2) • Low rise block of flats (7 units/GIA 641m2) • Mid rise block of flats (28 units/GIA 2,125m2) • High rise block of flats (169 units/GIA 15,541m2)	• Large industrial unit (GIA 12,153m2) • Small industrial unit (4 units/GIA 466m2)
West Oxfordshire	• Terrace House (95m2) • Medium-rise apartment (5 storey/3000m2)	• Office (3 storey/4000m2) • School (3 storey/6,000m2)
Essex	• Terrace house (GIA 95m2) • Bungalow (GIA 93m2) • Semi-detached house (2 storey/GIA 108m2) • Low rise block of flats (3-4 storeys/GIA 641m2)	• Office (7 storeys/GIA 4000m2) • School (3-4 storeys/GIA 6000m2) • Industrial (2 storeys/ GIA 9,000m2)

	• Mid rise block of flats (5 storeys/GIA 3200m2) • High rise block of flats (15 storeys/GIA 15,500m2)	
South Oxfordshire and Vale of White Horse	• Detached house (2 storeys) • Semi-detached house (2 storeys) • Terraced house (2 storeys) • Medium to low rise block of flats (retail unit on ground floor)	• Free standing retail unit (1 storey) • Primary school (2 storeys) • Office block (3.5 storeys) • Warehouse

3.2 All of the case studies tested feasibility against different typologies of residential development in form of housing/ or blocks of flats. Meanwhile, in terms of detailed analysis on non-residential, Central Lincolnshire, Newham, Essex and South Oxfordshire & Vale included assessments of industrial units, whilst West Oxfordshire's work for the Salt Cross AAP, South Oxfordshire & Vale and Essex included analysis of a set of offices. A typical school typology was tested by five authorities (Central Lincs, Greater Cambridge, West Oxfordshire, South Oxfordshire & Vale and Essex).

3.3 Once typologies were chosen, these were then modelled with various design improvements to fabric and heating technologies to understand whether they could practically be built to standards that would allow them to achieve the energy targets necessary to demonstrate accordance with net zero carbon policy (e.g. able to perform to strict limits on EUI, space heating demand, ability to generate energy on-site). In relation to the modelling process that has been applied across the studies, various types of software are employed, though most often it was the Passivhaus Planning Package (PHPP). Cornwall's evidence base, notes that their approach was to develop assumptions in the mindset of a developer, using simplest most economic ways to comply with each requirement, and it is assumed a similar approach has been taken by the other authorities.

3.4 As these studies were typically prepared in advance of the new UK Net Zero Carbon Buildings Standard which was referenced earlier, it should be noted that they generally focus on gauging performance against the best practice recommendations arising from earlier guidance from bodies such as LETI. As Table 1 set out earlier, performance targets are generally fairly consistent with the new best practice targets coming out of the UKNZCBS, though there is some variation, particularly in relation to overall EUI performance.

4. Results of technical feasibility analysis – what is feasible?

4.1 This section reviews the results of the other local authority feasibility studies and frames these around the four key metrics of a net zero carbon development as set out in section 2:

- **Limiting space heating energy demand**
- **Limiting total Energy Use Intensity (EUI)**
- **Including enough on-site energy generating capacity to match total EUI**
- **Low/Zero carbon heating technology (no fossil fuels)**

Limiting Space Heating energy demand

4.2 Space heating demand is effectively the amount of energy a building requires to keep it habitably warm. It can be influenced by various factors such as the form/shape of the building, its orientation and exposure to solar gain, the air tightness and insulation used within its fabric, as well as types of ventilation systems and windows used.

4.3 Having a specific limit on energy used for space heating is intended to encourage fabric efficient design and to minimise the share of total energy for the development that is dominated by heating systems (typically a large proportion of a building's operational energy use). This literature review did not identify any prominent typologies of concern in new development for meeting high fabric efficiency/ low space heating energy demand targets, though there is a little less certainty with non-residential uses with less standardised designs, which will be touched upon at the end of this section (further consideration for non-residential).

4.4 The findings from Cornwall/BANES set out that all typologies they assessed (residential only) were capable of meeting the space heating targets proposed in their DPD as can be seen in Figure 4.1. This target is not as stringent as the recommendations in terms of best practice, but they do also conclude that the typologies can meet more stretching requirements of a 'future scenario' that are aligned with the recommended targets of between 15-20 kwh/m^2/yr set out by bodies such as UKGBC, LETI, Committee on Climate Change and RIBA.

