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Milton Keynes City Council

Carbon & Climate Study

Analysis Report

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Contents

1. Introduction

1.1 Overview

This ‘Analysis’ report follows the Baseline report of the Milton Keynes Climate and Carbon Study. In this report, the options for the MKCC administrative area’s future growth are considered and the impacts identified.

This includes the following sections of analysis:

- Section 2: Spatial Option Analysis – In this section four spatial options are considered each representing a different way in which Milton Keynes could grow, the scenarios comprise: 1. Densification of the urban area; 2. Strategic urban extension; 3. A new settlement; and 4. Rural growth. The impacts of each spatial option are considered in respect of carbon, transport emissions, climate risk and air quality.
- Section 3: New Development Analysis – First, this section identifies opportunities for how land in Milton Keynes could be used to generate renewable energy. Second, this section analyses the policy options for new development in Milton Keynes by considering net zero buildings, sustainable design features and green roof and wall options. It also sets out costing information for the options presented.

We held public consultation to inform this stage of the study. Consultation was open to all and sought views on what the proprieties should be for reducing emissions in Milton Keynes, what a sustainable place looks like and which areas in the MKCC administrative area are vulnerable to climate change. All responses received have been carefully considered and are referenced in this report. A summary of all the comments made by members of the public can be found in Appendix A.1.

1.2 Note on terminology

On the terminology used in this Analysis report, two key terms are defined as follows:

- Where the term ‘New City Plan’ is included, this should now be read as ‘MK City Plan 2050’; and
- Where the terms ‘Milton Keynes’, ‘Borough’, ‘MKCC’ or variations thereof are included, these should be read as ‘MKCC administrative area’.

2. Spatial Options Analysis

2.1 Introduction

This chapter sets out an assessment of the carbon and climate risk profile of different growth scenarios coupled with different transport scenarios.

The assessment covers four topics:

- Carbon emissions;
- Transport and logistics;
- Climate risk; and
- Air quality.

For each topic the assessments consider the benefits and disbenefits of different spatial patterns of growth, and in the case of carbon emissions and transport, a quantitative assessment of impacts is provided. The aim of the assessments is to inform decisions on how growth should occur to support MKCC achieve their carbon reduction targets.

Four spatial options have been assessed and these are described in the following section.

2.2 Overview of Spatial Options

Four spatial options have been considered; these are theoretical spatial distributions, designed deliberately to be distinct from each other in order to understand the impact of each.

The four spatial options are not exclusive and in reality, actual growth of the city will likely be based on a combination of options and locations according to needs, opportunities and market demand.

The spatial growth options influence the housing mix, employment land uses and transportation choices. These will affect the total absolute emissions as carbon dioxide equivalent (CO2e) and common air pollutants as part of the wider anthropogenic emissions.

The four spatial options are illustrated in Figures 1-4 below.

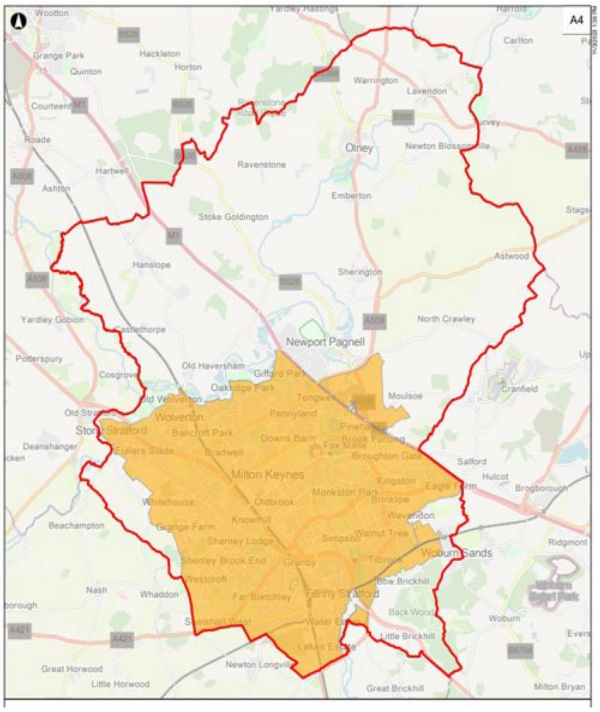

Figure 2: Spatial Option 1: Densification

Orange area indicates zone for densification including Milton Keynes City and Plan: MK strategic site allocations.

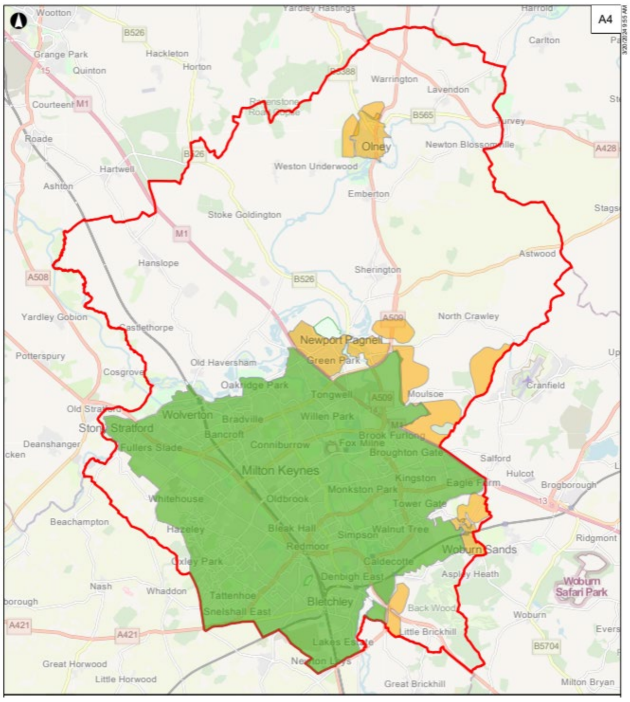

Figure 3: Spatial Option 2: Strategic Urban Extension

Green areas indicate existing settlements including Milton Keynes City and Olney. Orange areas indicate 2050 Strategy recommended growth options.

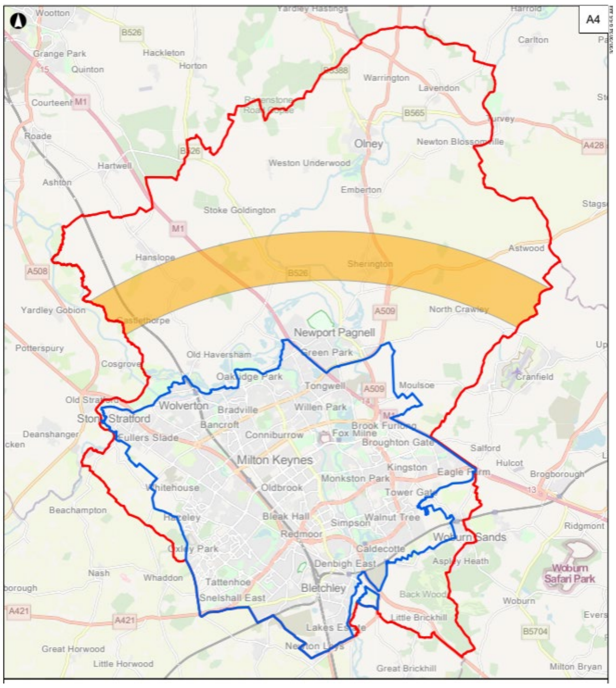

Figure 1: Spatial Option 3: Area of search for new settlement

As site selection has not taken place the orange area represents the potential location of a new settlement.

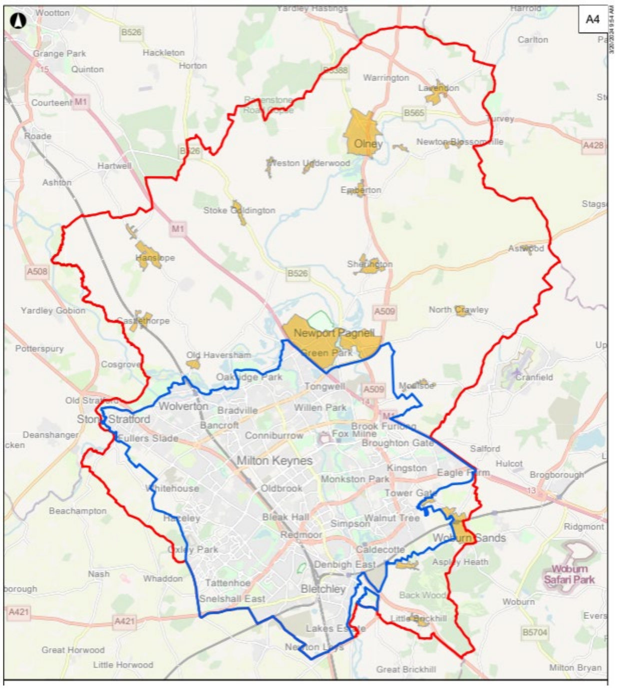

Figure 4: Spatial Option 4: Rural Approach

Orange areas indicates potential settlements for expansion.

The housing mix in each spatial option was informed by the draft version of the Housing and Economic Development Needs Assessment (2022) and the analysis of seven wider areas: Central MK, Urban South, Urban West, Rest of MK Urban, Newport Pagnell, Woburn Sands and Rural North. The four spatial options are described in Table 1.

Table 1: Growth spatial option descriptions

Spatial Options	Description	Development type / size	Employment land
Densification of urban areas	This spatial option reflects all new developments prioritised within Settlement Hierarchy 1. Milton Keynes City (as defined in the current Local Plan). This covers the range within this settlement hierarchy including Central Milton Keynes development and New Strategic Growth Areas. This spatial option is characterised by higher density housing accommodation (e.g. flats and terraced housing) than the other spatial options, as well as higher transport connectivity. The proposed MRT network expansion is included within this spatial option.	Housing mix: Semi-detached 30% Detached 10% Terraced 45% Flats 15% House size: 1 Bedroom: 15% 2 Bedrooms: 25% 3 Bedrooms: 50% 4 Bedrooms: 10%	Industrial / Storage (B1/B2/B8) 15% Hotels, residential care homes, colleges (C1/C2) 15% Retail, food, offices, recreation (E) 50% Libraries, community halls (F1/F2) 20%
Strategic urban extension	This spatial option proposes a strategic urban extension adjacent to Milton Keynes. These sites were the Growth Options identified in the 2050 Strategy. This spatial option is characterised by accommodation types and numbers similar to observed in urban extensions such as Newport Pagnell. Housing density is lower than the Densification of urban areas spatial option, similar to New Settlement option but higher than Rural approach. In general, as an urban area there is relatively high level of transport accessibility and connectivity to the key areas (within Milton Keynes and beyond). The proposed MRT network expansion is included within this spatial option.	Housing mix: Semi-detached 35% Detached 30% Terraced 20% Flats 15% House size: 1 Bedroom: 5% 2 Bedrooms: 25% 3 Bedrooms: 40% 4 Bedrooms: 30%	Industrial / Storage (B1/B2/B8) 30% Hotels, residential care homes, colleges (C1/C2) 20% Retail, food, offices, recreation (E) 30% Libraries, community halls (F1/F2) 20%
New Settlement	This spatial option proposes a new settlement within the open countryside. In accordance with the proposal for a New Settlement, it is assumed there are amenities and provision of new schools etc. This spatial option is characterised by accommodation types and house sizes similar to stand-alone urban areas such as Newport Pagnell. Housing	Housing mix: Semi-detached 35% Detached 30% Terraced 20% Flats 15% House size: 1 Bedroom: 5%	Industrial / Storage (B1/B2/B8) 30% Hotels, residential care homes, colleges (C1/C2) 20% Retail, food, offices, recreation (E) 30% Libraries, community halls (F1/F2) 20%

Spatial Options	Description	Development type / size	Employment land
	density is lower than the Densification of urban areas spatial option, similar to Strategic urban extension option but higher than Rural approach. As a newly created urban area, we anticipate provision of public transport however longer journeys will likely rely on private vehicle use. The proposed MRT network expansion is not included within this spatial option.	2 Bedrooms: 25% 3 Bedrooms: 40% 4 Bedrooms: 30%	
Rural approach	This spatial option combines growth of well serviced villages as well as less well serviced villages. Overall characteristics observed within Rural North have informed the accommodation types and house sizes. Housing density is lower than all other spatial options. Transport accessibility level is relatively poor overall, albeit more public transport provision and active travel encouraged in well-serviced areas. The proposed MRT network expansion is included within this spatial option but DOES NOT benefit future development associated with this option.	Housing mix: Semi-detached 30% Detached 45% Terraced 20% Flats 5% House size: 1 Bedroom: 5% 2 Bedrooms: 20% 3 Bedrooms: 40% 4 Bedrooms: 35%	Industrial / Storage (B1/B2/B8) 30% Hotels, residential care homes, colleges (C1/C2) 20% Retail, food, offices, recreation (E) 30% Libraries, community halls (F1/F2) 20%

The total number of new dwellings from 2022 to 2050 is fixed across all spatial options. In overall, 53,200 dwellings are expected to be needed based on the total 28-year dwelling growth to 2050 under Spatial Option 2b in the "Milton Keynes City Council: Housing and Economic Development Needs Assessment 2022" (HEDNA).

Total non-domestic built area in the spatial options was 50,860 sq.m. (5 ha) following the change in employment land by use class over the period 2022-2050 in the mid spatial option of the HEDNA 2022 report. This is summarised in Table 2 below.

Table 2: Summary of new dwellings, population and employment land

	1. Densification of urban areas	2. Strategic urban extension	3. New Settlement	4. Rural approach
Number of new dwellings 2025 to 2050	53,200 homes (2,128 per year)	53,200	53,200	53,200

	1. Densification of urban areas	2. Strategic urban extension	3. New Settlement	4. Rural approach
Population growth by end of development[1]	210,410	231,420	231,420	240,464
Employment land area	5 ha	5 ha	5 ha	5 ha

The spatial options are considered in respect of carbon, air quality, transport and climate risk in the following sections.

2.3 Carbon

Achieving significant carbon reductions in Milton Keynes will require coordination between how buildings are developed (as directed by planning policy) as well as where they are located and how they are grouped, as determined through Local Plan site allocations and growth spatial options.

This section outlines the methodology used to assess carbon emissions and its findings. The analysis identifies the key carbon parameters and variables across the spatial options to understand the likely impact on emissions arising from future development in each spatial option. This section also sets out consideration of the carbon sequestration potential for each scenario.

2.3.1 Methodology

The carbon emissions associated with each spatial option were modelled using input data for the size and type of developments in each spatial option, the energy performance of buildings and building systems efficiencies, waste, and transport. There are different decarbonisation levers in the form of key dates of policy/standards/systems changes, and percentage reductions achieved from specific actions that are expected to enable change towards more sustainable transport modes and behaviours. Key assumptions are summarised in Table 3. Transport related assumptions are presented in detail in Section 2.4.

Table 3: Key carbon modelling assumptions for the MK spatial options

	1. Densification of urban areas	2. Strategic urban extension	3. New Settlement	4. Rural approach
Heating systems	Air Source Heat Pump (ASHP) from 2030	ASHP from 2030	ASHP from 2030	ASHP from 2030
Efficiency standard	Future Homes Standard from 2025	Future Homes Standard from 2025	Future Homes Standard from 2025	Future Homes Standard from 2025
Rooftop PV	Avg. 3.5kWp in 60% of homes	Avg. 3.5kWp in 60% of homes	Avg. 3.5kWp in 60% of homes	Avg. 3.5kWp in 60% of homes

[1] Each scenario has a fixed number of new dwellings, however the size of these varies by scenario. The population growth has been calculated by applying an estimated number of occupants per dwelling based on dwelling size, e.g. a 1 bedroom house or flat has 2 occupants; a 2 bed house or flat has 3 or 4 occupants, a 3 bedroom house or flat has 4, 5 or 6 occupants etc.

	1. Densification of urban areas	2. Strategic urban extension	3. New Settlement	4. Rural approach
	adjusted further for flats	adjusted further for flats	adjusted further for flats	adjusted further for flats

Figure 5 shows the main steps in the methodology. The aim of the carbon modelling is to provide evidence to facilitate a discussion on the preferred options and policy ambition going forward. The absolute level of emissions is indicative of the expected new development and population growth. The population growth was not fixed to the HEDNA numbers in the model, and it was calculated based on the housing mix and house sizes. This may result in an overestimation of total population growth as dwellings may be occupied by existing residents, large houses may be occupied by less than assumed number of people, and demographic factors are not included in the analysis. The model considers future developments / growth related emissions only.

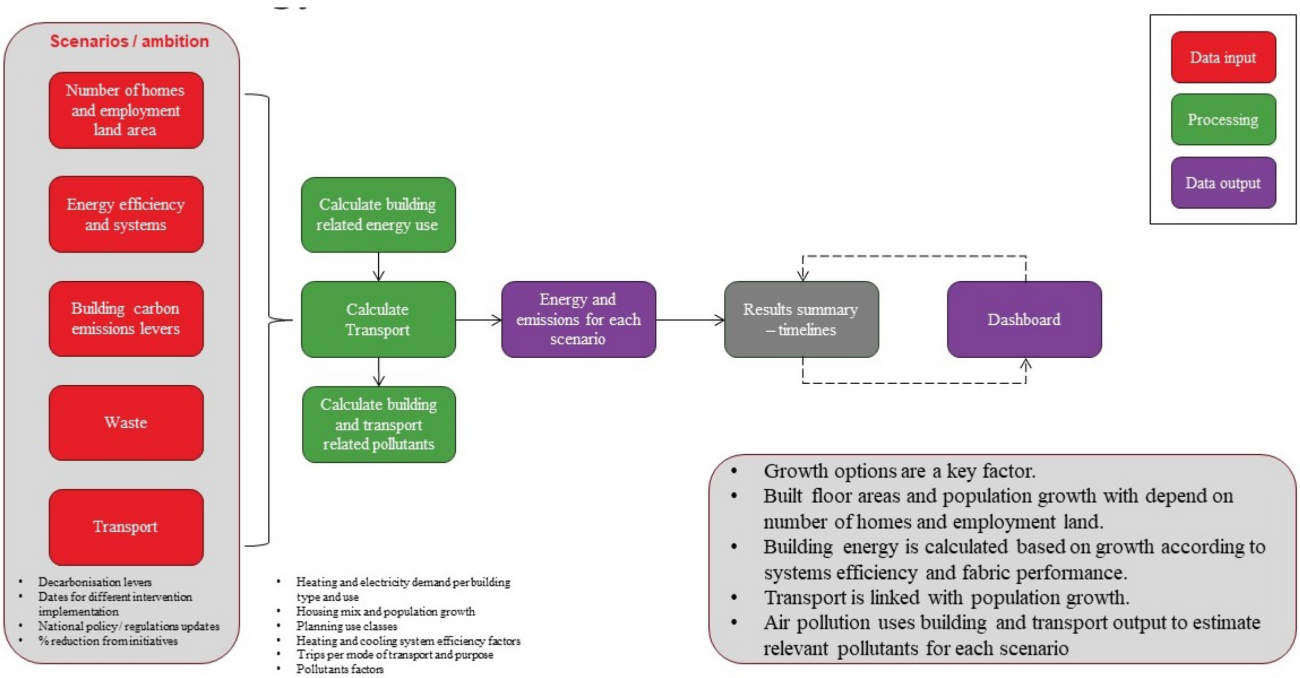

Figure 5: Main steps in the spatial option modelling methodology

2.3.2 Analysis

Spatial Options that favour intensification result in lower annual emissions in the period from 2025 to 2050, as illustrated on Figure 6 below. The associated urban density cannot be estimated as the exact sites and characteristics of development are unknown at this stage. All regulations and policies should be followed to avoid overcrowding in any spatial option.

All spatial options are affected by the grid decarbonisation rate. Heating and transport are electrified at the same rate over a period in the spatial options, and all spatial options assume major electrification and fossil fuel-free development. Eventually emissions from all four spatial options converge after 2045. It is expected that with low-carbon grid intensity the spatial options will become less important as high energy performance buildings, electric vehicles (EVs) and a transition to active travel will mitigate the impact of sprawl and low densities.

The cumulative emissions over this period follow the same trend, with Spatial Option 4 Rural approach resulting in around 200,000 tCO_2e emitted more than Spatial Option 1 Densification in 2050.

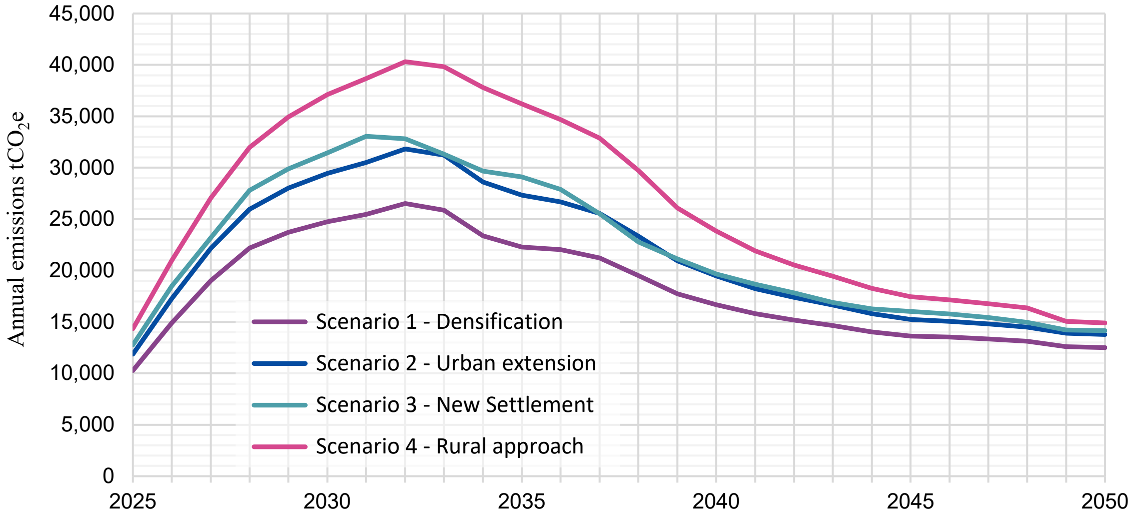

Figure 6: Annual total absolute emissions from the spatial options (incl. PV avoided emissions).

The modelling assumptions account for the fact that industry and supply chains will need time to adapt to fossil fuel-free development. This is the reason air source heat pumps are introduced in 2030. It was also interesting to show the potential impact of delaying such policy or reducing the relevant ambition. Figure 7 shows that gas emissions will remain the most significant source of emissions to 2050 across all spatial options if gas boilers continue to be installed as the main heating system and are not replaced with low-carbon electric heating or district heating. Any delays are essentially creating an “inherited” amount of emissions for the next 15 to 20 years, assuming the gas boilers will start approaching their end-of-life, and/or gas price and availability, or policy changes, will drive the market towards electric heating.

Non-residential buildings have been modelled based on the median energy use of existing office buildings with cooling and warehouses. Their impact on carbon emissions will likely be lower than the levels shown in the results (Figure 6). The results point out that non-residential development will account for a small share of the total building emissions due to the relatively small area of development and the large amount of new dwellings. Emissions from construction activities have not been considered in the model. Construction Environment Management Plans will play an important part in reducing construction emissions.

Finally, the results indicate that renewable generation (modelled as rooftop PV) can have an important role in reducing the emissions from electricity use. This “emissions avoidance” is expected to be higher in the first years of development as it is based on the replacement of electricity from the grid with local generation. Grid decarbonisation reduces the impact PV panels will have on emissions, but it is important to note that renewable generation is important to achieve lower grid carbon intensities. The marginal abatement cost of carbon with PV may increase but investment is necessary to achieve the projected grid decarbonisation and consequent reduction of emissions from all sectors. Local electricity generation and use can have energy performance and financial benefits, as well as reducing energy losses associated with longer transmission. However, battery storage will be required to maximise these benefits. Battery technology is mature but increases the costs of the installed systems.