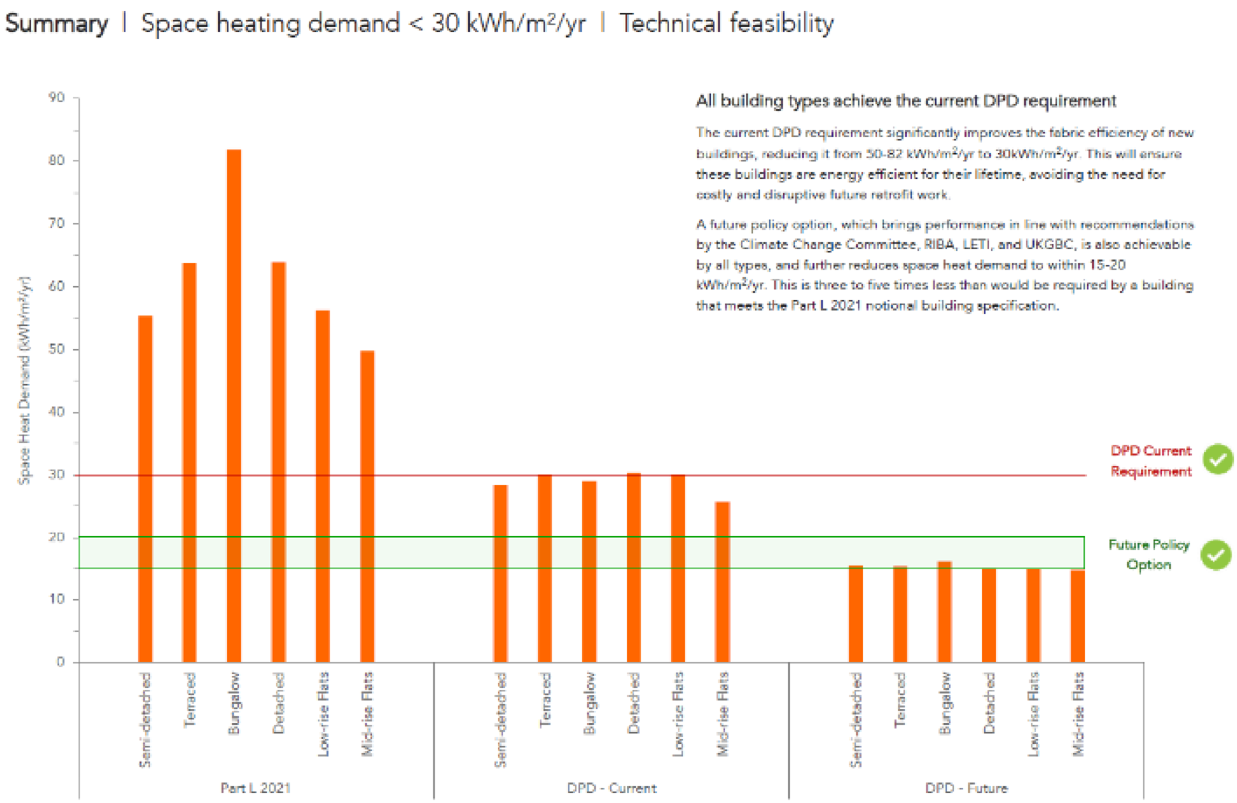

Figure 4.1: space heating performance of the six residential typologies assessed by Cornwall all able to meet stretching targets of 15-20 kWh/m2/yr (Cornwall Council, 2021).

4.5 Central Lincolnshire concluded that a target of 20 kwh/m^2/yr or better was achievable for all their residential dwelling typologies (bungalows, semi-detached and detached) as well as the primary school typology, without the need for improvements to building form or glazing proportions. For other types of non-residential buildings, it was harder to be conclusive due to variation in design and they noted that achieving this target was dependent on the use of the building and its layout. For some retail/industrial typologies, the target was considered to potentially be challenging in some cases.

4.6 Greater Cambridge concluded that of their four typologies assessed, the flats and the school were able to meet the targeted space heating demand of 15 kwh/m^2/yr, where they incorporated reasonable upgrades to the building fabric. The detached and semi-detached houses could achieve a heating demand of 21 kwh/m^2/yr (just above their recommended 15-20 kwh/m^2/yr range) with reasonable upgrades to building fabric, but with additional improvements to walls, roof, floors or amendments to design of features like roof slope and walls could secure a more stringent energy demand.

4.7 The work from the Essex net zero study determined that five of their six residential typologies were able to meet a space heating limit of 15 kwh/m2/yr, however, the bungalow typology would exceed this slightly though keeping under the upper limit of 20 kwh/m2/yr. Of their non-residential typologies (a school, office block and industrial unit), all could keep comfortably within 15 kwh/m2/yr.

4.8 Newham Council found that of the four residential typologies they assessed, where these were built to ultra low energy specifications, they would be able to conform with their target of 20 kwh/m^2/yr (Figure 4.2). The performance of flatted development was better than the townhouse, able to attain increasingly restricted space heat targets with increasing scale. Meanwhile, the two types of non-residential development tested, a small and large industrial unit, were both also able to meet a space heating target of 15 kwh/m^2/yr where they were built to appropriate high energy efficiency fabric specifications.