Operational emissions may have a direct impact on local air quality and carbon reduction targets but embodied emissions should also be closely monitored and be part of decision making and policies going forward. Embodied emissions are emissions associated with the raw materials, manufacturing processes and transportation of the materials, components and supporting infrastructure associated with new development. Materials for buildings, solar PV panels, batteries, heat pumps all have emissions associated with their lifecycle and end-of-life treatment. The model assumes for the embodied carbon of buildings that by 2030 ambitious supply chain changes and policy will result in embodied carbon intensity <500 $kgCO_2e/m^2$ and <700 $kgCO_2e/m^2$ for office/warehouse buildings respectively.

In reality, such low embodied carbon intensities may not be feasible and viable to achieve in large scale developments within the next 5-10 years. Many developers have set near and long term decarbonisation targets. In many cases the targets do not include emissions from materials used in construction and the supply chains (also known as Scope 3 emissions under the Greenhouse Gas Protocol guidance). There is however an increasing interest to understand the structure of the emissions inventories, identify the hotspots of emissions and drive industry wide change with the widespread implementation of green construction principles, low carbon design and procurement of low carbon materials where applicable.

Variations between each spatial option are considered in more detail below.

Spatial Option 1: Densification

Emissions in Spatial Option 1 Densification are illustrated on Figure 7 below. This spatial option results in the lowest annual and cumulative emissions of all spatial options. Intensification reduces the gross floor area of residential development and results in a lower energy use for heating and hot water, and less electricity consumption. Intensification of urban areas is also assumed in the model to reduce trip levels and mileage, encouraging with supporting policies a mode shift to active travel and less use of private cars for short trips. This option is beneficial as it allows MKCC to use the Local Plan to influence heating demand and look further for ways to meet this sustainably through low-carbon street to city scale heat networks.

The proposed MRT network expansion is assumed to affect the transportation options in Spatial Option 1 Densification and Spatial Option 2 Strategic Urban Extension. Although under these spatial option assumptions, the proposed MRT expansion does not result in big differences in overall emissions.

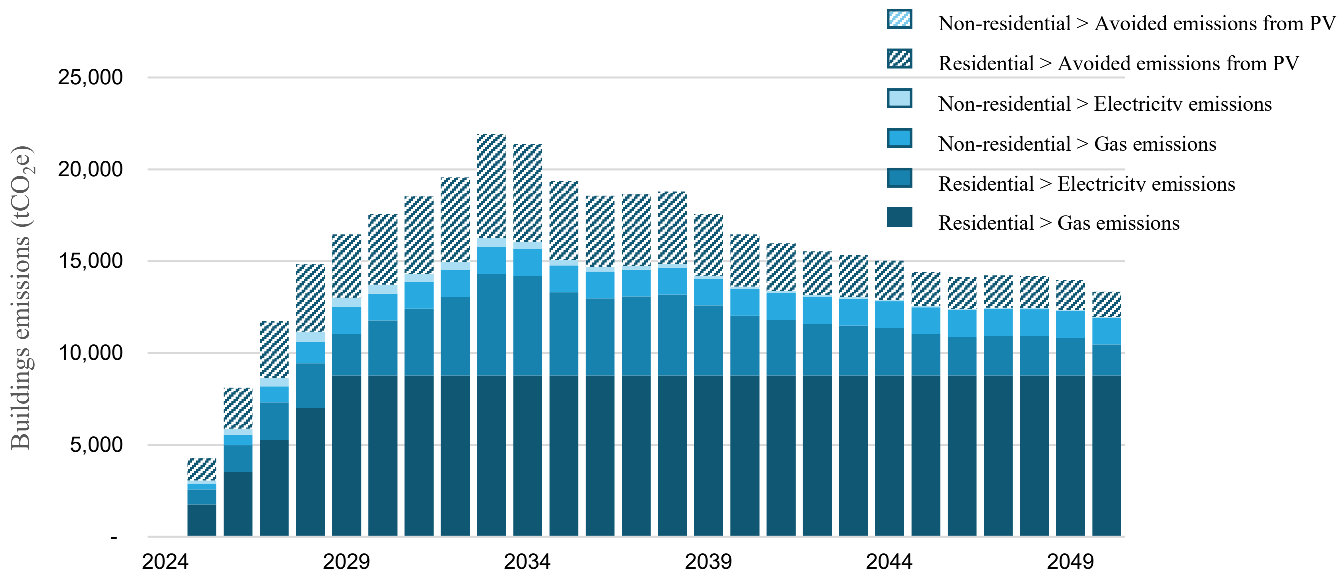

Figure 7: Annual Building emissions forecast for Spatial Option 1 Densification

Spatial Option 2: Strategic Urban Extension

Emissions in Spatial Option 2 Strategic Urban Extension are illustrated on Figure 8 below. Spatial Option 2 results in the second lowest annual emissions after Spatial Option 1 and follows a similar profile to Spatial Option 3 New Settlement. Although this spatial option includes a large percentage of flats, the overall built floor area will be higher than Spatial Option 1 due to larger numbers of semi- and detached houses instead of 1 bedroom and terraced housing. This results in higher population growth because population is linked with house types and size. Non-residential land use classes in this spatial option assume that there is more warehouses and care homes/hotels/colleges than Spatial Option 1 which has a higher concentration of offices, food and retail use. All other differences between the spatial options are due to travel assumptions.

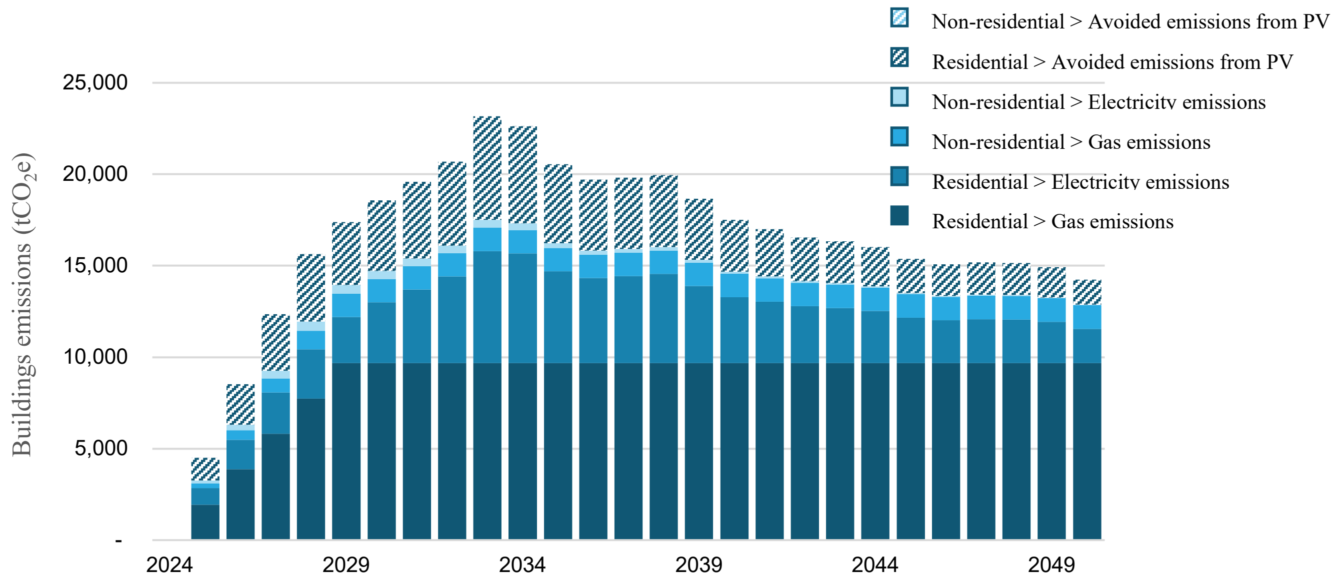

Figure 8: Annual Building emissions forecast for Spatial Option 2 Strategic Urban Extension

Spatial Option 3: New Settlement

Spatial Option 3 New Settlement, illustrated on Figure 9 has similar carbon emissions across the studied period to Spatial Option 2 Strategic Urban Extension. The small differences are mainly associated with differences in travel patterns and behaviours, based on the varying transport assumptions for each option. The housing mix, employment land use class distribution and population growth are the same as Spatial Option 2.

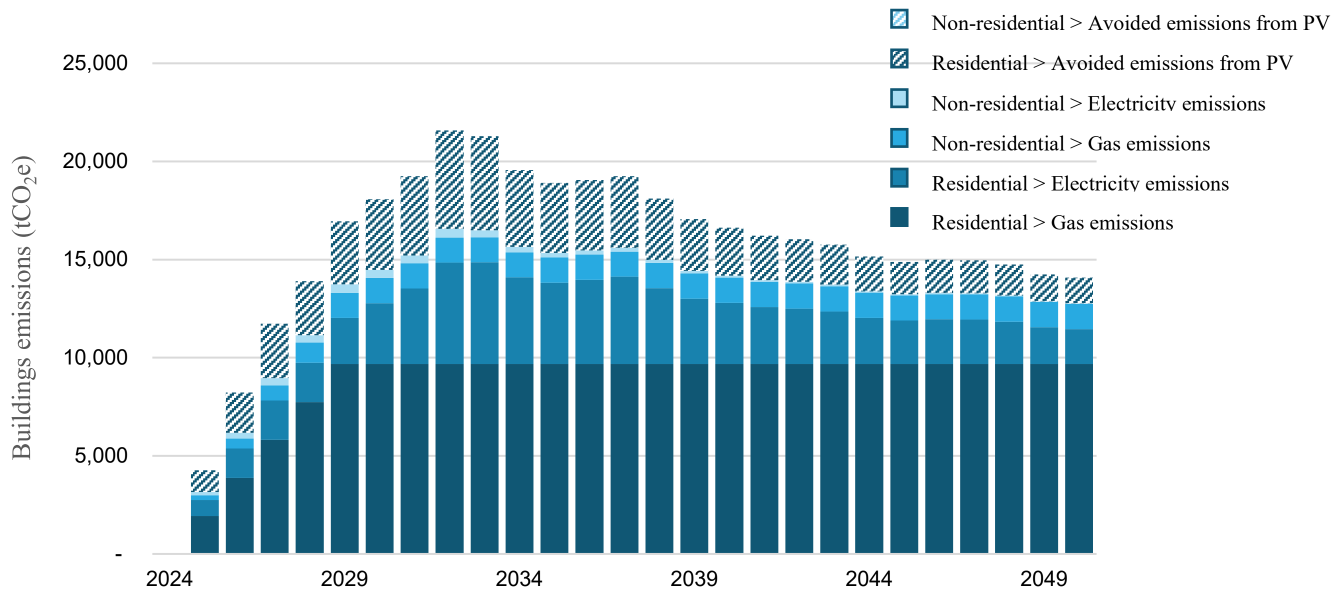

Figure 9: Annual Building emissions forecast for Spatial Option 3 New Settlement

Spatial Option 4: Rural Approach

Spatial Option 4 Rural approach is illustrated on Figure 10 below, it will result in bigger houses and larger floor areas, which subsequently affects heating demand and population growth (it is assumed that larger houses are built to accommodate more people). Dispersed living in this spatial option will likely result in higher levels of car use and longer journey distances compared to more urban oriented living. This analysis has assumed that a rural approach will result in higher number of kilometres travelled, higher private car use and slower implementation of electrification of refuse collection vehicles (RCV) and lower reduction of RCV trips. Consequently, Spatial Option 4 has the highest emissions. However, Spatial Option 4 may have higher opportunities for on-site renewable generation (due to potentially larger roof area and plot size) and benefits from living closer to nature and greenspace.

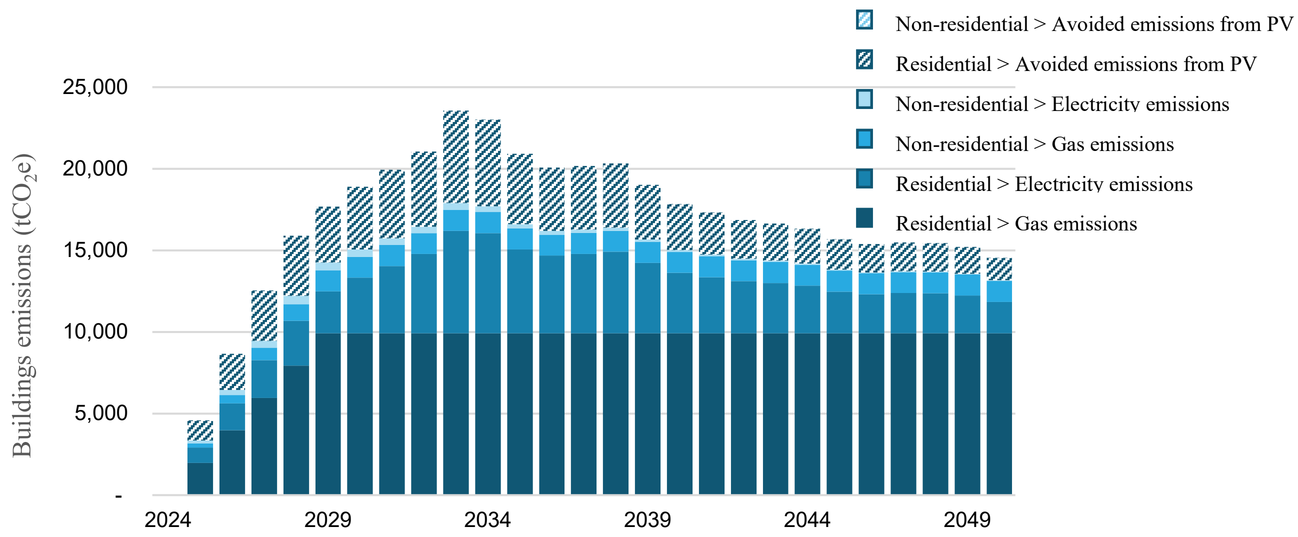

Figure 10 Annual buildings emissions forecasts for Scenario 4 Rural approach

2.3.3 Carbon Sequestration

Milton Keynes is dominated by agricultural land (57%), followed by urban land (34%) (including structures and transport infrastructure, for example roads, railways), trees with other vegetation (for example trees and shrub) (5%) and woodland (1%).

Most urban settlements are located in the south of the MKCC administrative area and are intersected by green infrastructure. There is an area of dense woodland and trees with other vegetation in the south east of Milton Keynes which is mainly occupied by a golf course. The rest of Milton Keynes is dominated by agricultural land with pockets of woodland, trees with other vegetation, marsh, grassland, orchards and scrub.

Land use change impacts on carbon sequestration potential has been considered and is set out in Table 4.

Table 4: Carbon sequestration Spatial Growth Options Analysis

Spatial Option	Land use assumption	Impact
Densification of urban areas	No land use change	No impact on carbon sequestration potential
Strategic urban extension	Conversion of 50% brownfield land, 45% agricultural land and 5% woodland or other vegetation to settlement land	Some carbon sequestration potential may be lost and existing carbon stocks released. New habitat creation as part of developments may partially mitigate this.
New settlement	Conversion of 90% agricultural land and 10% woodland or other vegetation to settlement land	Some carbon sequestration potential is likely to be lost and existing carbon stocks released. New habitat creation as part of developments may partially mitigate this.
Rural approach	Conversion of 90% agricultural land and 10% woodland or other vegetation to settlement land	Some carbon sequestration potential is likely to be lost and existing carbon stocks released. New habitat creation as part of developments may partially mitigate this.

2.3.4 Conclusion

Spatial Option 1 Densification has shown the largest potential for sustainable growth in respect of carbon emissions. Densification reduces gross floor area in residential development and in turn reduces heating demand. Densification of urban areas would also reduce trip levels and mileage, encouraging a mode shift to active travel and less use of private cars for short trips. It also makes best use of existing infrastructure, something which Anglian Water noted as a principle they support in their consultation response.

This option is also beneficial because it offers the greatest potential for the Local Plan to influence heating demand and look further for ways to meet this sustainably through low-carbon street to city scale heat networks.

Spatial Option 1 Densification of urban areas is also likely to have the lowest impact on carbon sequestration potential. Spatial Option 3 New settlement and Spatial Option 4 Rural approach are likely to have the most impact on carbon sequestration potential. This is because development in rural areas is more likely to result in removal of existing natural land uses which will release carbon stocks and reduce the carbon sequestration potential of the land, however, installation of multifunctional green and blue infrastructure in developments may partially mitigate this.

2.4 Transport and Logistics

Emissions from transport account for 28% of the total area-wide emissions in Milton Keynes, of which 98% are from on-road transport and the remaining 2% from rail transport. With the anticipated future growth and development in the study area, there will be a larger population of residents and workers who will need to travel. The additional travel demand will subsequently contribute to the existing level of transport and logistics emissions in Milton Keynes.

There is a significant opportunity to coordinate this growth such that any additional impact on area-wide transport emissions is minimised. This section evaluates the four spatial options (described in Section 2.2) and assesses the travel demand, patterns, and behaviours arising from future development within the different spatial options.

This section outlines the methodology used to assess transport emissions and its findings. The analysis identifies the key transport parameters and variables across the spatial options to understand the likely impact on transport emissions arising from future development in each spatial option.

2.4.1 Methodology

Figure 11 shows the overall methodology and approach used to assess the transport and logistics emissions, as part of the spatial option analysis.

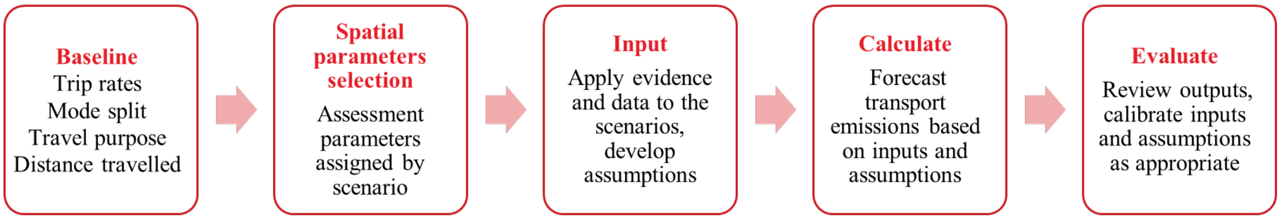

Figure 11: Methodology of transport and logistics emissions spatial option analysis

Establishing baseline

The transport baseline analysis is developed further and expanded. The key inputs considered in this stage included:

- Travel demand – informed by TRICS (Trip Rate Information Computer System);
- Mode of travel – informed by Census 2011 database, National Travel Survey (NTS), and the Milton Keynes Mobility Strategy;
- Travel purpose – informed by NTS; and
- Journey distance – informed by NTS.

These form the basis of the quantifiable parameters in the next stage of assessment, which accounts for the impact of transport interventions and changes (relative to the baseline) in infrastructure, policy, behaviours, and patterns, which by extension would impact the transport and logistics emissions pertaining to future growth.

Defining spatial parameters

The parameters selection process has been informed by discussions with MKCC officers and with other key stakeholders. The parameters were driven by several high-level principles such as the practicality of the change / interventions, the potential for impact on transport emissions, and the alignment with existing MKCC policy and strategic direction. This process required a comprehensive evidence base. The parameters considered are shown in Table 5.

The impact of each parameter on the transport and logistics emissions associated with future growth depends on the characteristics and the type of growth, the impact of some parameters is therefore assumed to be non-uniform across the four spatial options, as seen in Table 5. Transport interventions and changes would play out in different ways for each growth scenario, and this is reflected in the forecast.

Table 5: Transport parameters

Parameters	Densification of urban areas	Strategic urban extension	New Settlement	Rural approach	Rationale / assumptions
Private vehicle EVs in 2050 (%)	~100%	~100%	~100%	~100%	Informed by EV uptake forecasts provided by MKCC using NEVIS data.
Servicing vehicle LGVs* EV in 2050 (%)	~100%	~100%	~100%	~100%	Informed by EV uptake forecasts provided by MKCC using NEVIS data.
Milton Keynes Bus fleet assumed to be 100% EV in Year	2035	2035	2035	2035	Informed by progress towards target outlined in MKCC Bus Service Improvement Plan (Oct 2021) with further adjustments based on MKCC liaison.

Parameters	Densification of urban areas	Strategic urban extension	New Settlement	Rural approach	Rationale / assumptions
Average distance travelled	↑	↑↑	↑↑↑	↑↑↑↑	Informed by National Travel Survey trip distance data. Disaggregated by mode.
Reduction in commuter trips due to WFH / new working patterns	↑	↑↑	↑↑	↑↑↑	Working from home rates are based on assumption on the number of workdays that residents are working from home, i.e. not commuting to a workplace. (Note: HEDNA work from home data was not used as Census 2021 was heavily skewed due to pandemic / lockdown restrictions during Census survey.)
Local living – Reduction in overall trips	↑↑↑	↑↑	↑	-	Reduction in overall trips may be influenced by the density, land use mix, and accessibility to amenities within walking distance. These may result in linked trips across different travel purposes; or impact the need to travel. 'Local living' planning principles are generally more applicable and effective in urban areas. As such the weighting is more focused on S1 and S2.
Reduction in car mode share – short-distance trips	↑↑↑	↑↑	↑	-	Mode shift from private car to walking, cycling, and micro-mobility modes.
Reduction in car mode share – long-distance trips	↑↑↑	↑↑	↑	-	Mode shift from private car to public transport modes, including the proposed MK mass rapid transit system.
Logistics Hubs – Reduction in OGV* trips	↑↑↑	↑↑	↑↑↑	-	Logistics Hubs may be practical to implement in S1, S2, S3 growth scenarios. Difficult to operate and serve rural, dispersed settlements.
Servicing vehicle OGVs* EV in 2050 (%)	35%	35%	35%	35%	Agreed with MKCC transport officers. There is uncertainty as battery technology is not proven for application to large vehicles, e.g. OGVs. Assumed that technology and roll-out will advance ahead of TAG forecasts by 2050.
Milton Keynes taxi fleet assumed to be 100% EV in Year	2033	2033	2033	2033	Agreed with MKCC transport officers, according to progression towards private taxi fleet electrification in Milton Keynes.
Motorcycles assumed to be ~100% EV in Year	2050	2050	2050	2050	Informed by national policy direction and likely shift in travel behaviour in response to the 100% zero emissions at tailpipe commitment by 2035

* LGV: Light Goods Vehicle; OGV: Ordinary Goods Vehicle.

Model building

The following formula is used to calculate the emissions from transport and logistics:

$$Transport\ activity \times Emission\ Factor \left(\frac{kgCO_2e}{km}\right) = Transport\ Emissions\ (kgCO_2e)$$

Where:

- Transport activity: informed by the trip forecast of the new development, mode share and distance travelled per trip; and
- Emissions factors: factors published by the Department for Energy Security and Net Zero (DESNZ) and the Office of Rail and Road (ORR).

The transport emissions considered comprise tailpipe emissions, with some degree of uplift to account for emissions associated with the generation and transfer of electricity. Well-to-tank[2] emissions are not considered.

The model includes annual emissions of the following modes, as well as accounting for the electricity-powered proportion of each mode:

- Walking;
- Cycling;
- National Rail;
- MRT;
- Bus;
- Taxi;
- Motorcycle;
- Private vehicle (car);
- Micro-mobility (scooters, e-scooters);
- Light Goods Vehicle (LGV); and
- Ordinary Goods Vehicle (OGV).

The model outputs have been tested rigorously to identify and understand unexpected or unrealistic results. Inputs and assumptions were subsequently calibrated, where required, to ensure a robust and refined set of outputs for each spatial option.

2.4.2 Analysis

The transport and logistics emissions by spatial option are outlined in Table 6. The table shows a comparison of the cumulative emissions throughout the forecast period and the annual emissions in key years, across the four spatial options.

Table 6: All spatial options – Cumulative emissions and annual emissions in key years

Spatial Option	Year 2030	Year 2035	Year 2040	Year 2045	Year 2050	Cumulative Total (2025-2050)
1 Densification of urban areas	9.9	8.6	4.5	2.1	1.3	143.6
2 Strategic urban extension	13.2	12.7	6.7	2.9	1.8	200.2
3 New Settlement	15.3	14.3	7.0	3.1	2.2	225.1
4 Rural approach	19.8	21.1	11.1	4.5	2.7	313.5

* All data shown in units of thousands of tCO_2e (thousands of tonnes of CO_2e).

[2] Well-to-tank emissions include all greenhouse gas emissions from the production, transportation, transformation and distribution of the fuel used to power the vehicle.

Transport emissions are categorised by mode of transport to illustrate the evolution of emissions arising from each mode throughout the forecast period. The transport emissions forecasts per year by mode for each spatial option (options 1 to 4) are shown in Figure 12 to Figure 15.

Transport modes that produce negligible emissions are not shown in the graphs. These include micro-mobility travel. Micro-mobility vehicles are expected to be fully electric-powered, and the relatively negligible emissions impact of charging micro-mobility vehicles are not included as part of the user carbon emissions.

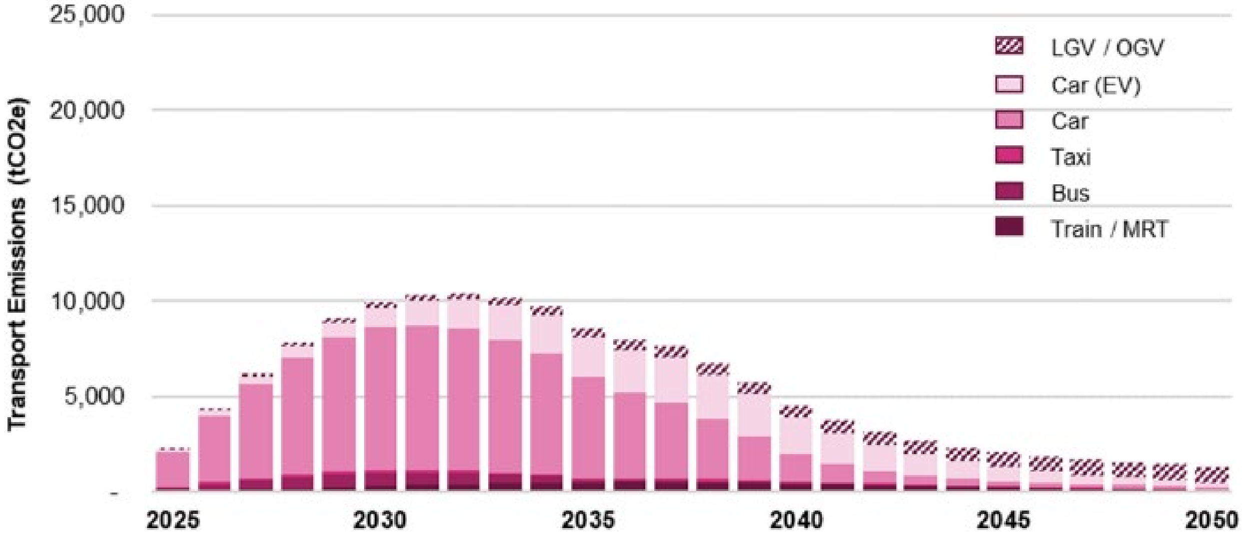

Figure 12: Spatial Option 1 annual transport emissions

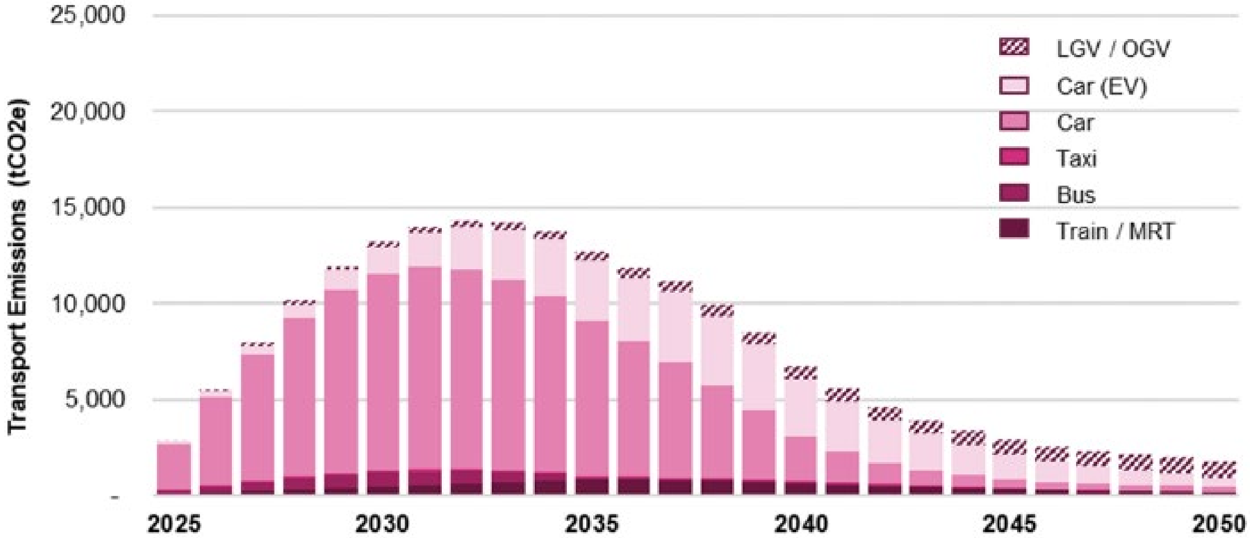

Figure 13: Spatial Option 2 annual transport emissions

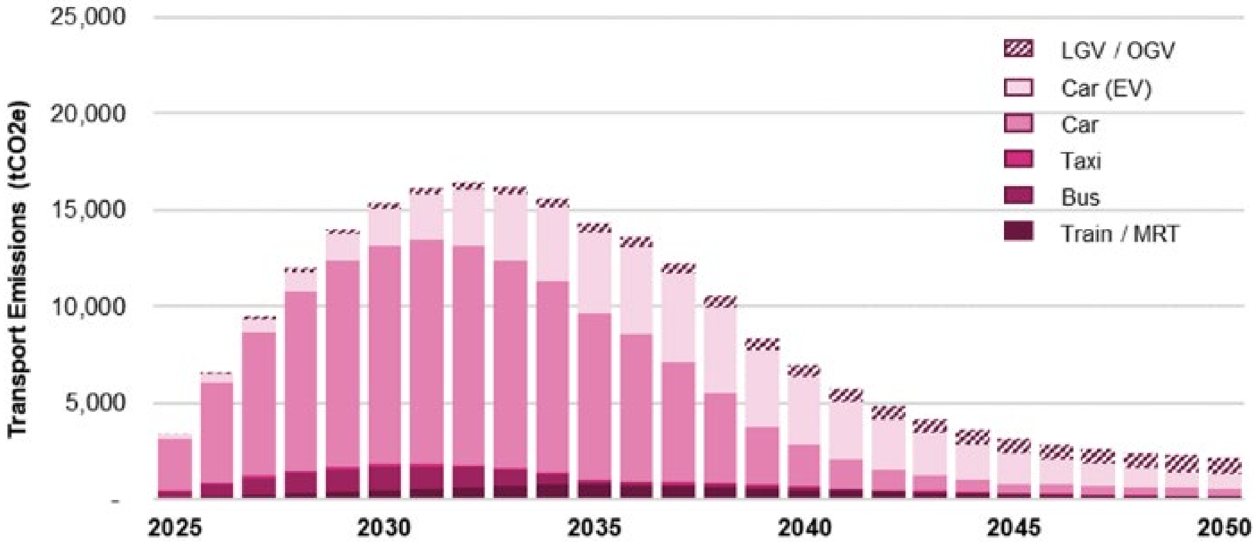

Figure 14: Spatial Option 3 annual transport emissions

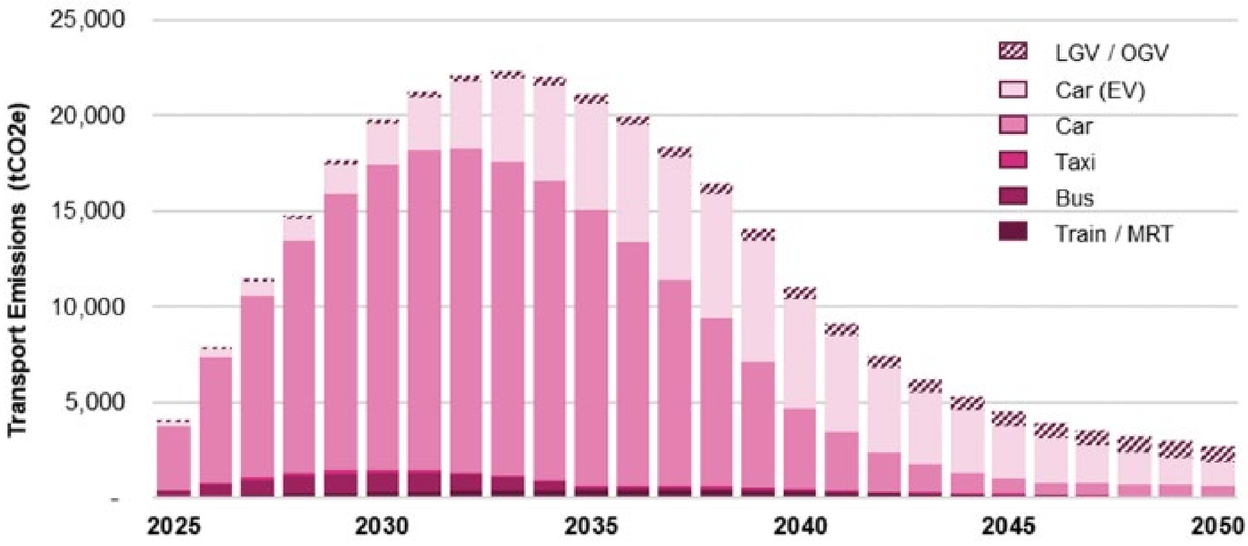

Figure 15: Spatial Option 4 annual transport emissions

There is a consistent trend across all spatial options of a steady increase in annual emissions from the initial development year until the early 2030s. The year-on-year increase in development quantum produces additional emissions, resulting from increased travel demand and from servicing and logistics trips associated with new development.

The rate of the increase, however, stabilises and reverses from the early-mid 2030s. The annual transport emissions steadily decline for the remainder of the forecast period. At this stage, the transport and logistics sector decarbonises at a rate which outweighs the impact of the increased travel demand and trip generation. By 2050, the emissions of all transport modes show significant reductions compared to the peak year emissions, as transport fleets of different modes are expected to be mostly or fully decarbonised (with the exception of OGVs, where there are currently foreseeable significant technological barriers to full decarbonisation).

Public Transport

Public transport emissions are primarily influenced by the proportion of the fleet that is electrified, the mode share of public transport modes, and the route distance of services. The bus fleet in Milton Keynes is assumed to decarbonise and be fully electric by 2035, as discussed and agreed with MKCC officers. Rail journeys are assumed to be made using electric-powered rolling stock. The proposed MRT system is assumed to be fully electric from its first year of operating.

The decarbonisation of the UK electricity grid therefore has a significant impact on emissions associated with public transport modes, and triggers an overall decline in bus, rail and MRT emissions despite an increase in ridership throughout the forecast period.

Public transport ridership is highest in the Spatial Option 1 Densification and lowest in Spatial Option 4 Rural approach. The average journey distance on public transport modes is lowest in Spatial Option 1 Densification and highest in Spatial Option 4 Rural approach. The interaction between these two factors is important to understand when interpreting the results and explains, for instance, why in Spatial Option 3 New settlement public transport emissions are higher than Spatial Option 1 Densification emissions despite comparatively lower ridership.

Car

Emissions from car use account for the majority of the overall transport emissions for each spatial option. Private car emissions are significantly higher in Spatial Option 3 New settlement and Spatial Option 4 Rural approach where the car mode share is larger, and the average car journey distance is greater.

In Spatial Options 1, 2, and 3, there is a gradual reduction in the car mode share throughout the forecast period. This is driven by the overarching policy aim to reduce car use and provide alternatives to private cars. These may include interventions such as the opening of MRT system and improved active travel infrastructure (e.g. Redway). The modal shift away from cars to public transport and active travel has a subtractive impact on transport emissions. This reduction in car mode share is most pronounced in Spatial Option 1 Densification, where it is most practical and viable to achieve mode shift from cars; while Spatial Option 3 New settlement shows the least pronounced reduction in car mode share. The reduction which is evident in Spatial Option 3 is a result of some public transport options and facilities being available locally. Spatial Option 4 does not show a significant reduction in car share mode as new residents living in rural areas will continue to rely on private cars.

The uptake of private EVs is based on the MKCC predictions of close to 100% adoption in 2050. The same percentage uptake is assumed across the spatial options. Along with the gradual decarbonisation of the electric grid, the uptake of EV cars is the most significant reason for reducing overall transport emissions.

Logistics

The emissions associated with servicing mostly derive from Light Goods Vehicles (LGV) and Ordinary Goods Vehicles (OGV). There is an overall increase in these emissions as new developments are built over the course of the forecast period.

LGV emissions drastically decrease over the development years, as electric LGVs are expected to be gradually rolled out. According to forecasts provided by MKCC, electric LGVs will account for approximately 100% of the LGV fleet in Milton Keynes by 2050. The pathway towards decarbonisation of OGVs, however, is unclear, as the technology to enable this is currently unproven.

Furthermore, the vast majority of emissions from servicing (and a significant proportion of all transport and logistics emissions) arise from OGV trips, in all spatial options. The idea of implementation of logistics hubs has been tested in spatial options 1, 2, and 3, accounting for the feasibility and practicality of adoption in each spatial option. The logistics hubs aim to reduce the proportion of servicing trips made by OGVs, thereby reducing OGV carbon emissions. Instead, these servicing trips are expected to be replaced by smaller electric vans, electric cargo bikes, pedal cycles, or robots. These alternatives are not expected to generate any significant carbon emissions.

Other Modes of Transport

Trips made by active travel modes – walking, cycling, wheeling – account for a significant proportion of the overall trips. These modes (and trips) do not produce any carbon emissions and therefore would not contribute to the overall transport and logistics emissions assessed in this study.

Taxi trips account for a small proportion of overall trips. The taxi fleet in Milton Keynes is assumed to electrify in the 2030s, as agreed with MKCC officer. Therefore, the impact of taxi trips on emissions is not significant in any spatial option.

Motorcycle emissions are included in Table 6 and in the figures. The proportion of overall trips made by motorcycle is forecast to be very small, and the associated emissions are imperceptible. As such, this mode is not included in the mode of travel categories.

2.4.3 Conclusions

This section outlines the comprehensive methodology that was developed and applied to understand the baseline emissions from the transport and logistics sector. The baseline context was used to build a forecast of emissions throughout the development period that reflects the likely changes, opportunities, and constraints in the future of transport for Milton Keynes. Various travel purposes were considered, and all relevant modes of transport were assessed to understand how they each contribute to the overall transport emissions.

The spatial option analysis assesses the distinct context and characteristics of each future growth option, and a transport emissions forecast which reflects the key differences is produced for each option. Some of the key factors built into the model which influenced transport and logistics emissions include:

- Level of travel demand / overall number of trips;
- Distance travelled per trip;
- Mode split;

- Proportion of electrified vehicles / proportion of overall distance travelled by electrified vehicles; and
- Decarbonisation of the UK electricity grid.

Overall, it is clear from Table 6 that Spatial Option 1 Densification is the optimal future growth option in the context of minimising transport and logistics emissions. The cumulative emissions for Spatial Option 1 densification are 28% lower than Spatial Option 2 Strategic urban extension, 36% lower than Spatial Option 3 New settlement, and 54% lower than Spatial Option 4 Rural approach. It is also apparent that the 'turning point' where annual emissions begin to stabilise and decline occurs slightly earlier in Spatial Option 1 Densification (2032), particularly compared to Spatial Option 4 Rural approach (2033) which is much more car-dependent.

Reducing car dependence is a crucial component in decarbonising transport. Without modal shift from private cars to more sustainable modes, there are fewer mechanisms to progress transport decarbonisation. Reducing transport emissions would then be over-reliant on increasing the proportion of EVs and on the decarbonisation of the electricity grid (an over-reliance which can be seen in the Spatial Option 4 results). A shift to more sustainable modes of transport creates wide ranging benefits, for example with less space being used for driving and parking cars there are opportunities for healthier urban environments. Furthermore, there are public health and air quality benefits of sustainable transport which would not be achieved by simply switching to an EV fleet, please refer to Section 2.7 for more information on Air Quality.

Comparison of the four spatial options demonstrates a trend of increasing emissions from the most urban-focused Spatial Option 1 Densification to the most rural-focused Spatial Option 4 Rural approach. This can be understood by contextualising each spatial option and considering some of the key factors affecting transport emissions: there is less car dependence and a higher proportion of trips made by sustainable modes in urban areas; the average journey distance for most transport modes is significantly lower in urban areas; and the potential to influence travel behaviours and patterns is greater in urban areas. Thus, the potential for transport emissions reductions is also greater.

2.5 Climate Risk

Milton Keynes is at risk from a range of climate hazards, as documented in the climate risk section of the *Climate and Carbon Study - Baseline Report*[3]. The baseline assessment provided direction about the key climate risks that should influence the planning and design of future development with respect to the New City Plan.

This section aims to build on the baseline report, to provide an overview of the relationship between new development in the city and climate risk. This assessment will consider:

The climate risk **to** and **of** new development, regardless of which spatial option is pursued; and
The climate risk **to** and **of** new development, as influenced by spatial option.

It is important to note that this section considers the climate risks facing the city at a high level. In addition, the conclusions drawn in this chapter are greatly driven by the assumed locations for the four spatial options; changes to these areas, or the identification of specific developments, would influence the chapter's findings. It is assumed any development would go through a thorough site investigation including flood risk assessment. The policy recommendations stage of this project will be crucial to help manage these climate-related risks.

2.5.1 Methodology

To consider the full breadth of climate risks to and of new development in Milton Keynes, this assessment adopts a number of assessment approaches.

Firstly, the assessment **qualitatively** considers any climate risks which are spatially agnostic and are influenced by new development itself rather than the location of the new development.

This is followed by assessments of the climate risks facing and being driven by the four spatial options. This is informed by qualitative analysis, public consultation and spatial analysis, depending on climate hazard, as presented in Table 7.

The **qualitative analysis** teases out the nuances in how climate hazards could affect the four spatial options differently, through identifying the options' drivers of exposure and vulnerability. This leans on some of the assumptions made about the four development options, such as housing mix and land use change (Section 2.2). It also links to the 'Vulnerable Neighbourhoods' (Section 2.6), to understand the vulnerabilities of existing communities, in terms of key community infrastructure, physical assets and socio-economic factors. Key findings from the **public consultation** are incorporated into the qualitative analysis.

This spatial options assessment is supported by **spatial analysis** where possible. The spatial analysis is comprised of a series of maps, to understand how the proposed spatial options intersect with the areas that are exposed to different climate hazards. The climate hazard data aligns with that presented in the climate risk baseline assessment, and is presented in a manner which aligns with the Milton Keynes' Draft Strategic Flood Risk Assessment.

The only exception to this is the surface water flood risk data, which is typically hard to visualise due to the localised and complex nature of the risk in the city. Instead, the surface water flood risk data was processed, with output maps showing the percentage of each Lower layer Super Output Area (LSOA) which lies within the flood extent for a 1 in 100 year (plus 40% climate change allowance) event. The higher the percentage, the greater the area within the LSOA which is exposed to surface water flooding.

The aim of this processing is to give a clearer picture of relatively high or low areas of surface water flood risk across Milton Keynes. These maps are analysed to identify areas that are of particularly low/high exposure to climate hazards, that could inform the sites to prioritise/avoid for development.

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[3] Arup (2023) Milton Keynes City Council: Climate and Carbon Study - Baseline Report.

Table 7: The analysis approaches adopted for all climate hazards.

	Spatial analysis	Public consultation	Qualitative analysis – climate hazard	Qualitative analysis – spatial option
Fluvial flooding	Y	Y	Y	Y
Reservoir flooding	Y		Y	Y
Surface water flooding	Y	Y	Y	Y
Groundwater flooding	Y		Y	Y
Drought/water scarcity			Y	Y
Extreme heat	Y		Y	Y
Extreme wind			Y	Y

2.5.2 Analysis

Climate risks associated with new development that are agnostic to spatial option

It is important to highlight the climate risks that are found across all spatial options, and that can be exacerbated by development regardless of the spatial option. It is important these risks are appropriately considered and managed throughout the New City Plan, from inception, through design, construction and maintenance.

In terms of **fluvial flood risk**, new development has the potential to increase risk, both to new settlements and to existing development elsewhere in the catchment. Without appropriate mitigation, the impacts on new settlements could be similar to those on existing settlements, as described in the climate risk baseline assessment. In addition, new structures or development within the floodplain could affect flow pathways and cause floodwater to extend into existing development areas, and increase risk to existing residents and the built environment. These impacts could be felt locally, or further downstream, as urbanisation of river catchments can increase peak river flows that drive downstream flooding. The same is true for reservoir flood risk.

For **surface water flooding**, new development can increase surface water runoff if not appropriately managed. This can translate to an increase in surface water flood risk, both locally or further downstream in the drainage catchment. For example, if drains become overwhelmed due to an increase in runoff, this could cause storm overflow events or sewer flooding. In addition, the development on greenfield land and potential **loss of green spaces** can increase surface water flood risk, due to the loss of natural infiltration.

The likelihood of a flood event driven by **groundwater flooding** is not anticipated to change with new development, as the susceptibility of an area to groundwater flooding is influenced by underlying geology. However, groundwater flood risk can contribute to surface water and fluvial flooding, as there is less opportunity for infiltration in areas with naturally high water tables.

Areas at risk of groundwater flooding can be challenging for development, as sustainable drainage systems (SuDS), commonly used to manage surface water flood risk, may not be suitable. If a development site is proposed within an area at risk of surface water and groundwater flooding, the Sequential and Exception Tests would likely apply.

Housing typologies can influence the potential impact to residents from flooding. For example, flood risk is magnified for residents who live exclusively on the ground-floor of a property, for example in a ground-floor flat. With 15% of new development assumed to be flats in spatial options 1, 2 and 3, it is important this risk is managed appropriately.

The risk of local **extreme heat** events can also increase due to the potential **loss of green spaces** from greenfield development, via the increase in albedo associated with impermeable surfaces compared with green surfaces, as well as natural shading from trees. The effect of extreme heat events on residents' comfort in their homes is influenced by housing typology; a recent Arup report delivered for the Climate Change Committee found that flats and smaller houses are typically at higher risk of overheating than larger homes[4].

Water scarcity, or **drought**, is a major concern in Milton Keynes, as the Environment Agency states that the Anglian Water region is currently under serious water stress[5]. This is expected to become more acute in the future, given the impacts of climate change and extreme drought, which can reduce water supplies. Additionally, the development and associated increase in local population will increase the demand for water in Milton Keynes.