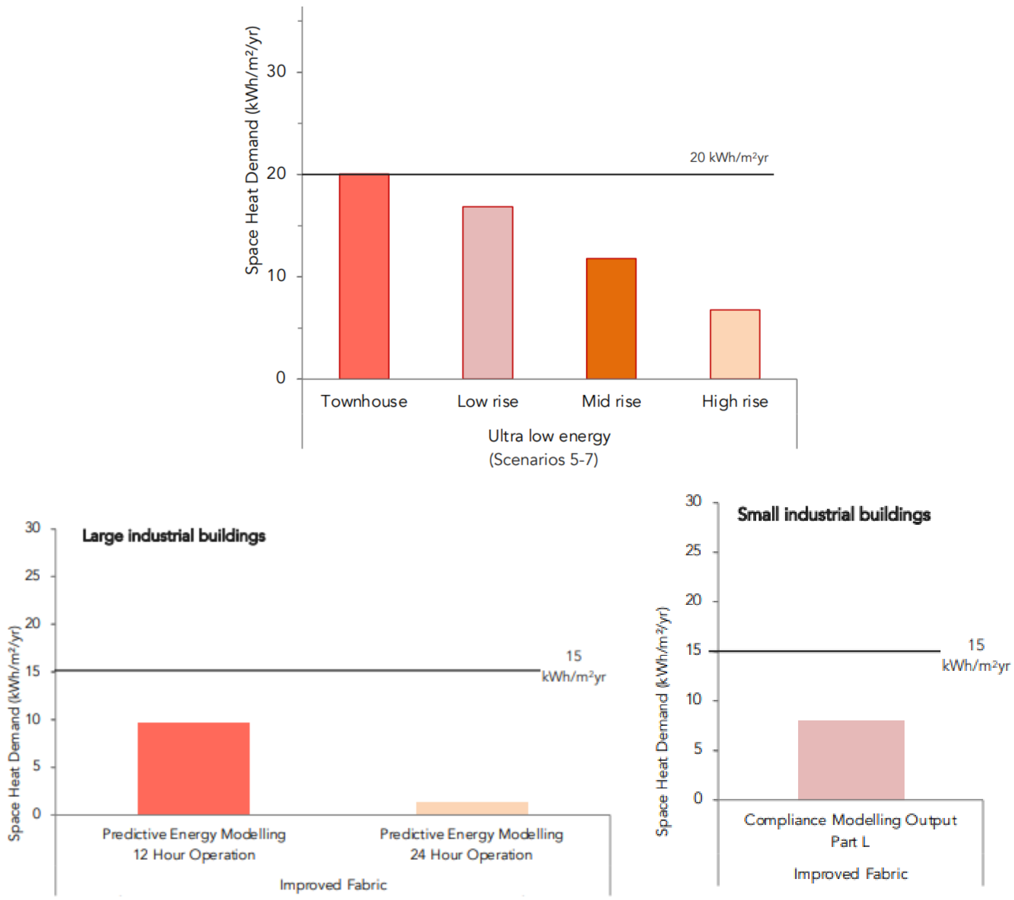

Figure 4.2: analysis of space heat demand of the four typologies of residential development assessment by Newham (top left), all able to meet target of 20kWh/m2/yr, and large (top

right) and small (bottom) industrial buildings, both able to meet 15 kWh/m2/yr (Newham Council, 2022)

4.9 The findings from the feasibility modelling for South Oxfordshire and Vale found that all of their modelled typologies across both residential and non-residential were able to comfortably meet their 15kWh/m2/yr space heating demand target. They also noted the important role that building form factor has on ability to meet space heating demand targets, with buildings that favoured a more efficient and compact form with lower surface area able to more easily decrease space heating demand. This supports the idea that space heating targets can potentially drive more efficient design.

Limiting total Energy Use Intensity (EUI)

4.10 Having a total energy use intensity limit is intended to drive overall energy efficiency in new development. It is beneficial for limiting occupants' energy bills as well as reducing demands on the grid, but is also helpful in reducing the amount of onsite renewables required to match energy needs overall. Total Energy Use Intensity (EUI) will include the energy used for space heating, so naturally, setting targets on space heating will support reductions in total EUI. In addition, it will include other energy demands like those for ventilation needs, cooking, appliances, fittings like lighting as well as any cooling needs (likely to be of increasing demand in future).

4.11 Whilst EUI is more standardised across residential uses, there is likely to be more variation across non-residential uses, with some uses having higher operational energy demands than others (e.g. commercial with refrigeration; research labs with energy intensive equipment). The literature review found that generally, a strict target for total energy use intensity as recommended by bodies such as LETI, is feasible for the majority of typologies assessed by the various authorities, however, there are exceptions which are explored further in section 5.

4.12 Findings from Cornwall's study conclude that achieving significant reductions in total Energy Use Intensity is feasible for each of their assessed typologies, particularly where heat pumps are incorporated into the development as the main heating source. All development types were able to meet the most stretching target of 35 kwh/m^2/yr recommended by LETI, RIBA and the UKGBC in their net zero definitions (Figure 4.3)