Without appropriate mitigation, there is a chance that the development associated with the New City Plan could increase the likelihood of drought, with impacts on water availability. In addition, new landscaping may struggle if planted during a drought period, or insufficiently maintained (e.g. if affected by a temporary, or non-essential, use ban). Water resource and supply is not a matter wholly within the control of MKCC. Partnership working between neighbouring Local Authorities, Anglian Water, and the Environment Agency is essential to ensure that new development does not hinder delivery of Anglian Water's Water Resource Management Plan. MKCC is preparing an Integrated Water Management Study which will consider setting higher water efficiency standards.

Housing typology can influence water demand from Milton Keynes' new development. Smaller properties could lead to fewer residents per property, which can increase domestic water use compared with the efficiencies that come from multiple occupancy, and have adverse impacts for water scarcity. However, flats are less likely to have private gardens, which can contribute to water scarcity when residents use mains water supplies for garden watering.

The combination of new development and the increased likelihood of concurrent **drought** conditions and flash **surface water flooding**, associated with climate change, can also have a detrimental impact on Milton Keynes' natural environment. Without sufficient infrastructure upgrades, the greater volumes of wastewater associated with additional development could increase the use of combined sewer overflows that can pollute and degrade fresh watercourses – the impacts of which are particularly acute during drought periods, when rivers cannot naturally dilute the wastewater effluent.

Extreme wind was identified as an issue for transport and health and safety in Milton Keynes within the baseline assessment. New development could increase the health and safety concerns with new trees at-risk of being thrown. This may be exacerbated by the enhanced focus placed on street trees within the latest versions of the NPPF. The impacts of travel disruption could be more significant if there are more people travelling in the city due to the population growth that development will support. If the Mass Rapid Transit project is taken forward, it will be important that the impacts of extreme wind are considered across the project lifecycle, to reduce the potential for service disruption.

Finally, it is important to consider the factors that can influence **resident or community resilience** – their ability to prepare, react, recover and adapt to climate hazard events. For example, housing typology could influence the relative rate of single occupancy living in the city, which could lead to social isolation and poor community resilience.

Spatial Option 1: Densification

The first spatial option represents the densification of Milton Keynes' city centre, as shown in Figure 1.

In terms of **fluvial and reservoir flood risks**, the spatial option area includes land that lies in the present and future floodplain of the River Ouzel, as well along the right (south) bank of the River Great Ouse, in the northern boundary of the spatial option boundary – as shown in Figure 16. However, these risks are mostly mitigated by the historic approach within Milton Keynes of creating a network of linear parks around fluvial river networks in the city. Figure 16 also shows there are large areas within the spatial option shown not to be at risk from fluvial or reservoir flooding – such as Milton Keynes city centre and West Bletchley.

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[4] Addressing overheating risk in existing UK homes (Arup) - Climate Change Committee (theccc.org.uk)

[5] Water stressed areas – 2021 classification - GOV.UK (www.gov.uk)

Groundwater flood risk (Figure 18) follows a broadly similar spatial distribution to present-day fluvial flood risk, linked to the influence of the river on nearby superficial geology of alluvium and river gravels.

Figure 17 illustrates that **surface water flood risk** is present across the spatial option area, with some of the highest risk LSOAs in Milton Keynes lying in the spatial option area, such as near Caldecotte, Stony Stratford and Furzton.

As with all development, there is a risk of increasing local **surface water flood risk** if not appropriately mitigated. However, it is assumed there would be no net land use change within the Densification option, and so the increase in flood risk is anticipated to be minimal.

The risk of **overheating** during hotter temperatures is most acute for the Densification spatial option, as it is the option most likely to increase the 'urban heat island' effect within Milton Keynes, making the local area hotter for both new and existing residents. The urban heat island modelling has found there to be a notable UHI intensity, as shown in Figure 19. The whole of Central Milton Keynes is affected by this, with Wolverton a particularly strong 'hot spot' within the city. An increased local population would bring increases in demand for heat generating activities, including provision of resources such as water and energy, which may exacerbate the UHI.

As this spatial option aims to densify the city centre, it is expected the sites will be more spatially constrained. This may make it more challenging to integrate green spaces of sufficient size to mitigate local overheating risk. Small scale green infrastructure measures, such as street trees and green walls help to mitigate overheating at the building scale. If measures are widely adopted across a neighbourhood, they could also contribute to a neighbourhood-scale green network that contributes to a localised reduction in the urban heat island affect. In addition, this spatial option is characterised by more multi-occupancy buildings (flats and terraced houses) which are at higher risk from overheating compared with single unit housing. Building-scale design interventions (e.g. external louvres) could help improve internal thermal comfort during periods of hot weather.

The impacts of **extreme wind** and **water scarcity/drought** are discussed above, as they are considered less influenced by geographical location, and more linked to new development itself. The same holds true for all four spatial options.

In addition, it is important to consider hazard-agnostic factors that may affect the resilience of new development in this spatial option. For example, new residents associated with this spatial option may rely on existing infrastructure, or the capacity of existing facilities may be increased to accommodate the increased population. However, these existing or expanded facilities may not have been designed to be resilient to the impacts of climate change.

In contrast, the New Settlement option is likely to require a greater development of new infrastructure, including social infrastructure such as schools and medical facilities. These would be of a more modern specification than existing infrastructure in the city, and therefore potentially more resilient to the impacts of climate change. There could be potential for retrofitting existing infrastructure in the city, to reduce the associated climate risks.

As presented in the 'Vulnerable Neighbourhoods' Section 2.6, the parts of the MKCC administrative area that have the highest levels of socio-economic deprivation are located in the urban area of Milton Keynes. New development in these areas can bring opportunities to improve local community resilience to climate hazard events and reduce vulnerability.

The spatial option also includes areas at lower levels of socio-economic deprivation. If development is focussed instead in these less deprived areas, there is the potential for greater polarisation in socio-economic vulnerability across the city, making the relative risk to vulnerable populations even higher.

Overall, there are some areas within this spatial option that may be helpful to avoid, based on the high risk from flooding. These are the areas in the floodplain for the River Ouzel, along the right (south) bank of the River Great Ouse, and along the Loughton valley in the centre-west of the spatial option area, as well as the LSOAs at greatest risk from surface water flooding (near Caldecotte, Stony Stratford and Furzton). From an extreme heat perspective, it may also be advisable to avoid the areas with greatest existing high urban heat island intensity, near Wolverton.

There are ways of managing these risks through planning policy, development criteria and design guidance; for example, development in areas at risk from groundwater flooding should avoid including underground/basement assets. It is recognised that any development would go through a thorough flood risk assessment, and the purpose of this assessment is to provide a high-level overview across a range of climate risks. In addition, a wider range of policy recommendations will be provided in the upcoming *Climate and Carbon Study - Policy Recommendations*.

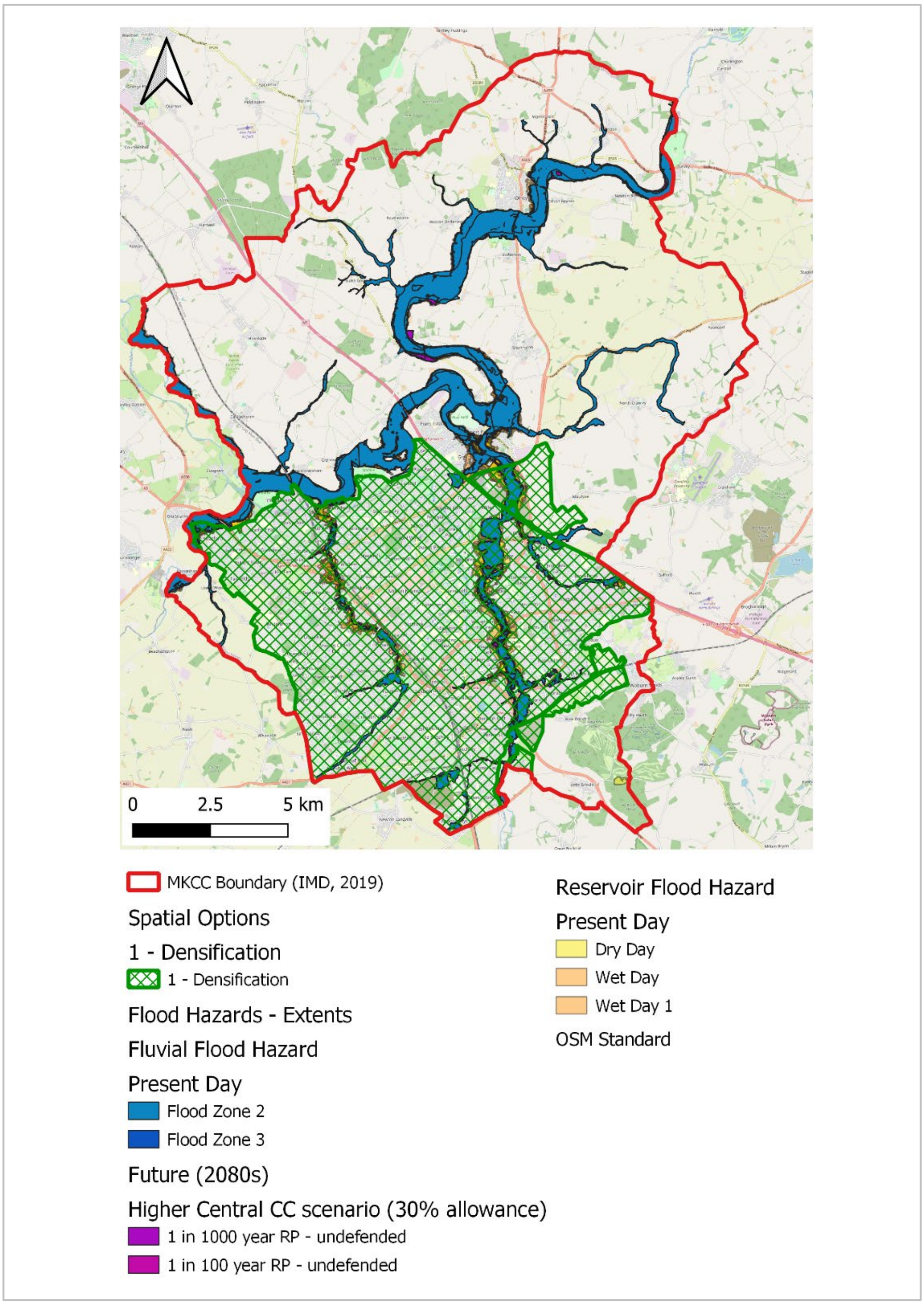

Figure 16: Spatial Option 1 (Densification) and fluvial and reservoir flood risk

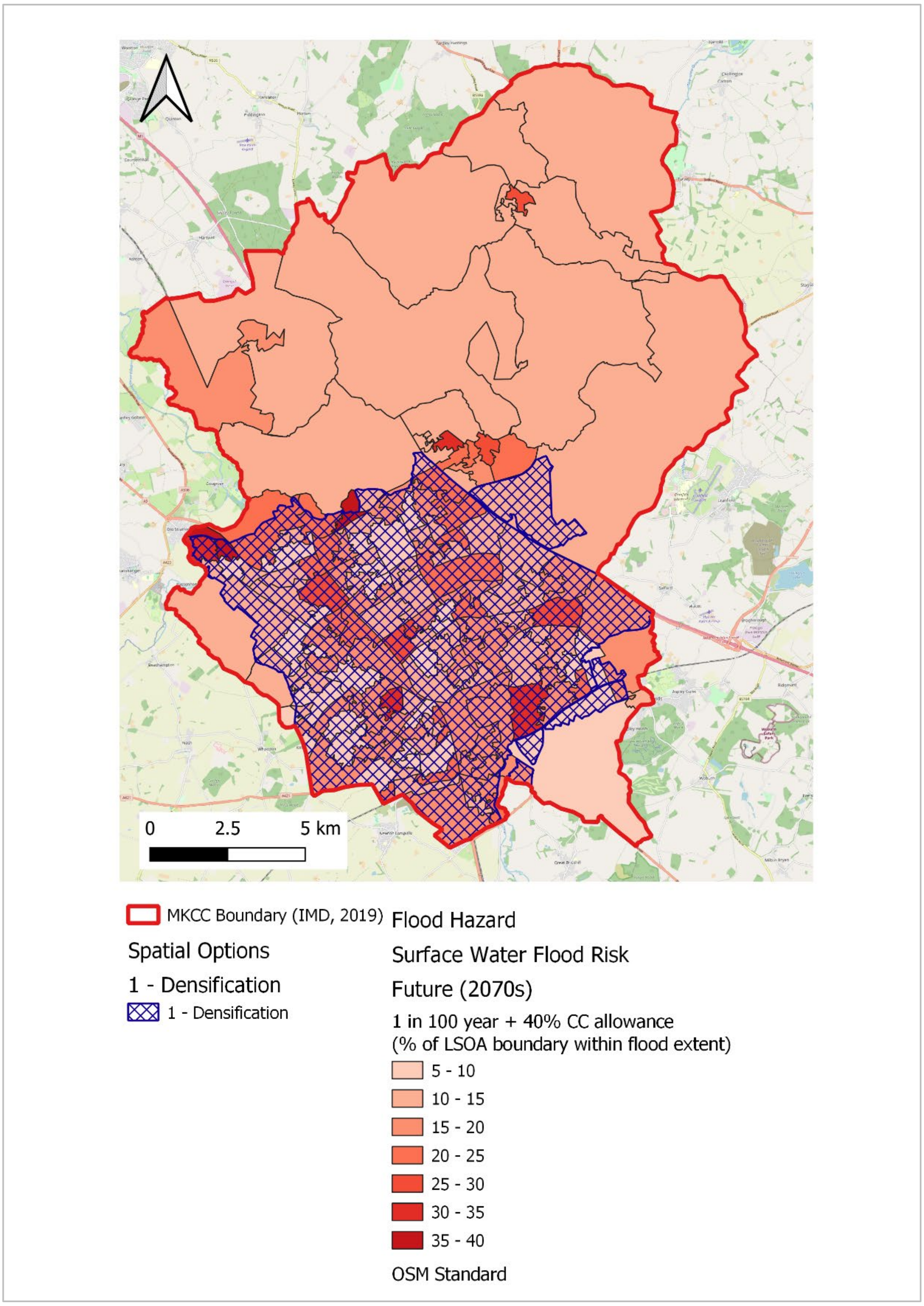

Figure 17: Spatial Option 1 (Densification) and surface water flood risk

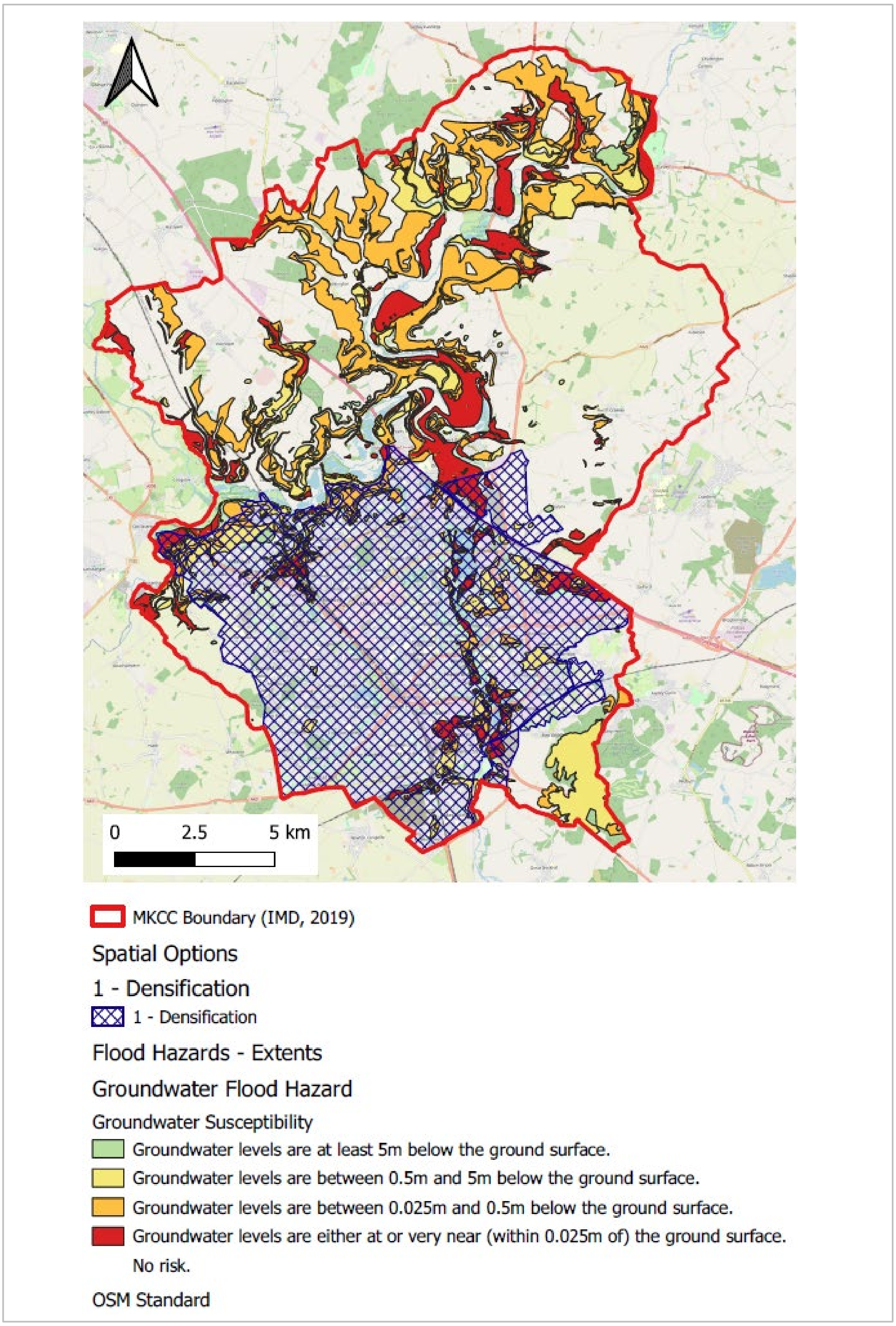

Figure 18: Spatial Option 1 (Densification) and groundwater flood risk.

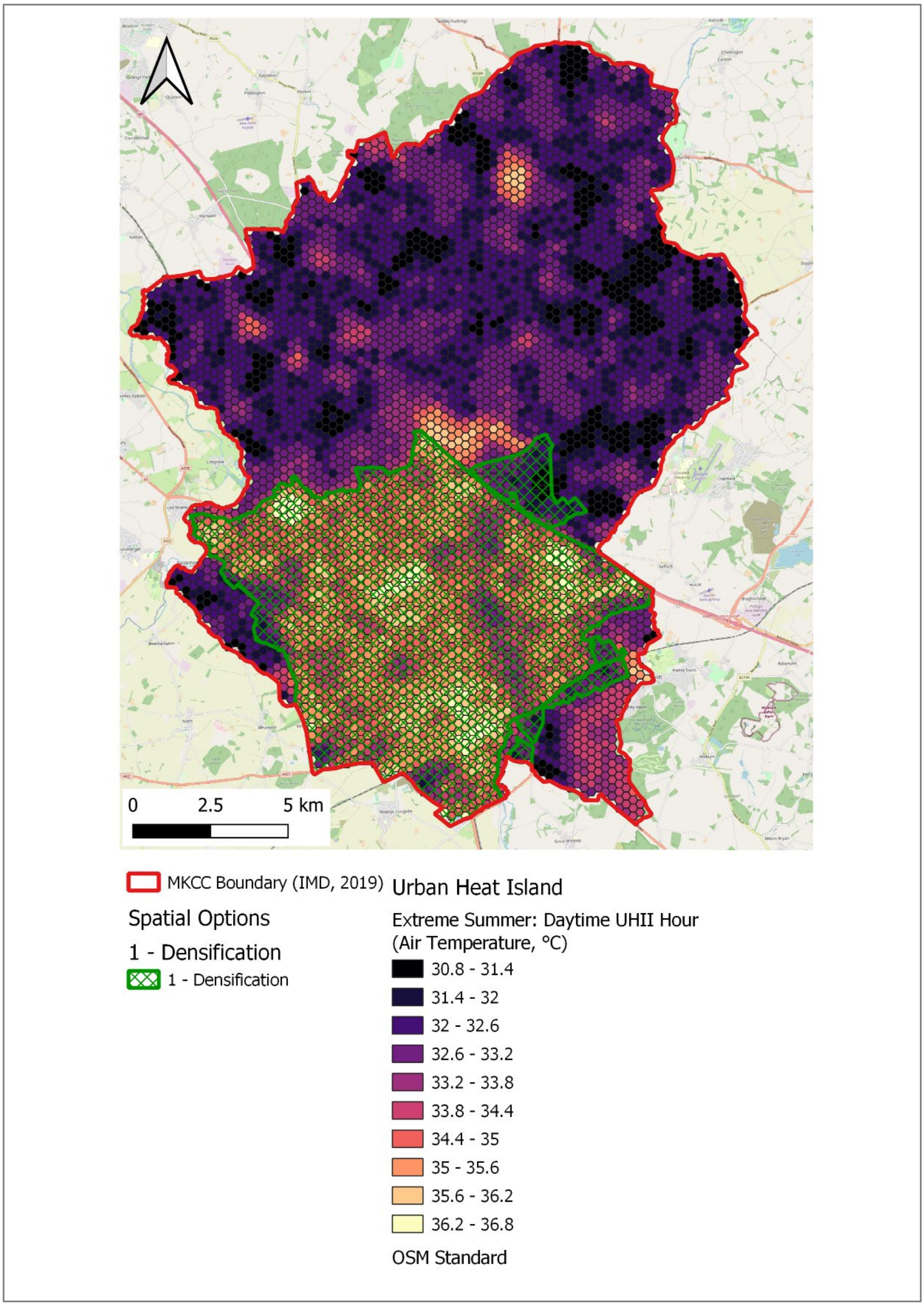

Figure 19: Spatial Option 1 (Densification) and heat risk.

Spatial Option 2: Strategic Urban Extension

The second spatial option represents urban extensions to the urban area of Milton Keynes, and key settlements, such as Olney, as shown in Figure 2. It is worth noting however that the areas considered in this section reflect the recommended growth areas set out in the Strategy for 2050 and may not include all potential growth options that may arise from the Land Availability Assessment (LAA) when it is complete. A full assessment of the sustainability of all sites identified by the LAA will take place within the Sustainability Appraisal later in the plan-making process. The nature of the climate risks associated with these additional sites may, due to different locations, differ from the conclusions presented here.

In terms of **fluvial and reservoir flood risk** presented in Figure 20, most of the sites considered within this spatial option are not within fluvial flood risk extents, across present day and future modelling spatial options. There is some overlap with the fluvial flood extent in the area to the east of Broughton, while there is also only a very small area to the north of the Milton Keynes Coachway Interchange Park that lies within the reservoir flood risk area.

While **surface water flood risk** remains present within the potential development areas (Figure 21), the sites do not cover the LSOAs in Milton Keynes that face the greatest coverage of surface water flood risk. As with all development, there is a risk of increasing local surface water flood risk if not appropriately mitigated. The expected use of greenfield sites for this development option means flood mitigation will be required, taking account of climate change projections. The change in land use associated with new development can increase the impermeable surface, meaning existing surface water flood risk maps do not accurately reflect the future increase in risk associated with development.

The **groundwater susceptibility** varies across the potential sites, as shown in Figure 22. For example, the sites near Olney are at moderate susceptibility of experiencing groundwater flooding affecting surface assets, and those to the east of the M1 are at high susceptibility. Other sites are at low susceptibility, such as the area to the east of the Milton Keynes Coachway Interchange Park, and most of the area covering Lower End and Cross End (e.g. near Moulsoe). Developing on a site that is susceptible to groundwater flooding may make flood mitigation via sustainable drainage systems (SuDS) more challenging. This is discussed in more detail above.

Extending the footprint of the city via an extension could increase the 'urban heat island' effect, meaning new buildings could be more prone to **overheating** than if they were in a more rural setting. Figure 23 shows that the identified sites consistently sit in areas outside/on the periphery of the hotter areas. It is expected this would change if the sites were to be developed with associated change in land use from greenfield to brownfield, as land cover is a driving factor in the urban heat island effect. Given the identified sites are expected to be greenfield, it is expected to be relatively easy to integrate ambitious climate resilient building/infrastructure design criteria, as well as create effective green spaces within the development, to alleviate overheating as well as provide wider benefits such as health, air quality, flood risk mitigation and Biodiversity Net Gain.

It is anticipated new residents associated with this spatial option would rely on a combination of both new and existing infrastructure. The capacity of nearby existing facilities may be increased to accommodate the increased population. Existing or expanded facilities may not have been designed to be resilient to the impacts of climate change, whereas new infrastructure is more likely to be built to a climate resilient standard. There could be potential for retrofitting existing infrastructure, to reduce the associated climate risks.

Given this spatial option looks at currently undeveloped sites, it was not considered useful to refer to existing socio-economic vulnerability in these local areas, from the ‘Vulnerable Neighbourhoods’ section in Section 2.6.

Overall, the sites identified here are at relatively low risk from various types of flooding, and the impacts of extreme heat are expected to be less significant than in Spatial Option 1. Therefore, from a climate risk perspective, the potential development sites covered within Spatial Option 2, pose relatively lower risk than seen in the other three options.

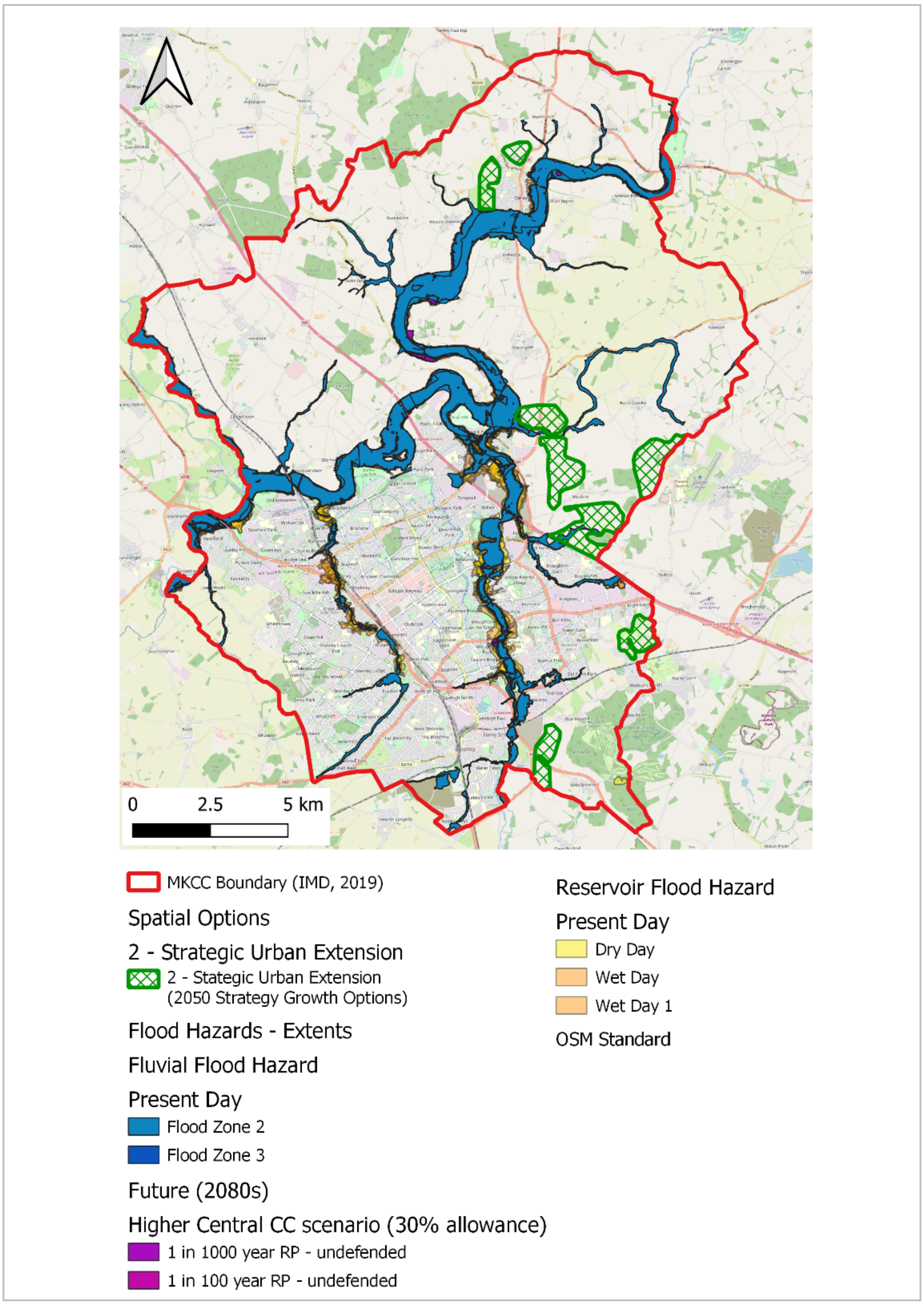

Figure 20: Spatial Option 2 (Strategic Urban Extension) and fluvial and reservoir flood risk.

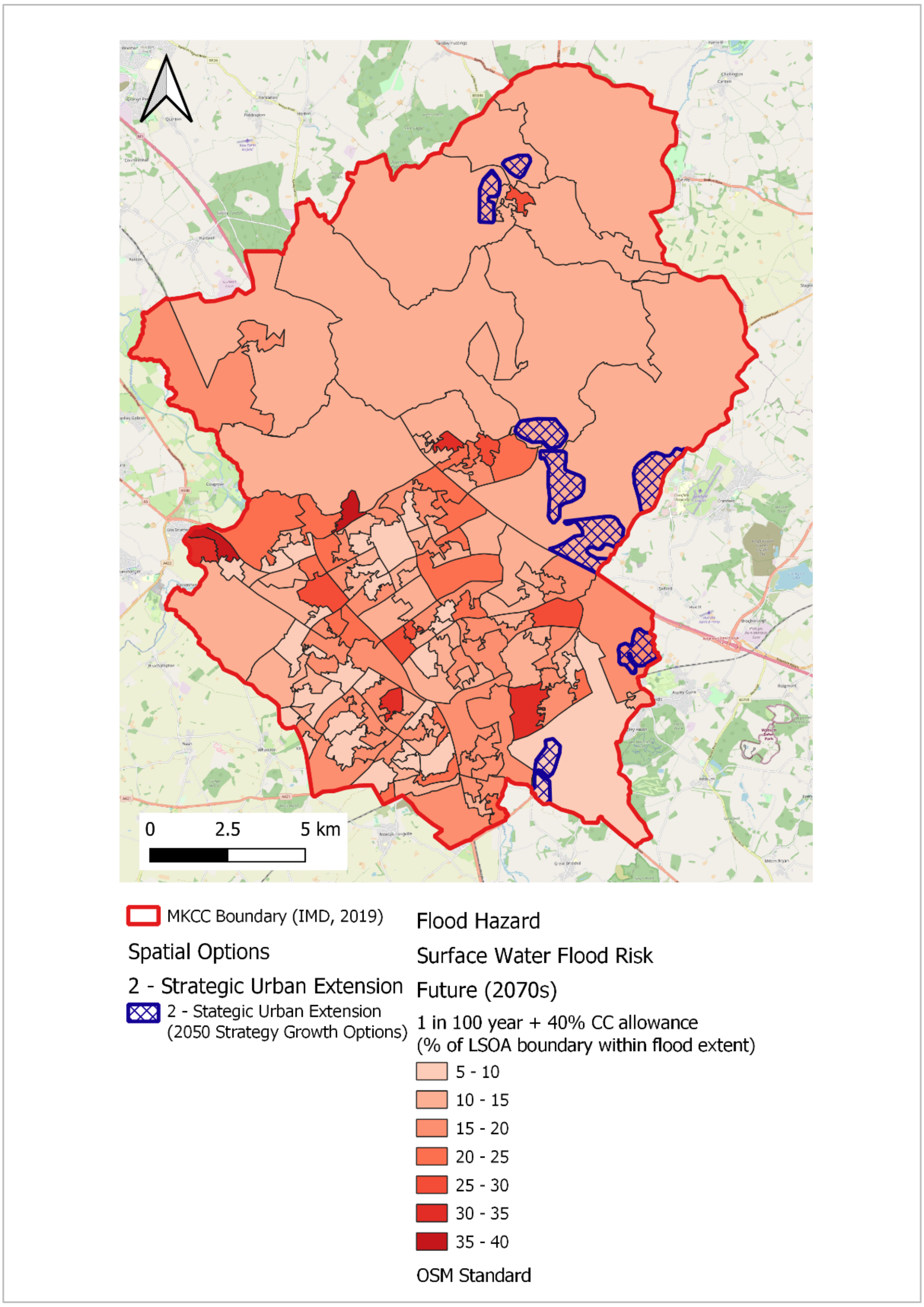

Figure 21: Spatial Option 2 (Strategic Urban Extension) and surface water flood risk

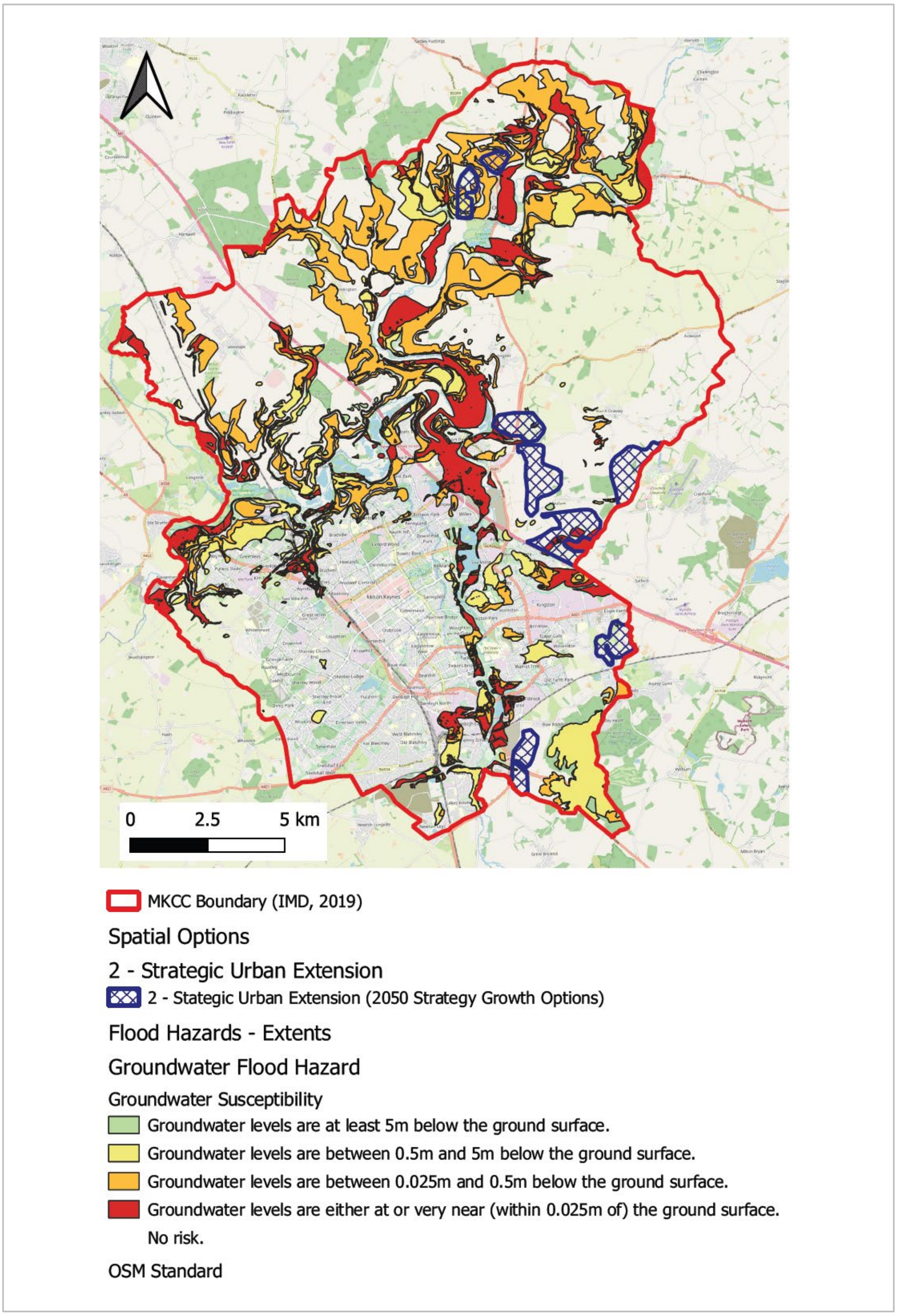

Figure 22: Spatial Option 2 (Strategic Urban Extension) and groundwater flood risk.

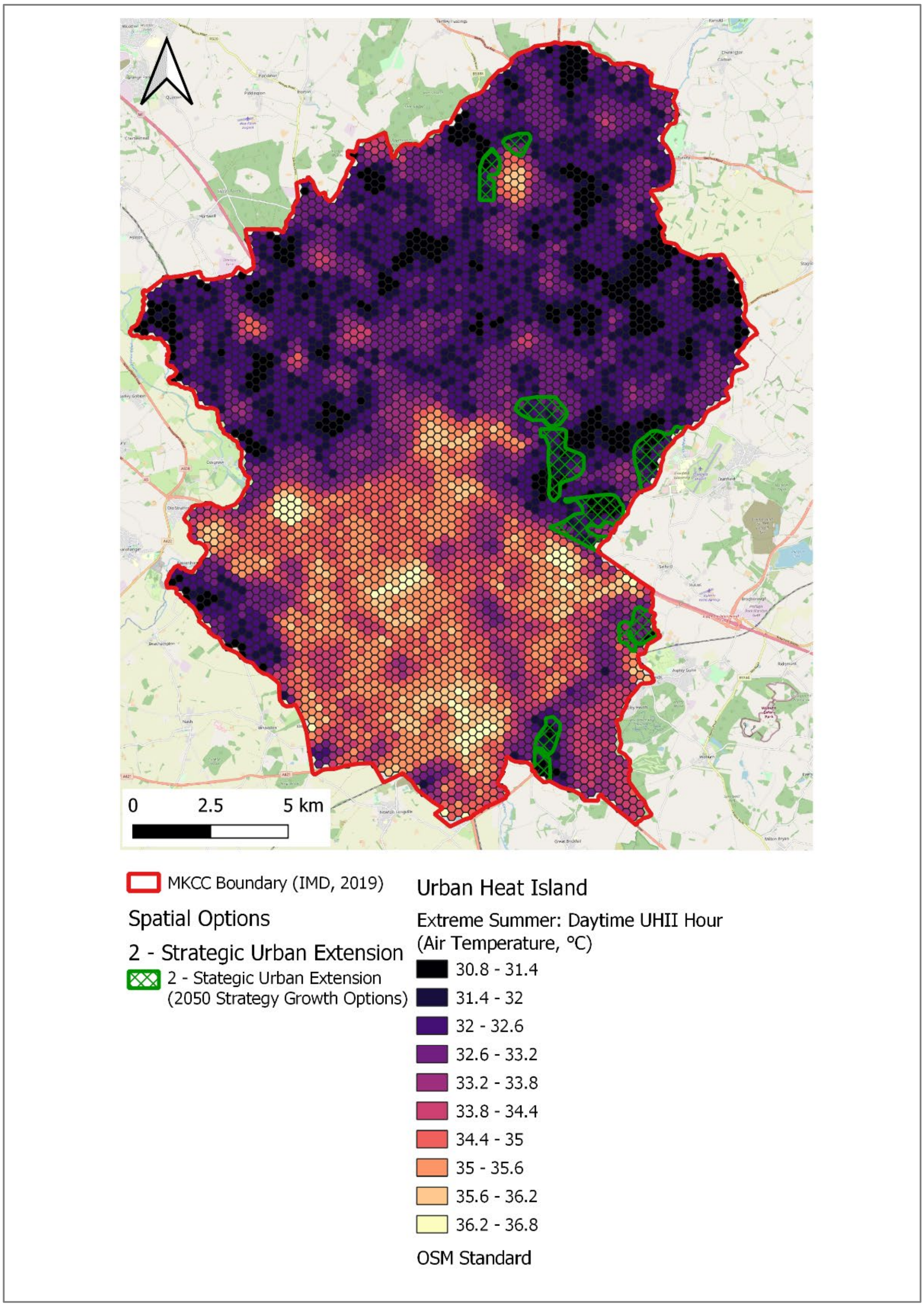

Figure 23: Spatial Option 2 (Strategic Urban Extension) and heat risk.

Spatial Option 3: New Settlement

The third spatial option represents a new settlement within the council boundary. A wide area to the north of Milton Keynes city centre has been identified as a potential location for this new settlement, as shown in Figure 3. It is important to recognise that the nature of the climate risks considered here, in particular the flood risks, are localised and so any changes to the location of the new settlement would require a re-visit of this climate risk assessment.

The **fluvial and reservoir flood risk** is presented in Figure 24. This spatial option includes land that lies in the floodplain for the River Great Ouse near Tyringham and Gayhurst. The same area is also at medium to high susceptibility from **groundwater flooding** (Figure 26), as well as the area near the watercourse by Tathall End, and between Castlethorpe and Hungate End. Developing on a site that is susceptible to groundwater may make flood mitigation via sustainable drainage systems (SuDS) more challenging. As a result, development in these areas is not recommended from a climate risk perspective.

While **surface water flood risk** remains present within the potential development area (Figure 25), this area does not cover the LSOAs in Milton Keynes that face the greatest coverage of surface water flood risk. As with all development, there is a risk of increasing local surface water flood risk if not appropriately mitigated. In addition, this new settlement would bring higher associated new infrastructure requirements than other options, to enable connectivity with the rest of the city and more widely.

This comes with an increase in impermeable area across a wider area than only the settlement itself. The expected use of greenfield sites for this development option means flood mitigation will be required. The change in land use associated with new development can increase the impermeable surface, meaning existing surface water flood risk maps do not accurately reflect the future increase in risk associated with development.

In terms of **extreme heat** impacts, the new settlement band area identified in the maps is relatively far from the existing city centre, where the impacts of any urban heat island effect are greatest (Figure 27). However, the existing towns in the band show relatively higher temperatures than the surrounding countryside. If development were to occur in an area currently shown to be cooler, it is expected this would change if the sites were to be developed with associated change in land use from greenfield to brownfield, as land cover is a driving factor in the urban heat island effect. Given the identified sites are expected to be greenfield, it is expected to be relatively easy to integrate ambitious climate resilient building/infrastructure design criteria, as well as create effective green spaces within the development, to alleviate overheating as well as provide wider benefits such as health, air quality, flood capacity and Biodiversity Net Gain.

Considering opportunities to manage climate risk in the round, this option is more likely to offer opportunities for best-practice, climate resilient building/infrastructure design criteria, such as multifunctional green infrastructure and sustainable drainage systems, compared with other options where development site areas are more constrained, such as Spatial Option 1 (densification within the city centre).

As with Spatial Option 2, it is anticipated new residents associated with this spatial option would rely on a combination of both new and existing infrastructure. The capacity of nearby existing facilities may be increased to accommodate the increased population. Existing or expanded facilities may not have been designed to be resilient to the impacts of climate change, whereas new infrastructure is more likely to be built to a climate resilient standard. There could be potential for retrofitting existing infrastructure, to reduce the associated climate risks.

Given this spatial option creates a new settlement, it was not considered useful to refer to existing socio-economic vulnerability in these local areas, from the 'Vulnerable Neighbourhoods' in Section 2.6.

Overall, this spatial option includes some key areas - Tyringham and Gayhurst - that may be best to avoid, based on the high present and future risk from flooding and limited options for mitigation using green infrastructure solutions. There are some areas in the east of the identified area that are at lower risk from flooding, and so may be a more suitable location for a new settlement when considering climate impacts.

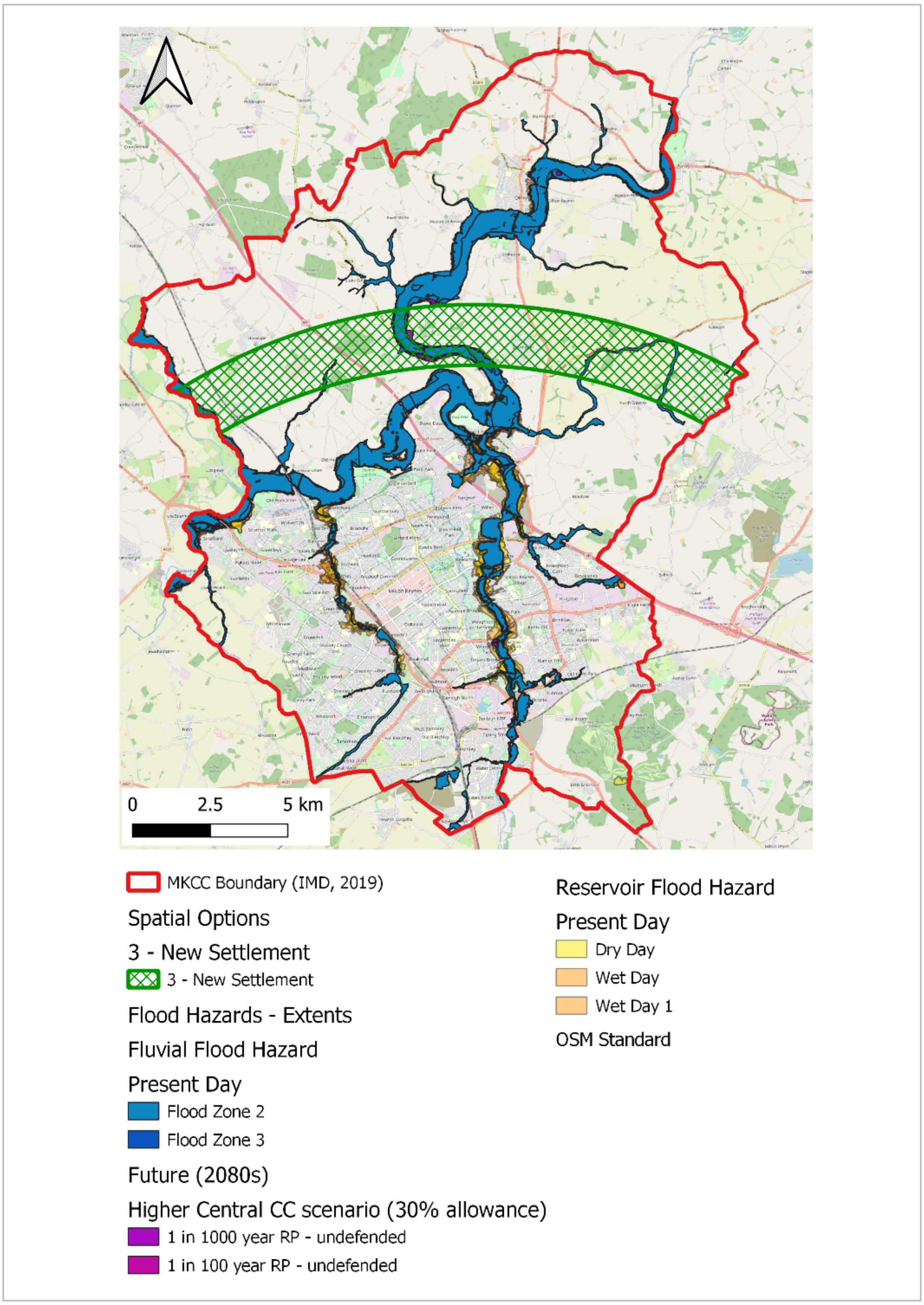

Figure 24: Spatial Option 3 (New Settlement) and fluvial and reservoir flood risk.