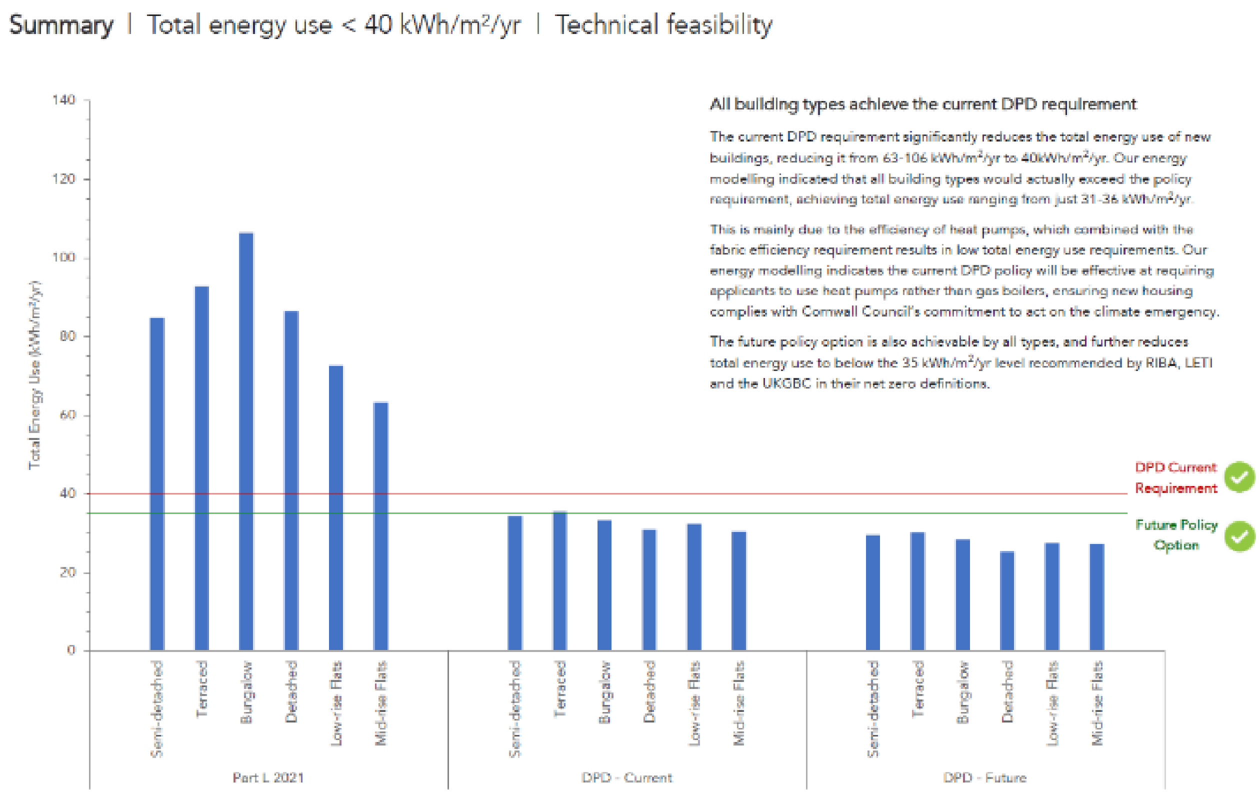

Figure 4.3: EUI performance of the six residential typologies assessed by Cornwall, all able to meet stretching target of 35 kwh/m2/yr (Cornwall Council, 2021).

4.13 Central Lincolnshire considered implications of choosing different types of heating tech on total EUI figures in their feasibility work also. The conclusions suggest that where buildings are using air source heat pumps (a very efficient way of heating), they can typically meet more stringent total EUI targets, with all typologies assessed being below the recommended 35 kwh/m^2/yr standard for net zero development. They concluded that challenges can occur with meeting this standard if direct electric heating is used as the heating source. In these cases, the typologies' total EUI values were higher, at between 40-45 kwh/m^2/yr.

4.14 There was more variation in the non-residential typologies they assessed, with the primary school typology being just over 35 kwh/m^2/yr, whilst the light industrial unit was almost triple this standard at just over 100 kwh/m^2/yr, though this finding was caveated with the note that EUI is likely to vary quite considerably depending on plug-in power use.

4.15 Greater Cambridge found that if a heat pump is used as the main heating technology, then all of their assessed building types were able to meet the targeted total EUI (35 kwh/m^2/yr for dwellings and 55 kwh/m^2/yr for the school). As with Central Lincs, they concluded that where direct electric heating was used instead, EUI values were higher because of the less efficient performance of this type of heating. In these instances, the tested typologies would exceed the EUI target, however, they conclude that installing additional solar pv on the roofs would still allow them to perform to a net zero carbon standard.

4.16 The net zero testing that accompanied the Essex study found that all six of their residential typologies were able to comfortably meet the 35 kwh/m2/yr EUI target, with four of the typologies (terrace house, semi-detached house, bungalow and high rise flats) below

30 kwh/m2/yr. In terms of non residential, the office, school and industrial unit were all below the EUI targets of 70, 65 and 35 kwh/m2/yr respectively.

4.17 The findings from Newham Council for their residential typologies assessed followed similar conclusions, with all four being able to comfortably attain below a target of 35 kwh/m^2/yr EUI in scenarios where they relied upon a heat pump (scenario 5 in Figure 4.4) in combination with ultra-low energy efficiency fabric standards. Again, the typologies were not able to meet this target when they relied upon direct electric heating (scenario 6 in Figure 4.4) instead. The study recommended that if direct electric is something a policy would seek to enable, then the EUI target would need to be set at a higher level (such as 50 kwh/m^2/yr, rather than 35 kwh/m^2/yr). For non residential, both sizes of non-residential development were able to meet the proposed EUI targets of 100 kwh/m^2/yr and 120 kwh/m^2/yr (for 24 hour operation large industrial).