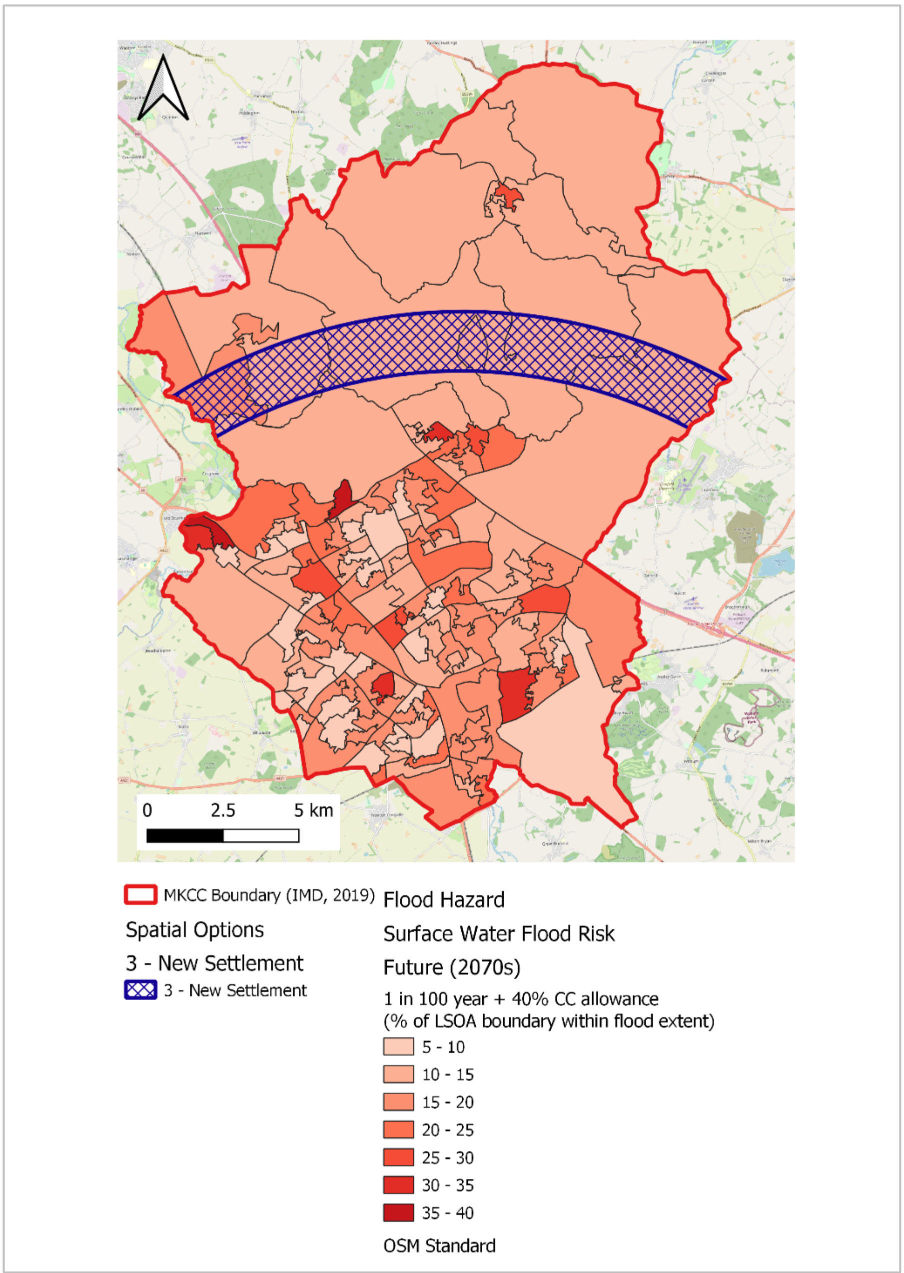

Figure 25: Spatial Option 3 (New Settlement) and surface water flood risk.

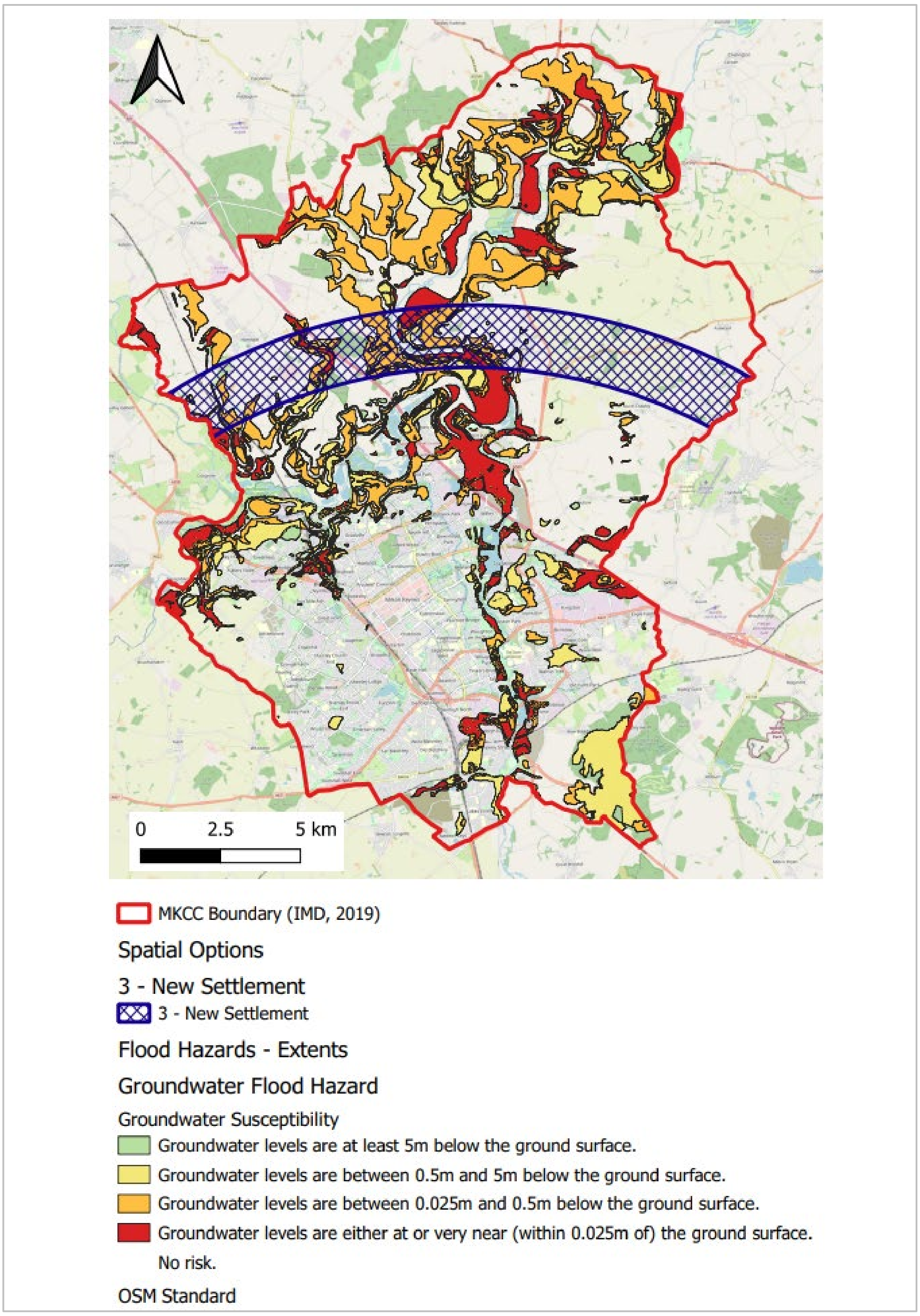

Figure 26: Spatial Option 3 (New Settlement) and groundwater flood risk.

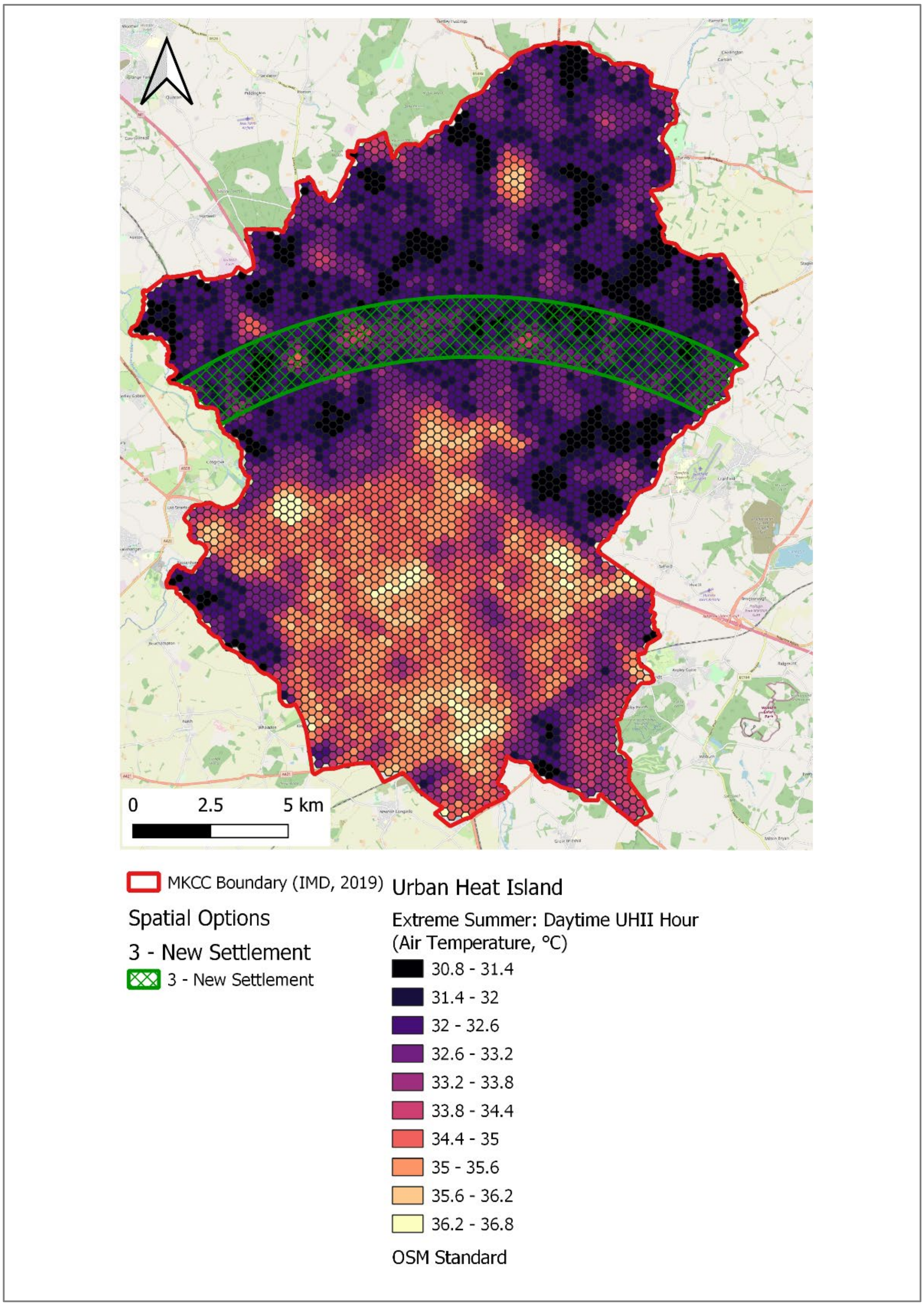

Figure 27: Spatial Option 3 (New Settlement) and heat risk.

Spatial Option 4: Rural approach

The fourth spatial option represents an increase in development across Milton Keynes' rural areas, linked with existing rural settlements, as shown in Figure 4.

Figure 28 shows that there are several potential development areas at risk from **fluvial and reservoir flooding**. These are the areas that lie in the floodplain for the River Great Ouse; Newport Pagnell is particularly at-risk, as well as Lavendon, Ravenstone and Stoke Goldington. This spatial option also includes potential rural areas for development not shown to be at-risk from fluvial flooding, such as Hanslope and Castlethorpe in the north-west of the city, and Sherington, North Crawley and Astwood in the east.

Groundwater flood risk (Figure 29) follows a broadly similar spatial distribution to present-day fluvial flood risk, linked to the influence of the river on nearby superficial geology of alluvium and river gravels. Newport Pagnell, Olney and Lavendon are shown to lie in areas at highest risk from groundwater flooding. Developing on a site that is susceptible to groundwater may make flood mitigation via sustainable drainage systems (SuDS) more challenging. Conversely, the village of Astwood is particularly far removed from areas identified to be at some degree of groundwater risk.

As with all development, there is a risk of increasing local surface water flood risk if not appropriately mitigated. Areas included in the spatial option at elevated risk of **surface water flooding** regardless of further development, are Newport Pagnell and Olney. The expected use of greenfield sites for this development option means flood mitigation will be required, taking account of climate change projections. The change in land use associated with new development can increase the impermeable surface, meaning existing surface water flood risk maps do not accurately reflect the future increase in risk associated with development.

The risk of **overheating** during hotter temperatures is anticipated to be lowest for some sites associated with this option, and the option least likely to increase the 'urban heat island' effect within Central Milton Keynes. Figure 31 shows that some proposed areas for development are at elevated risk of overheating associated with existing development and land use, such as Newport Pagnell and Olney, showing relatively higher temperatures than the surrounding countryside. If development were to occur in an area currently shown to be cooler, it is expected this would change if the sites were to be developed with associated change in land use from greenfield to brownfield, as land cover is a driving factor in the urban heat island effect. Given the identified sites are expected to be greenfield, it is expected to be relatively easy to integrate ambitious climate resilient building/infrastructure design criteria, as well as create effective green spaces within the development, to alleviate overheating as well as provide wider benefits such as health, air quality, flood capacity and Biodiversity Net Gain.

It is anticipated new residents associated with this spatial option would rely on a combination of both new and existing infrastructure. The capacity of nearby existing facilities may be increased to accommodate the increased population. Existing or expanded facilities may not have been designed to be resilient to the impacts of climate change, whereas new infrastructure is more likely to be built to a climate resilient standard. There could be potential for retrofitting existing infrastructure, to reduce the associated climate risks.

When considering how the rural areas identified in this spatial option align with socio-economic vulnerability data presented in the 'Vulnerable Neighbourhoods' section in Section 2.6, the areas are broadly located in the LSOAs with relatively low levels of deprivation. The identified villages with the highest levels of deprivation across all identified areas for development in this spatial option, are those in the east (Sherington, North Crawley and Astwood), which are located in an LSOA in the middle (fifth) decile for deprivation.

This is a stark contrast to Option 1, where many areas were in the highest two deprivation deciles. Adopting this spatial option, and therefore developing less deprived areas may be a missed opportunity to improve local community resilience to climate hazard events and reduce vulnerability. This could lead to greater polarisation in socio-economic vulnerability across the city, making the relative risk to vulnerable populations, such as those in the city centre, even higher.

However, encouraging new residents into rural areas may help re-balance local demographic profiles in villages with an aging population, which could help community response and resilience during climate hazard events.

Overall, this option identifies several rural areas across Milton Keynes for development. Areas of elevated risk of flooding should be avoided, whereas areas with the lowest flood risk could be developed with the right mitigation and subject to other constraints.

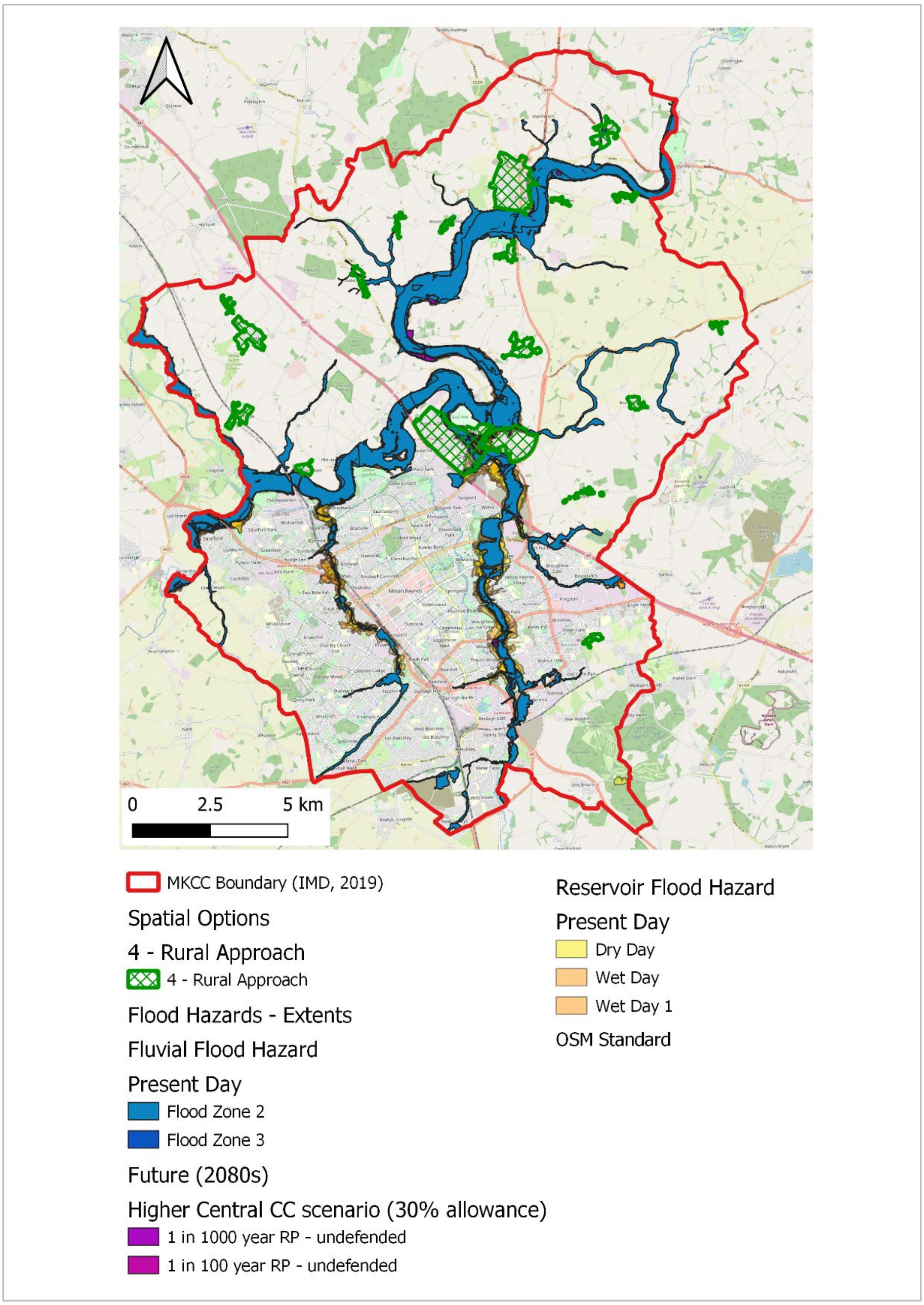

Figure 28: Spatial Option 4 (Rural approach) and fluvial and reservoir flood risk.