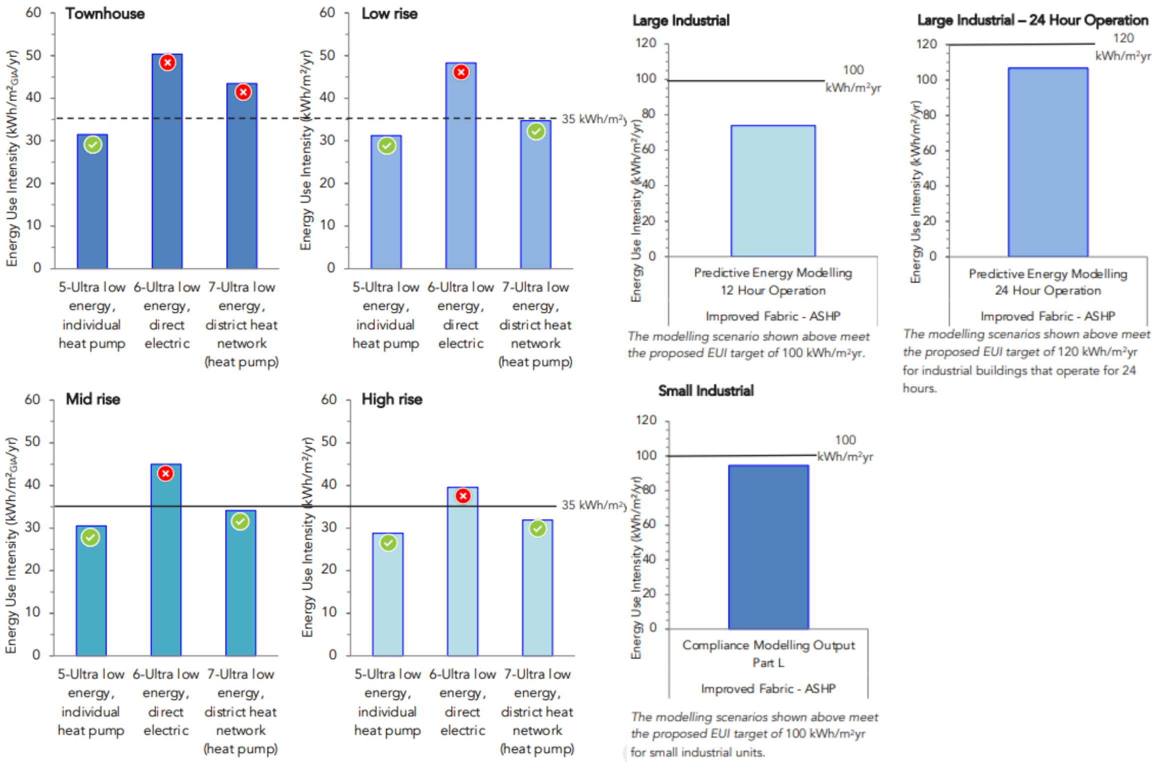

Figure 4.4: analysis of EUI performance of the four typologies of residential development assessment by Newham (left), all able to meet target of 35kWh/m2/yr, and small/large industrial buildings, both able to meet 100 kWh/m2/yr (and 120 kWh/m2/yr for 24 hour operation) (Newham Council, 2022)

4.18 The South Oxfordshire and Vale testing indicates that all modelled typologies can meet their targeted EUI requirements which vary between 35 kWh/m2/yr for residential, retail and warehouse typologies and 55 kWh/m2/yr for offices and primary schools. However, their study went on to test variations in the type of retail and warehouse units, modelling versions of these buildings to take into account more energy intensive scenarios where convenience stores and data centres could come forward. The modelling exposes the potential for unregulated energy demands associated with the operation of these uses to far exceed the overall EUI targets.

Meeting total energy needs through on-site generation

4.19 To demonstrate net zero in operation, the primary objective is to ensure all energy needs are being met through renewable energy generation onsite. In assessing the feasibility of this topic, the Cornwall evidence base concluded that there would be sufficient roof space for all typologies they assessed to install the required amount of solar panels to generate enough energy on-site in order to meet energy demands (the total EUI). The Cornwall work goes into detail identifying the numbers of panels needed on the roof of each typology to meet the total EUI. In their analysis undertaken for their semi-detached dwelling typology, for example, they show that with their total energy targets applied the development would require up to ten solar panels to meet energy needs. Notably, they identify that having a more stretching standard of energy efficiency, meaning more rigorous targets for energy demand, helps in reducing solar pv capacity required for meeting total energy need, reducing to 8 panels.

4.20 Of relevance to the comparability of these findings to other locations, they acknowledge that achieving net energy balance is easier in Cornwall due to mild climate reducing heat demands and increased solar radiation for solar generation. This issue was however subsequently addressed in a separate guidance note in Bath's evidence base via a supporting document prepared by South West Energy Hub highlighting that: *Regional variance in insolation is not expected to reduce supply by more than 7kWh/m2/year for any scenario, approximately equivalent to a maximum of three additional PV panels (based on 380W panels in the North East of England).*

4.21 The Central Lincolnshire study focussed in detail on only low rise typologies but found that for all of these, if the roof space was maximised, then they were able to generate more energy on-site through solar pv technology than was needed to meet the development's total EUI. They conclude that the detached house typology, for example, can generate enough surplus to run two electric cars, and that the light industrial unit assessed had potential of being a large energy exporter after on-site needs were met. They do note that for non-residential typologies not studied in detail (they only looked at a light industrial unit and school and relied on case studies for other typologies), such as offices, research and leisure, there may be difficulty in meeting EUI through on-site generation.

4.22 Greater Cambridge, who included one typology that was higher rise than those in the Central Lincolnshire study (a four storey block of flats), concluded that all of their typologies could comfortably meet total energy needs through on-site solar pv installation when incorporating a heat pump and including the reasonable fabric upgrades required to meet the space heating/total EUI targets. Where direct electric is used instead, this would require additional solar pv to meet the additional energy demands needed to provide the required heating (these systems are typically less efficient than heat pumps).

4.23 As with the Central Lincolnshire work, they highlight that with careful adjustments to the design of the buildings (e.g. most efficient orientation and design of roof tops, or careful placing of solar panels e.g. concierge patterns) often the buildings can generate more than their energy needs where the roof space is then maximised. For example, their terraced house typology could reach net zero carbon in operation with 10 solar panels installed, or it could generate up to three times as much power as is needed where built with an east-west orientation and 32 panels installed (to max out roof space); meanwhile the block of flats could achieve net zero carbon with 328 panels (8.2 per flat) to fill about 75% of available roof space, with potential through careful design choices to reach 200% of energy needs through additional panels. But conversely, where roof space is required for other uses (e.g. plant equipment in the flats) then this will impede ability to maximise generation potential.

4.24 Findings from Newham indicate that for the townhouse and low-rise flatted development typologies they tested, on-site renewable energy generation was found to be able to exceed or match energy use where the buildings were built to an ultra-low energy fabric standard and incorporated a heat pump. The higher rise buildings were still able to incorporate some level of pv generation but would then have to rely on off-site provision to balance out (these higher rise are likely to be higher than what is expected in the majority of Oxford). In terms of the non-residential uses which they assessed, in the form of a couple of sizes of industrial units, whilst the larger unit was comfortably able to generate enough energy through renewables to meet projected consumption levels, the smaller unit could not meet all needs due to limited roof space and again would need to rely on off-site provision to address the deficit.

4.25 The typologies tested in South Oxfordshire and Vale's work showed greatest variation in performance in terms of onsite renewables generation versus energy demand. Across their residential typologies, all four were policy compliant and able to generate enough energy through PV to match demand as well as having spare capacity to generate additional renewable energy. They do note that typologies with better space heating performance, e.g. terraced house, was more comfortably able to balance out energy generation due to lower energy demand in first place.

4.26 Across non-residential typologies, the testing shows that buildings with greater roof space can naturally more easily accommodate sufficient solar pv generation to match demand, as is the case in the school typology. For the office typology, the impact of increasing storeys in height, which generally gives rise to greater energy demand, begins to push towards a need for relying on offsetting to be policy compliant because roof space to accommodate enough renewables cannot increase in tandem. The additional testing of high energy uses such as convenience stores and energy centres, which drives a much higher total energy demand because of the energy intensive operational requirements of these buildings, also demonstrates a need for relying on offsetting to allow for policy compliance, as again, solar pv onsite is unable to match total demand.

Low/Zero carbon heating technology (no fossil fuels)

4.27 All the feasibility studies reviewed from the other local authorities incorporated heating systems which did not rely on fossil fuels as part of their modelling assumptions. Typically, the assessments tested scenarios that either utilised a heat pump or direct electric heating.

4.28 What is clear is that the choice of heating system will have an influence on the energy demands of the building when in operation. The analysis above highlights that reliance on direct electric heating systems will drive greater Energy Use Intensity figures for a building compared with a heat pump, and thus require additional solar pv (or other renewable energy generation tech) to meet these energy demands. Greater Cambridge's feasibility work highlights the added efficiency of heat pumps over direct electric, remarking that they can deliver about 3 times as much heat energy as they consume in electricity, because they borrow energy from outdoors. Direct electric heating consumes 1 unit of electricity for 1 unit of heat delivered. Thus more heating demand can be met for less energy demand when heat pumps are chosen over direct electric.

4.29 There are a growing range of non-fossil fuel heating systems. For example, the Newham study highlights technologies such as direct electric heating, air and ground source heat pumps are generally compatible with most types of developments. A smaller selection of technologies are capable of being scaled up to larger communal or district heat schemes, including air to water heat pumps and ground source heat pumps. It is likely that technologies will continue to evolve and grow more efficient as the market adapts to respond to national and local net zero carbon requirements.

Further considerations with non-residential development

4.30 There is clearly more variation in the types of non-residential buildings that could come forward in an area and this variation brings with it a range of energy demands stemming from types of building profiles, uses and needs of occupants. Some of the studies reviewed looked in detail at certain types of non-residential uses which are typically more standardised, e.g. Greater Cambridge, Central Lincolnshire, Newham (who included schools and industrial units in their groups of assessed typologies), and South Oxfordshire and Vale. Some tried to also at least make some high level comments about other typologies based upon case studies.

4.31 Greater Cambridge's study highlights some of the subtle differences in challenges associated with different types of non-residential. It highlights the potential need for flexibility in setting targets for metrics like total EUI and space heating demand, making differing recommendations for types of non-residential which include:

- Offices – up two storeys can usually meet net zero carbon on-site through solar pv on their roofs, and can meet low heat demand targets. Three storeys and above may need to rely on off-site generation. Care also needs to be taken where a lot of window glazing could result in overheating, thus additional energy demands for cooling.
- Light industrial units – as staff may predominantly spend time in only small areas of building, these may be better to rely on alternative heating tech to heat pumps that heat whole building (e.g. radiant panel heaters). Where they are low rise, they are likely to have capacity to meet EUI needs through on-site solar pv.
- Retail units – these are highly variable depending on type of store. The challenge in these units could be energy use, such as where high levels of refrigeration are required, but is also likely to be heat demand due to large, open entrances/loading bays. However, there is evidence of retail units in Europe meeting tighter heat demand targets.
- Leisure Centres and Research – are likely to be able to meet low space heating targets as their heat demand is typically low, but can have very high energy demands, particularly where leisure centres include pools, or research facilities include energy intensive lab equipment (e.g. fume cupboards). Where buildings are low rise, they may be able to meet energy demands on-site, but are more likely to require off-site generation to match EUI.

4.32 The themes above are also illustrated in the feasibility work of South Oxfordshire and Vale, particularly in the case of testing in relation to more energy intensive non-residential typologies, which generally has knock on impacts for the unregulated energy loads associated with their particular operational requirements (e.g. data centres). This work illustrates the need for some flexibility in the approach to policy formulation to accommodate for particular operational demands which cannot be easily mitigated onsite.

4.33 The UK Net Zero Carbon Building Standard has subsequently identified recommended performance targets for a wide range of non-residential typologies in relation to Energy Use Intensity and this reflects the need for flexibility in setting targets, particularly for some typologies which have higher energy demands. Some typologies, such as science and tech have EUI targets set which are considerably higher (potentially more than double) than other more standardised non-residential uses like offices or schools.

5. Results of technical feasibility analysis – what may be more challenging/unfeasible?

5.1 It is clear from the studies covered in the previous section that net zero carbon development in operation should be achievable for most standard types of buildings coming forward in the city, but that there are thresholds over which this may not be the case. A couple of scenarios in which net zero is flagged as being more challenging seem to recur across the different studies though, in the case of non-residential, as some typologies have often not been looked at in the same level of detail, it is not always clear how much of this is precautionary, due to lack of detailed evidence. Nevertheless, they are worth flagging here as considerations for how Oxford's policy should be developed.