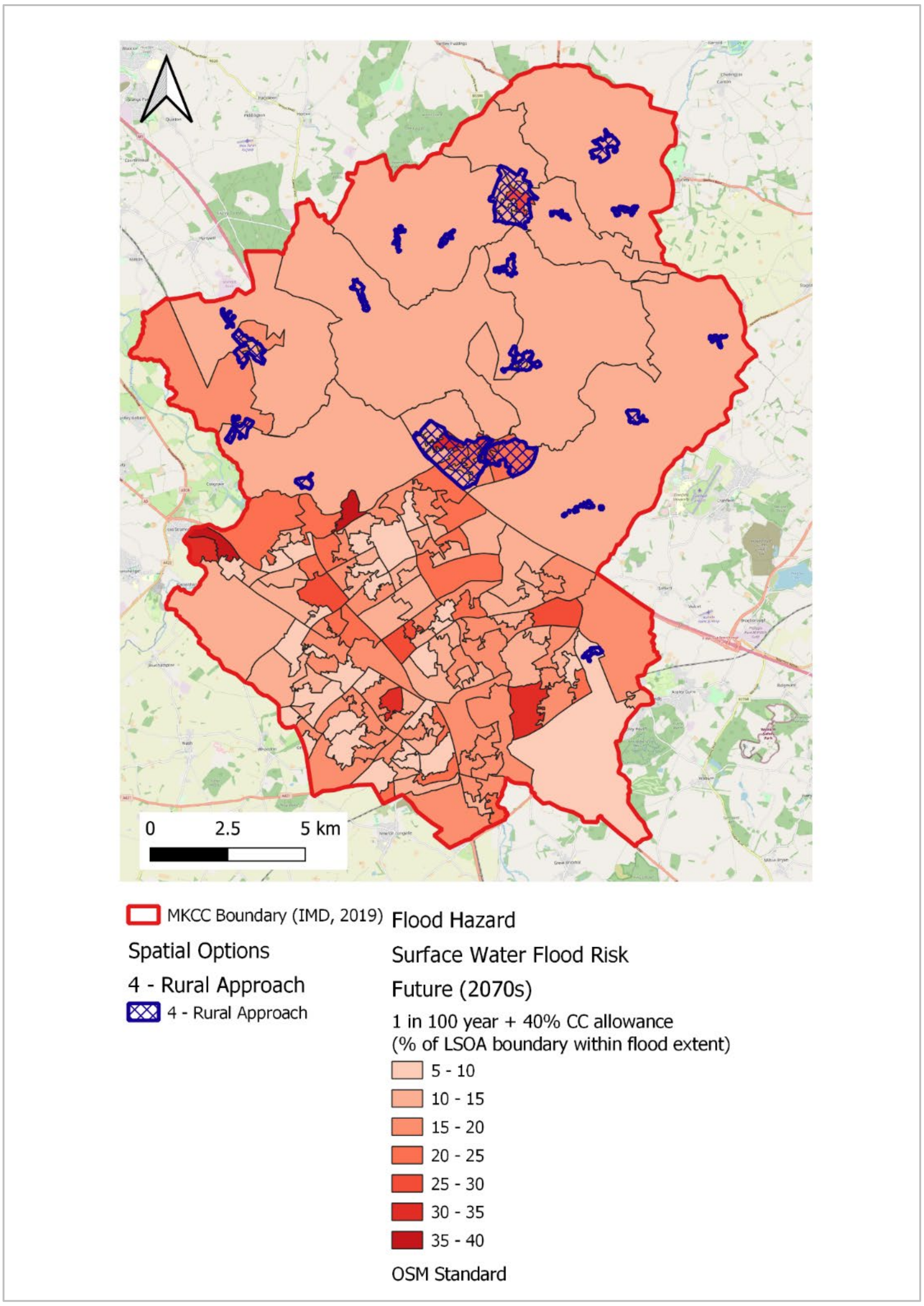

Figure 29: Spatial Option 4 (Rural approach) and surface water flood risk

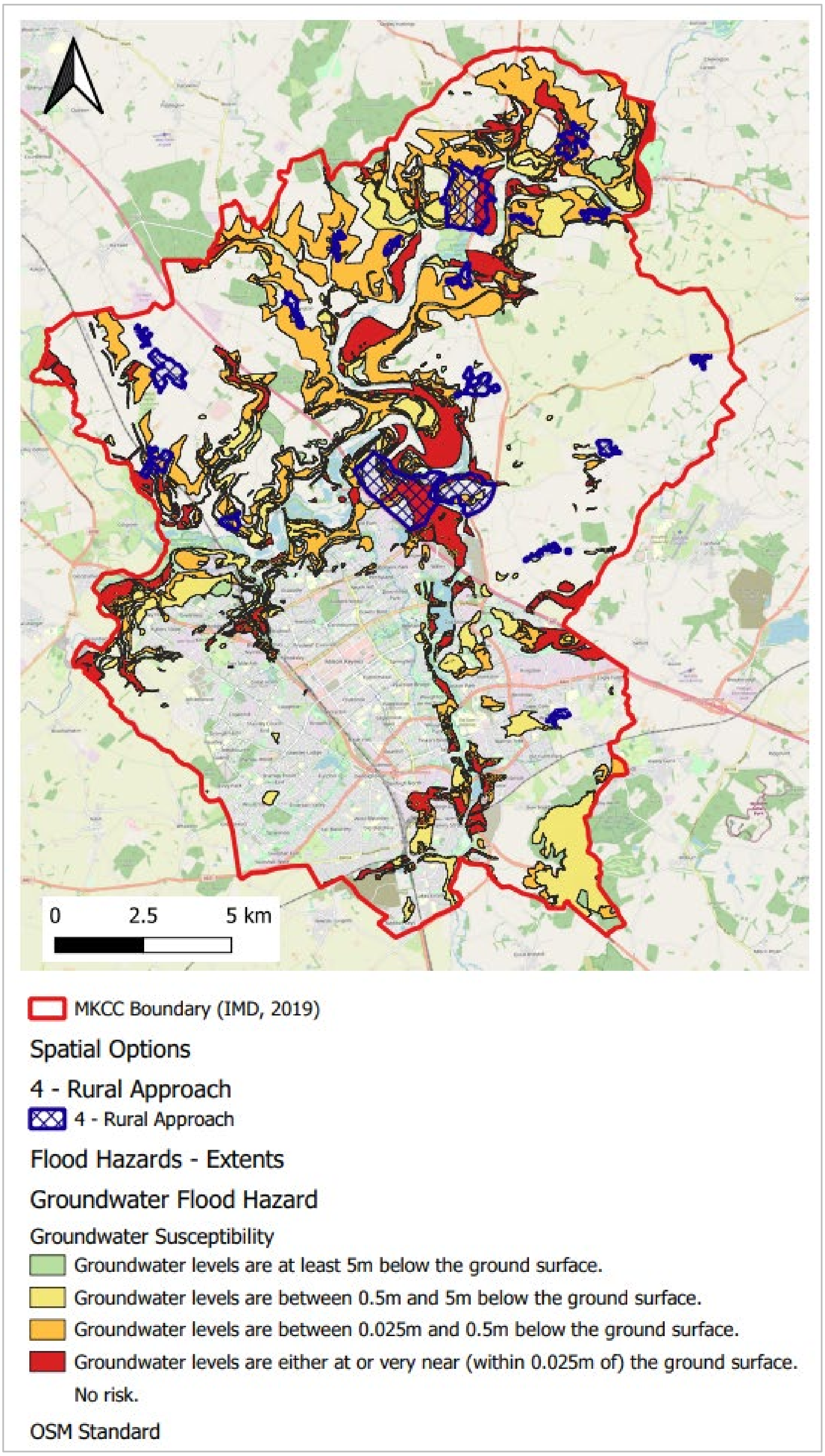

Figure 30: Spatial Option 4 (Rural approach) and groundwater flood risk.

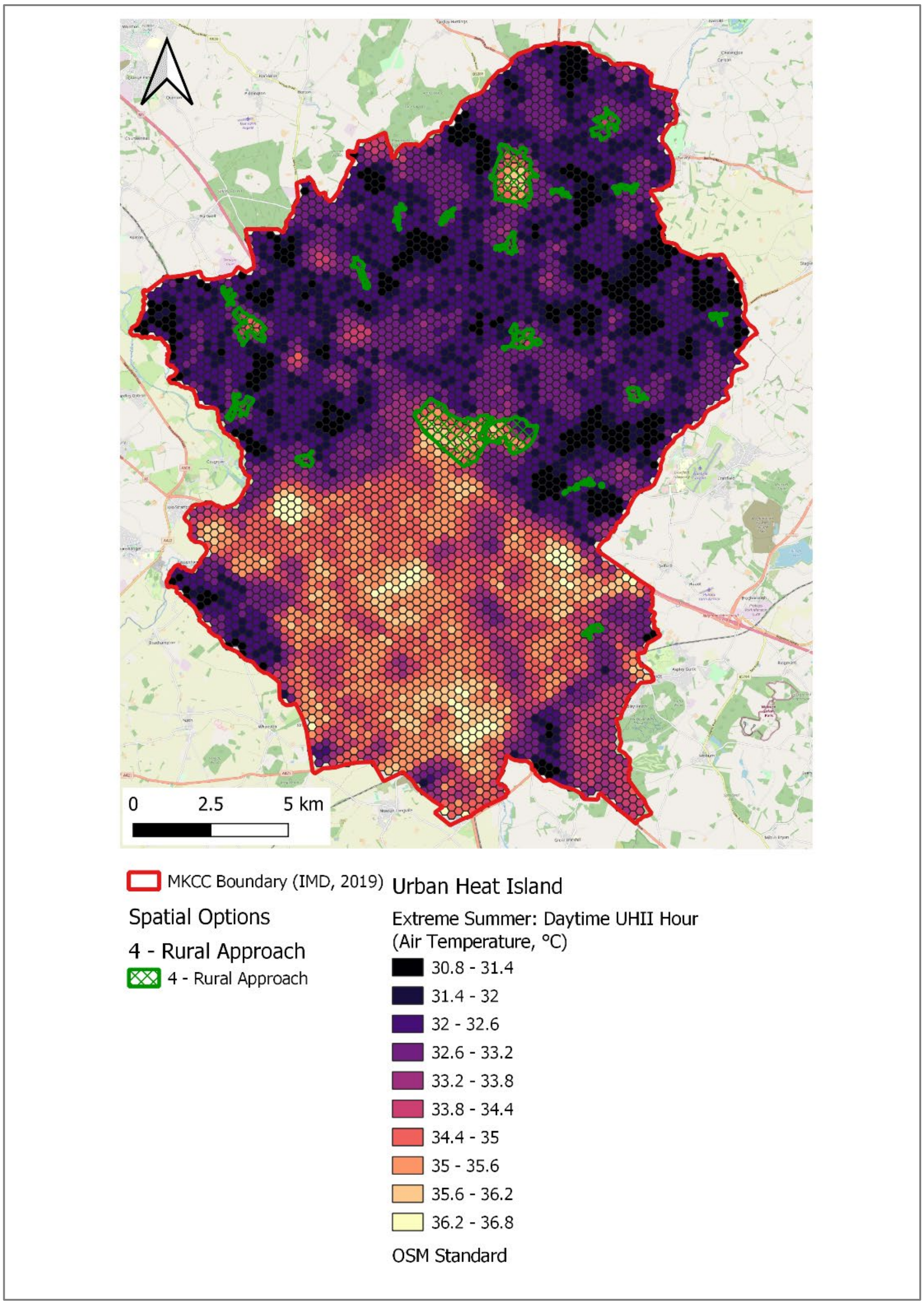

Figure 31: Spatial Option 4 (Rural approach) and heat risk.

2.5.3 Conclusion

This chapter has aimed to summarise the interlinkages between new development and the potential impacts of climate change and extreme weather events. It is crucial that future development associated with the New City Plan addresses the climate risks identified in this section, across:

1. The adverse climate risk of and to new development - regardless of the chosen spatial option; and
2. The climate risks associated with the chosen spatial option (summarised in Table 8 below).

Table 8 summarises the findings of the climate risk assessment for each spatial option, focussing on geographic areas within the option boundaries to either prioritise or avoid, based on their climate risk profiles. This analysis should be combined with the option-agnostic climate risks identified earlier, to inform the upcoming policy recommendations.

Table 8: Summary of climate risk assessment for the spatial options.

Spatial Option	Summary of areas to prioritise/avoid
1: Densification	There are some areas within this spatial option that may be helpful to avoid, based on the high risk from flooding. These are the areas in the floodplain for the River Ouzel, along the right bank of the River Great Ouse, and along the Loughton valley in the centre-west of the spatial option area as well as the LSOAs at greatest risk from surface water flooding (near Caldecotte, Stony Stratford and Furzton). In addition, the urban heat island effect is felt most acutely in Wolverton, and as such it may be beneficial to avoid development in this neighbourhood. In general, densification is known to increase UHI, due to the increase in building volumes.
2: Strategic Urban Extension	The sites identified here are at relatively low risk from various types of flooding, and the impacts of extreme heat are expected to be less significant than in Option 1. Therefore, from a climate risk perspective, the potential development sites covered within Option 2 pose relatively lower risk than seen in the other three options.
3: New Settlement	Tyringham and Gayhurst may be best to avoid, based on the high risk from flooding. There are some areas in the east of the identified area that are at lower risk from flooding, and so may be a more suitable location for a new settlement when considering climate impacts. As with Option 2, the impacts of extreme heat are expected to be less significant than in option 1.
4: Rural Approach	The areas near Newport Pagnell, and some parts of Olney, may be best avoided to reduce the flood-related climate risks to new development. Villages such as Sherington, North Crawley and Astwood in the west of the city may be more suitable to develop, based on the low risk of fluvial and groundwater flooding.

2.6 Vulnerable Neighbourhoods

This section considers how vulnerability varies across Milton Keynes with respect to climate hazards. In line with the International Organisation for Standardization (ISO) 14091:2021[6], vulnerability is defined here as "[the] propensity or predisposition to be adversely affected [by an adverse hazard – such as a climate hazard]. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.".

Given the context of this work in relation to MKCC's New City Plan, we consider the neighbourhood vulnerability of residents, as well as the built and natural environments. The New City Plan has great potential to address these vulnerabilities. For example, neighbourhood-scale interventions can be targeted at the most-deprived areas of the city, to improve human vulnerability. Policies for new employment uses and buildings can support the local economy, indirectly increasing the capacity of local people to respond to climate change hazards. Therefore, this section aims to identify the areas, facilities or assets that are most vulnerable, to help inform targeted intervention or prioritisation within the Plan.

Firstly, the vulnerability of critical transport and social infrastructure (such as schools and medical/care facilities) will be considered. These assets were chosen as the focus for this study, as they are considered to be particularly important influencing factors of local communities' vulnerability.

To achieve a complete review of infrastructure vulnerability, it is important to consider contributing factors, such as age, construction materials, asset condition/maintenance, and building typologies (presence of basements, etc.). The data review identified a gap in widespread coverage of information about these factors within geospatial data, and this type of analysis was not included in this scope of work.

As a result, this study considers the vulnerability of physical transport and social infrastructure in terms of only their geographical location – or exposure – to climate hazards. Further investigation of exposed assets would be advised in order to inform adaptation interventions.

[6] ISO (2021) *14091 Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment*. Accessible here: https://www.iso.org/standard/68508.html

Regarding climate hazards, this assessment considers the risk of fluvial flooding to transport infrastructure, and risks of fluvial and groundwater flooding for social infrastructure, given that buildings may have basements, making them particularly vulnerable to groundwater flooding.

The scope of climate hazards is influenced by those that have significant potential to cause health and safety impacts to local communities, as well as dictated by the availability of climate hazard spatial data, which is further discussed in the 'climate risk' section of the *Climate and Carbon Study – Spatial Growth Options Analysis*[7].

The vulnerability of residents is considered primarily in terms of socio-economic deprivation, making use of the Index of Multiple Deprivation 2019 data, published by the Ministry of Housing, Communities and Local Government (now Department for Levelling Up Communities and Local Government). This considers a wide range of deprivation indices, including health, education and income. In the context of climate risk, human vulnerability is a crucial key contributor as it influences the type and magnitude of impacts sustained from a given climate hazard.

More vulnerable populations are more significantly affected by climate hazards, as they may have reduced ability to react, respond and recover. To understand these links, fluvial and groundwater flood risk mapping is also overlaid on the socio-economic deprivation data, to identify 'risk' hotspots. Surface water flood risk has also been considered, referring to the data presented in the 'climate risk' section of the *Climate and Carbon Study – Spatial Growth Options Analysis*[8]. Analysis using the UHeat Urban Heat Island modelling results is also included, to understand if there are overlapping areas at risk from overheating and with high levels of deprivation.

2.6.1 Vulnerability of critical transport and social infrastructure

To consider the vulnerability of critical infrastructure and assets within Milton Keynes, we have mapped a range of geospatial asset data against modelled flood extent data within a Geospatial Information System (GIS). Some examples of these maps are presented in Figure 32 to Figure 34. Within the New City Plan, it is important to consider the vulnerability of both new infrastructure and existing assets such as those mapped here, which are likely to become more critical with the anticipated growth in the city's local population.

Figure 32 presents the present and future fluvial flood risk to key transport in Milton Keynes, including railway infrastructure and key roads such as those on local bus routes. The maps show a couple of overlapping areas between the flood extents and the railway routes (near Fenny Stratford in the south of the city, and Wolverton in the west), indicating a potential for fluvial flooding to disrupt rail journeys into and out of central Milton Keynes.

The road network is also exposed to fluvial flooding; this is particularly acute in Newport Pagnell, where there are no or few alternative routes outside of the area at risk of flooding. Milton Keynes Coachway (near J14 of the M1) is also very exposed to fluvial flooding, with much of the area in Flood Zone 3, with flooding expected in a 1 in 100 year event.

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[7] Arup (2023) *Milton Keynes City Council: Climate and Carbon Study - Spatial Growth Options Analysis*.

[8] Arup (2023) *Milton Keynes City Council: Climate and Carbon Study - Spatial Growth Options Analysis*.

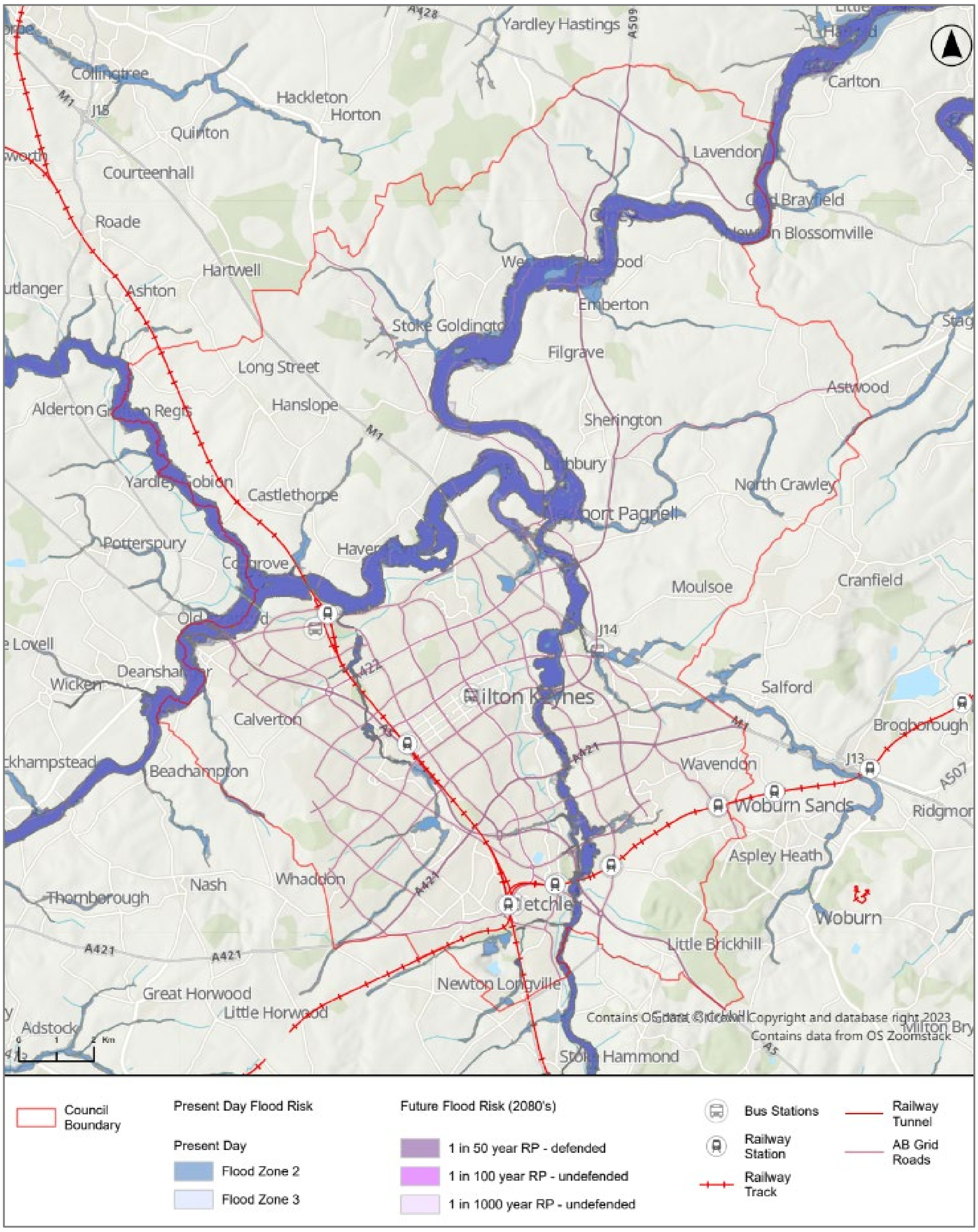


Figure 32: Fluvial flood risk to transport in Milton Keynes.

Figure 33 and Figure 34 present the spatial distribution of education and medical (care and residential homes) facilities across the city, and if and where they are exposed to fluvial and groundwater flooding respectively.

These maps demonstrate that some facilities are located in at-risk areas, however the relative number of exposed facilities across the city is low. For example, Figure 33 shows that Parklands Nursing Home in Woolstone lies close to the River Ouzel floodplain. The nursing home is also in a groundwater risk zone, where there is a risk of flooding to subsurface assets but surface manifestation of groundwater is unlikely (Figure 34).

Burlington Hall in Woburn Sands is also at risk from groundwater flooding to both surface and subsurface assets. No other care and residential homes presented on the map are shown to be at risk from fluvial or groundwater flooding.

The concentration of education facilities shown near Walton Hall represent the Open University. Some of these buildings lie within the floodplain of the River Ouzel. The buildings associated with two primary schools in Newport Pagnell, Brooklands Farm Primary School and Cedars Primary School, are shown to sit just outside River Great Ouse's floodplain, across the present day and future scenarios – however some of their grounds or playgrounds may be at-risk.

Figure 34 shows there are some schools in Milton Keynes that lie in the highest groundwater risk zone, where there is a risk of flooding to both surface and subsurface assets, and groundwater may emerge at significant rates and has the capacity to flow overland and/or pond within any topographic low spots.

These include Brooklands Farm Primary School, Cedars Primary School and Tickford Park Primary School in Newport Pagnell, and St Mary and St Giles Church of England Junior School in Stony Stratford. These schools are particularly vulnerable if they have basements, especially if important assets, such as the plant room, are located underground. This could lead to power outages and school closures – with associated disruptive impacts on families.

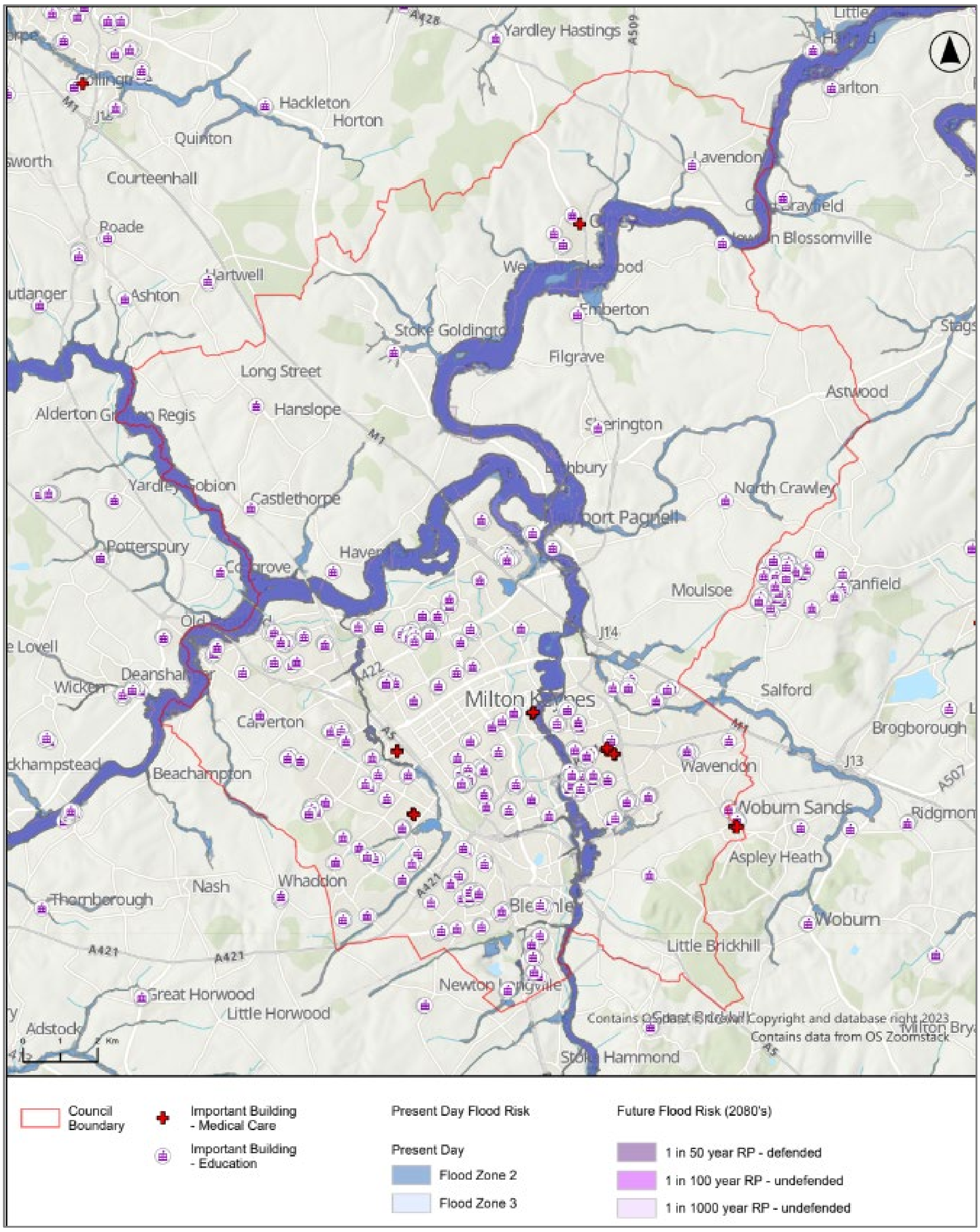


Figure 33: Fluvial flood risk to education and health facilities in Milton Keynes.