Tall buildings

5.2 The first scenario is that of taller buildings with limited roof space to accommodate all solar pv capacity required to offset energy needs of the occupants. As Greater Cambridge flag in their evidence base, every additional storey increases energy demand, but roof area would not change, thus height will get to a point where roof capacity is superseded by energy demand of each additional floor.

5.3 Central Lincolnshire's feasibility work highlight that *most of the typologies we modelled had enough roof area to generate enough renewable energy to cover all their energy needs over the course of the year.* But go on to say that: *Tall buildings, or those with higher energy demands, will find it challenging or impossible to generate enough energy to be "zero carbon" on-site.* The South West Energy Hub report which is a part of Bath's evidence base acknowledges similar saying that *high rise flats (and some medium rise flats where solar insolation is less) may not be able to fully meet net zero energy use onsite. In restricted situations it may be necessary to offset this shortfall whilst maximising onsite renewables.*

5.4 In terms of where the threshold for height sits, this is likely to depend on the use of the building, but the Cornwall study identifies: *In practice, it is usually possible to achieve a net zero energy balance on site in the UK in buildings up to six stories in height, though this requires best practice fabric efficiency and solar PV design*.

5.5 The challenge of tall buildings can be mitigated in a few ways. Greater Cambridge's work flags that there is potential for installing solar pv vertically on unshaded walls alongside roof space – though care will need to be taken to ensure these do not conflict with other regulations such as fire safety requirements of Building Regulations. Equally, net zero could be accepted 'on average' across a site whereby neighbouring buildings with free roof space are used to accommodate the additional solar pv capacity required to offset energy needs of the tall building. Central Lincolnshire flag that for more restricted situations the alternative for on-site delivery could also include payment into an offsetting scheme *created in order that buildings that cannot generate enough energy to match their energy use, can comply with the policy requirement.*

5.6 Of course in Oxford, tall buildings are perhaps less common than many comparable cities, due to the limits planning policy has traditionally placed upon building heights to avoid conflict with the conservation of the historic skyline and important views. Indeed, the Oxford High Buildings study (2008)[3] notes that: *much of the city comprises two storey residential suburbs* and that *the general height of buildings across the city is between 2 - 4 storeys.*

[3] https://www.oxford.gov.uk/downloads/file/7509/tan_7_high_buildings

Where higher buildings occur, they are rarely above 6 storeys. Thus, this issue may be less relevant and confined to certain areas of the city where tall buildings are deemed more acceptable. It will be important for policy and supporting guidance be articulated in a way that sets out clarity for how these scenarios ought to be addressed where they do occur however.

Energy intensive non-residential

5.7 There are likely to also be incidences of certain types of non-residential development that could struggle to be able to meet all energy demands through on-site generation of electricity. As opposed to tall buildings, where the challenge is one of limited roof space versus energy demand, the issue for many types of non-residential appears to be more about extremes of energy demand associated with day-to-day use.

5.8 Oxford sees ongoing interest in research and development (e.g. laboratories), for example, and higher energy demands can be attributed to certain types of equipment potentially used in some of these buildings. The same challenge appears to be relevant for some commercial and leisure uses too, particularly those with high energy needs associated with processes like refrigeration or heating. Whilst the, admittedly more limited, research seems to suggest that low energy demand space heating targets could be applied to many of these uses in the same way as residential, it may be more challenging to meet the same levels of total energy use targets to some developments within these typologies, as well as expecting them to match total energy demand through onsite renewables alone.

5.9 Again, it is important for policy and supporting guidance to be articulated in a way that sets out clarity for how these ought to be handled and potentially needs to factor in additional flexibility to address the variable nature of non-residential uses.

6. Implications for Local Plan 2045 policy

6.1 Whilst the studies reviewed in this work are considering feasibility of net zero in locations other than Oxford and represent secondary research, the focussed, building-specific analysis that these studies have undertaken is transferable to an Oxford context as the styles of construction expected in the city are unlikely to vary greatly in general. The key area where contextual factors could alter feasibility is likely to be from a financial viability position, as build costs (e.g. labour and materials) are subject to more variation on a geographical basis. Financial viability is of course an equally important factor, but this will be addressed through separate independent viability testing of the Local Plan and its policies as a whole.

6.2 Across the studies that have been explored through this literature review, a number of observations arise which are shaping the specific requirements of the Local Plan 2045's policy on net zero carbon buildings in operation. These are as follows:

- Net zero carbon buildings are primarily those which do not rely on fossil fuels, meet their energy needs through renewables and ultimately balance out any additional emissions into the atmosphere as a result of their operation so no net increase occurs. However, best practice is emerging around more specific standards which relate to elements of energy performance, specifically total energy demand, space heating demand, and requirements to matching demands through onsite renewables.
- Standard typologies should be able to meet the generally recommended energy demand targets from bodies such as LETI (and the new UKNZCBS). This appears to

be particularly the case for residential development which tend to vary less in their energy profiles. Some typologies may encounter challenges with the most stringent targets, for example, certain typologies of residential were found to struggle to meet LETI's more stringent 15kwh/m2/yr space heating target but could fit with a more flexible 15-20kwh/m2/yr range, which would be in keeping with the newer UKNZCBS.

- For non-residential uses, much more variety can be seen in the character of these buildings and their energy demands. Some more standard typologies e.g. schools, offices, industrial uses, are easier to make general predictions on performance and can more clearly meet the recommended targets. Other uses, particularly those with typically higher energy demands, may find it challenging to limit energy use to the same levels and there may be too much variability in these typologies to easily be able to set one specific target against which to assess applications.
- In particular, challenges in terms of limiting overall energy use and meeting energy needs onsite could occur for more energy intensive uses such as research labs and some leisure/commercial with big heating/refrigeration needs.
- Particular challenges could also occur for tall buildings meeting onsite energy generation needs. Oxford is generally quite low-rise, so the extent of this challenge may be more limited than in other cities.
- Whilst the general principles of net zero buildings (limit energy use, meet energy needs onsite, no fossil fuels) will still apply to non-residential buildings, policy needs to be prepared for scenarios where certain developments within these typologies may not be able to meet specific standards and the framing of particular performance targets will need to be considered accordingly.
- A range of non-fossil fuel heating systems are available which could be utilised in new development instead of fossil fuels e.g. air source heat pumps or direct electric heating. Choice of system could effect overall energy use of building as different systems are more or less efficient in terms of energy demand to heat generated. It is likely technologies will continue to evolve in future.

6.3 The first question posed at the beginning of this literature review was whether net zero carbon development is technically achievable for the most regular building typologies expected to come forward in the city over the Local Plan period? The evidence studies reviewed suggest that this should indeed be achievable for most standard typologies. The recommendations of bodies such as LETI for performance targets that net zero buildings should meet – e.g. limits on space heating demand and total energy use, as well as meeting all energy needs through renewables onsite also appear to be achievable, though some variation in levels of target for different types of uses would be pragmattic. Whilst these feasibility studies were prepared before the new UK Net Zero Carbon Buildings Standard emerged, it appears that the performance targets this sets out are generally still achievable in many instances, at least in terms of residential and some more standardised/lower energy demand non residential uses. The variety of building types that could come forward in Oxford, particularly in relation to non-residential uses means that policy should however be clear about what needs to happen where a specific development can demonstrate that targets are not feasible.

6.4 The second question leads on from the previous and was asking whether or not there are typologies, or thresholds at which net zero carbon becomes unfeasible on site, and how could policy be formulated to address these scenarios? The findings set out above suggest there could be situations that occur where elements of net zero policy are more challenging to meet. In particular, taller buildings with limited roof space which means they are unable to install sufficient renewable energy technologies to generate all energy needs onsite, as well as some non-residential typologies with higher energy demands that cannot easily be reduced with current technologies, like certain types of laboratories with specialised equipment.

6.5 The general principles of net zero carbon design (high energy efficiency, meet energy needs renewably, no fossil fuels) should still be applicable even to these more challenging typologies, however, policy will need to include additional allowances for enabling these developments to meet net zero. One option would be to allow for offsetting of energy generation capacity that cannot be met onsite, this would work by allowing applicants to pay towards new renewables offsite to match the energy demand they would need to take from the grid. It would also be beneficial to set out clear guidance/mechanisms for how the development management process could respond pragmatically to applications that are unable to fully meet targets but can demonstrate alignment with the broad principles of the net zero carbon design such as no fossil fuels, maximising energy efficiency where possible.

6.6 Guidance and best practice is likely to evolve over the lifetime of the Local Plan. So there would also be benefit from publishing separate Technical Advice Note similar to those that accompany current Local Plan, where this additional guidance could be signposted to aid applicants.

Appendix

Local Authority reports referenced

- Central Lincolnshire Local Plan review evidence base (2021) - range of detailed studies - https://www.n-kesteven.gov.uk/central-lincolnshire/planning-policy-library/
    - See Task G – Feasibility document in particular – *undertaken by Bioregional; Etude; Currie and Brown*.

- Cornwall Council DPD evidence base (2021) – also used as background evidence in Bath examination, *undertaken by Etude; Currie and Brown* - see document EB004: https://www.cornwall.gov.uk/planning-and-building-control/planning-policy/adopted-plans/climate-emergency-development-plan-document/cedpd-submission-documents-adoption-statement-and-background-documents/

- Essex Planning Officers Association/Essex Design Guide – Net Zero Evidence base: Net Zero Policy Study Report 1 (2023) *undertaken by Introba, Etude, Currie & Brown:* https://www.essexdesignguide.co.uk/climate-change/net-zero-evidence/

- Greater Cambridge Local Plan – background evidence to their 'first proposals' (issues/options) consultation – see in particular net zero technical feasibility (2021) *undertaken by Bioregional; Etude; Currie & Brown; Mode:* https://consultations.greatercambridgeplanning.org/greater-cambridge-local-plan-preferred-options/supporting-documents

- Salt Cross Area Action Plan – net zero examination evidence 'trajectory for net-zero buildings for the Oxfordshire Cotswolds Garden Village' (2020) *undertaken by Elementa; Currie & Brown; Etude; Levitt Bernstein:* https://www.westoxon.gov.uk/media/hdnjcnnf/trajectory-for-net-zero-buildings-for-the-oxfordshire-garden-village.pdf

- South Oxfordshire and Vale of White Horse Local Plan 2041 evidence base – Net Zero Carbon Study (2023), *undertaken by Bioregional* - https://www.southandvale.gov.uk/joint-local-plan-2041-examination-library/

- South West Energy Hub – Net Zero Buildings Evidence and Guidance to Guide Planning Policy (Dec 2021) – CDRCC025 of Bath evidence base - https://beta.bathnes.gov.uk/lppu-core-documents

- Newham Council Operational Energy and Carbon Evidence Base report (2022) *undertaken by Levitt Bernstein; Elementa; Currie & Brown; Etude:* https://www.newham.gov.uk/downloads/file/5382/newham-climate-change-evidence-base-part-1-operational-energy-carbon