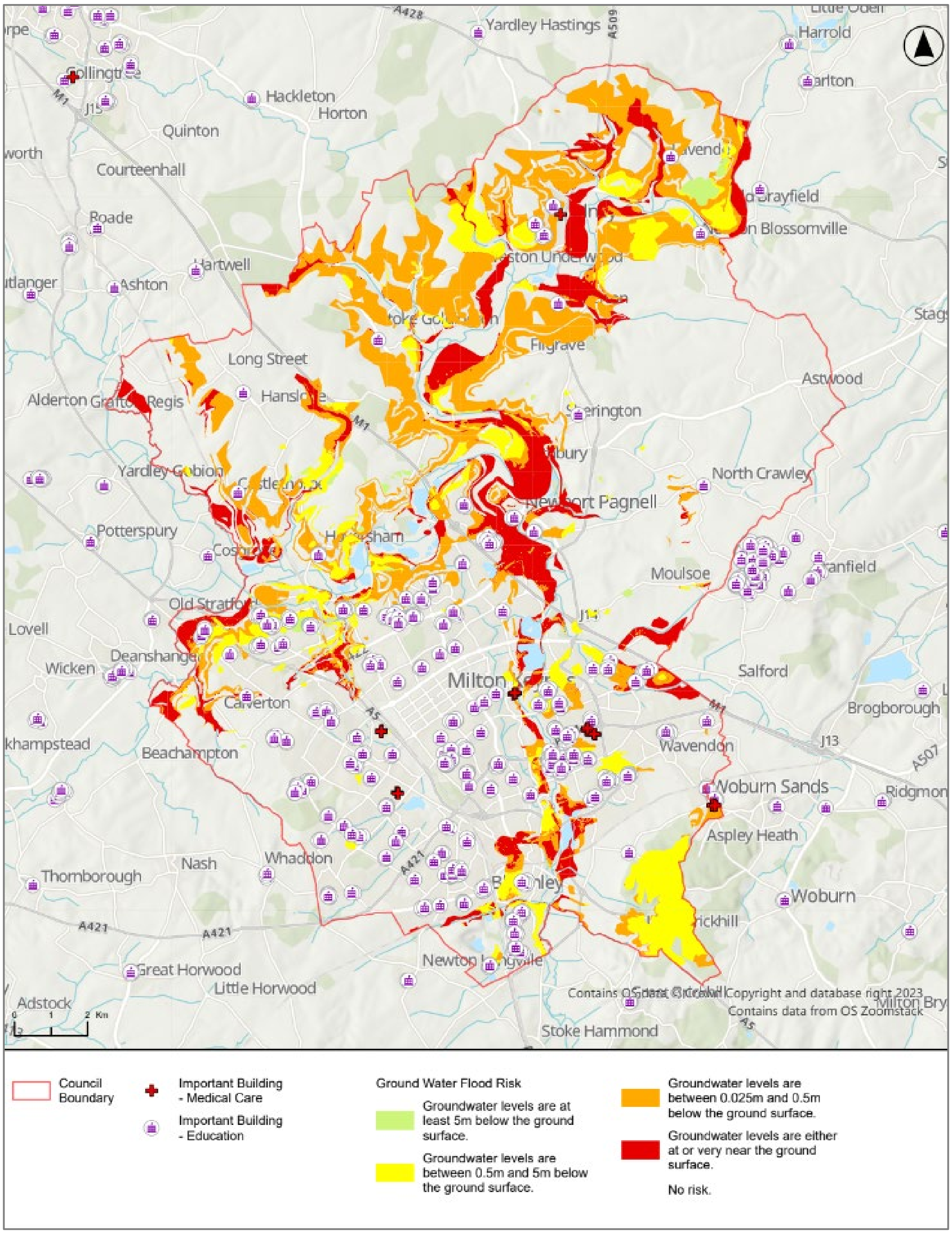


Figure 34: Groundwater flood risk to education and health facilities in Milton Keynes.

2.6.2 Socio-economic vulnerability

The Index of Multiple Deprivation (IMD) 2019 results provide a ranking of deprivation of all 32,844 Lower layer Super Output Areas (LSOAs) in England, which have an average population of 1,500. These are grouped into deciles, ranging from 1 (most deprived 10% of areas in England) to 10 (least deprived 10% of areas).

The decile results for Milton Keynes are presented in Figure 35. There is wide range in the levels of deprivation across the local authority area. Broadly, the areas with higher areas of deprivation are located in the city centre and the south of the city, as well as a pocket to the west.

Areas identified at levels of most acute deprivation are near Central Milton Keynes (Bleak Hall, Redmoor, Beanhill, Netherfield and Ashland), South Bletchley (around the Lakes Estate) and Fullers Slade near Stony Stratford. Residents in more rural areas in the city are generally shown to be at lower levels of deprivation, including the areas north of Olney and near Hanslope.

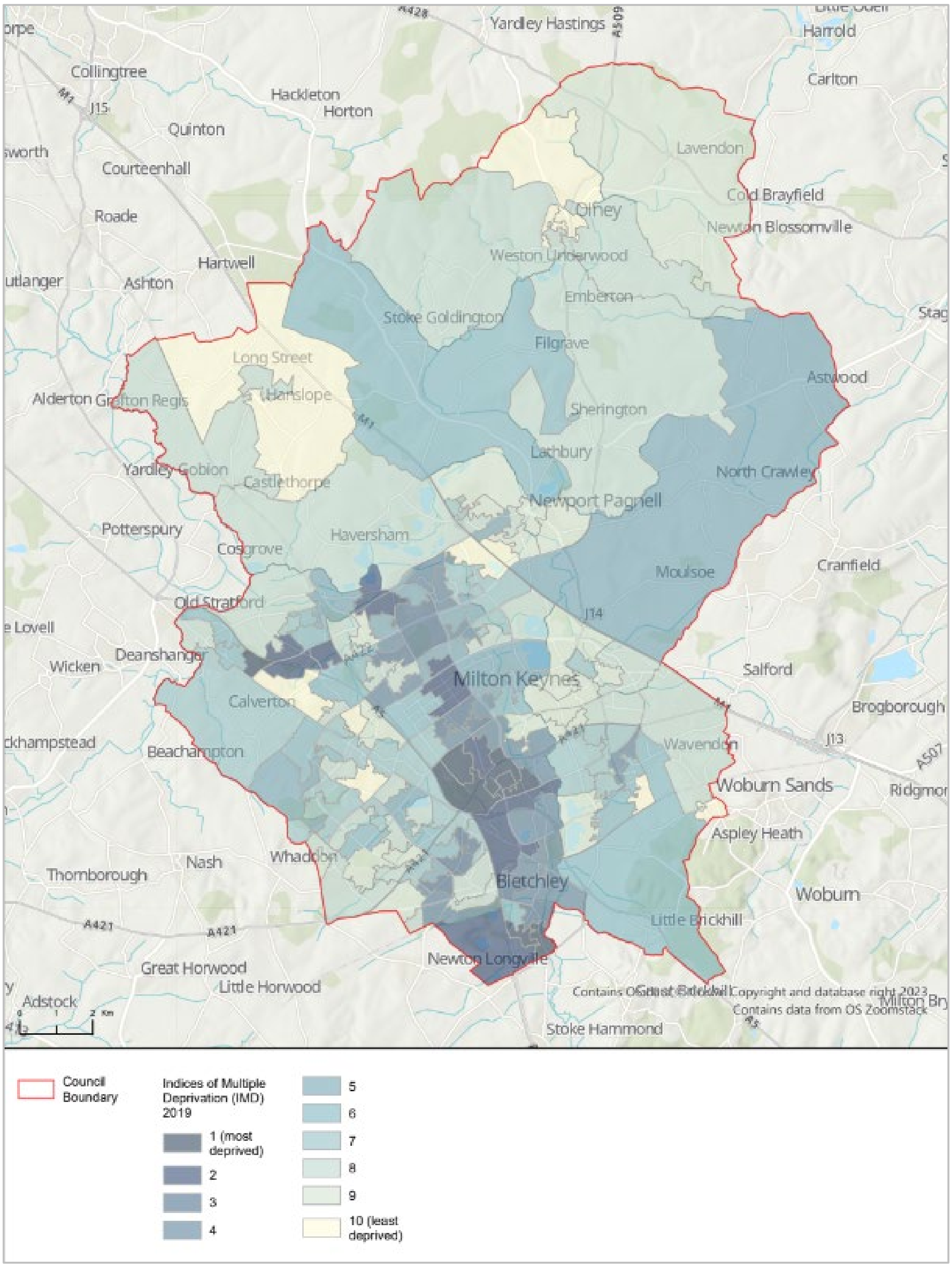


Figure 35: Index of Multiple Deprivation 2019 results, grouped by deprivation decile.

When considering the contribution of socio-economic vulnerability to how the impacts of climate change are experienced across the city, it can be useful to map the vulnerability data alongside data associated with climate hazards. Examples of this are provided in Figure 36 and Figure 37, that demonstrate the intersection of the deprivation data presented in with fluvial and groundwater flood risks, respectively. More information on the data presented here is provided in the climate risk section of the Spatial Options Analysis (Section 2.5). Both maps indicate that areas of greatest socio-economic deprivation broadly do not align with the areas at greatest exposure to these flood risks. There are some pockets of overlap, such as around Bletchley.

With respect to surface water flooding, the relative exposure map presented in Figure 17 (Spatial Option 1 Surface water flooding) in Section 2.5 of this Report on climate risk, which can be cross-compared with the IMD data presented at the same scale in Figure 35. As seen for fluvial and groundwater flooding, the LSOAs with greatest exposure to surface water flooding broadly do not correspond to the most socio-economically deprived areas, although New Bradwell is one particular area with elevated risk.

These are useful findings, as it allows more targeted flood interventions in those few areas that are both greatly exposed to the hazard and that have vulnerable communities with an assumed lower capacity to cope (based on the data. E.g. around Bletchley and New Bradwell).

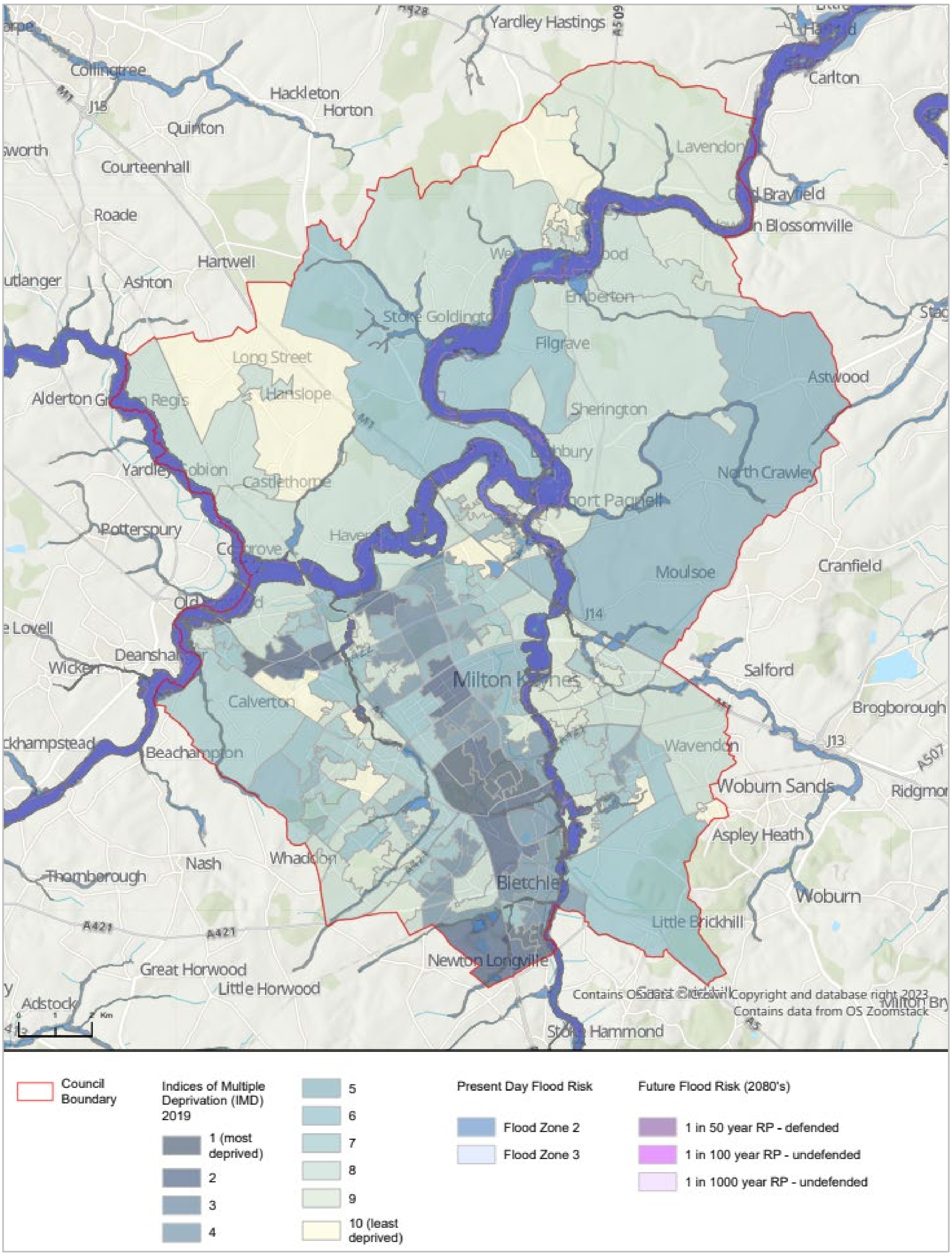


Figure 36: Intersection of socio-economic deprivation and fluvial flood risk data.

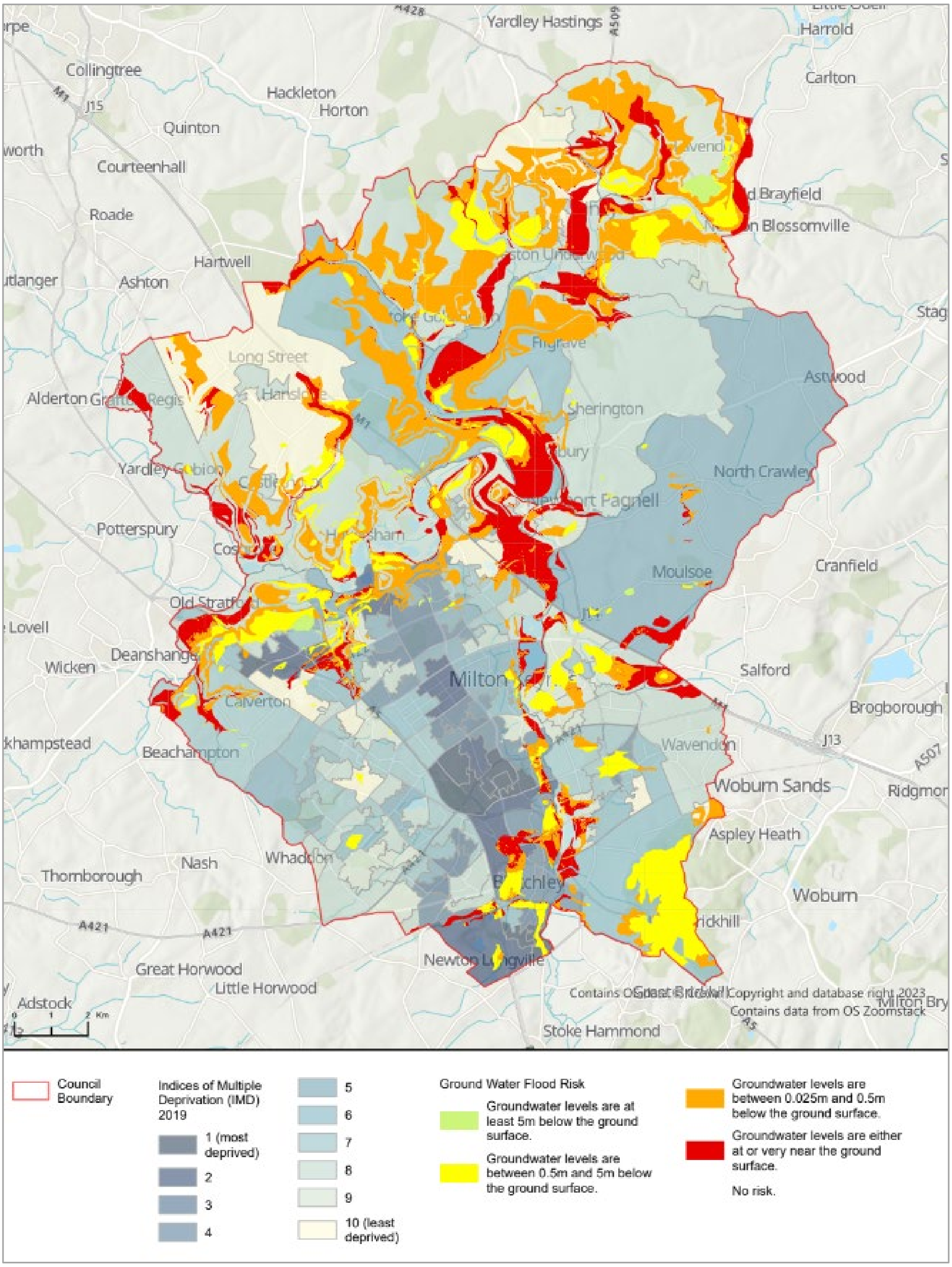


Figure 37: Intersection of socio-economic deprivation and groundwater flood risk data.

In terms of the links with other climate risks, overheating may exacerbate the risk to vulnerable neighbourhoods. From Figure 38, overheating is shown to be felt most acutely in the centre of Milton Keynes, where socio-economic deprivation is higher than in more peripheral areas of the city. Areas with particularly high temperatures and high levels of deprivation are Bletchley and the city centre.

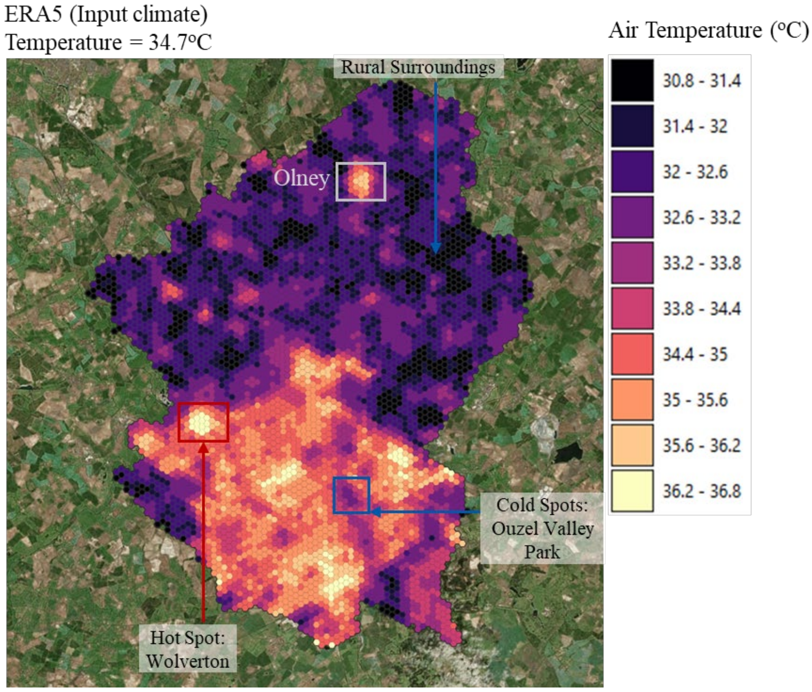


Figure 38: Air temperatures across Milton Keynes during the peak UHI intensity hour of the extreme summer day.

2.6.3 Findings from public engagement

The public consultation aimed to draw on the local residents' experiences of climate change across Milton Keynes, providing local knowledge to support the data analysis presented in previous sections, with a specific focus on extreme weather events. Using a map on Commonplace, an online public consultation engagement platform, local residents were able to place pins on any location they feel may be vulnerable to extreme weather events.

Residents were able to add details about the type of climate change events each location was susceptible to, describe what they consider makes the location particularly at-risk (e.g. frequency of events, lack of mitigation measures like shading or flood defences), and add the impacts of past events (such as physical damage to properties, transport access, impacts to specific community groups).

In total, there were 73 responses to this part of the consultation, with 62 respondents making comments and 11 responding agreeing with comments by others. The geographic areas identified with the greatest number of responses are the Ouzel Valley (10), Stony Stratford (5), Newport Pagnell (4) and Olney (3).

Flooding was identified as a common issue, with the areas highlighted aligning with those identified in the desk-based analysis, such as Stoney Stratford and Newport Pagnell. Consultees expressed concerned about additional development within the floodplain of the River Great Ouse, given the recent flooding of homes and other buildings that took place in Newport Pagnell in 2020 for example. Historic England also noted that areas which have historically flooded such as Newport Pagnell contain a diverse range of heritage assets.

Residents also identified localised flooding issues from small brooks, that may not be picked up in larger-scale mapping. Heavy rainfall and flooding affect residents who cycle around the Redways and the Ouzel Valley Park, in particular at underpasses. Historic England noted that looking along the course of local rivers uncovers other historic locations that are also prone to flooding, such as on the southern outskirts of Olney, potentially impacting the Grade I Church of Saints Peter and Paul, and Tyringham Registered Park and Garden (Grade II*) and Tyringham Bridge (Grade I and a Scheduled Monument).

There was appreciation from some residents that this may be a strategic planning decision to avoid flooding on roads, but that this can have material impacts on residents who rely on cycling for example to travel to work. One respondent also reported sewer flooding causing river contamination and adverse impacts for local wildlife, with three instances in 2023 during heavy rainfall events. The respondent associated this with excess building work and lack of improvement in services, with insufficient upgrades in infrastructure in line with the increased load.

Historic England also noted the potential for unrecorded deeply buried and waterlogged archaeology within the 'natural' floodplain deposit sequence. Buried waterlogged archaeological remains are fragile and can be vulnerable to changes in groundwater levels.

Anglian Water noted in their consultation response, that they are working with UK Power Networks and BT through the CReDo project to identify the infrastructure locations in the region which are vulnerable to climate change weather events.

In terms of managing flood risk, Anglian Water suggested that surface water should be managed through Sustainable Drainage Systems (SuDS) rather than via the public sewer network. Reducing water going into sewers provides more capacity and makes efficient use of the network and treatment facilities.

Drought was also identified as a risk by Anglian Water. They noted existing projects such as linking reservoirs in the west of the region have increased resilience to drought and meant they didn't have a hosepipe ban in 2022. In the short term the approach to reduce the risks of drought is to reduce demand through higher water efficiency in new and existing development. In the medium and longer term additional water supplies will come on stream. The reduction of demand through residents and business using less water helps to reduce emissions from that saved water and enables a reduction in the need for new infrastructure which itself generates GHG.

Central Milton Keynes was identified as vulnerable to extreme heat, as seen in summer 2022, due to a lack of shading and outdoor seating that can encourage rest when residents are active in public spaces. The consultees recommend looking at the potential to plant additional trees, with specific reference to additional trees in school playing fields. The link with air pollution and climate change has also been recognised by residents, with concern about schools and Redways located near main roads.

Other climate impacts identified include subsidence in areas of clay soils. This has been highlighted as a particular issue in areas with many very tall trees, that cause soil to dry up. Tall trees have also been identified as a risk during extreme wind events, such as those near houses that border Tattenhoe Valley Park, with additional maintenance being suggested as a potential solution. Anglian Water also noted that hotter weather means that we use more water. It also means that water and wastewater networks are more prone to leakage due to ground heave.

Anglian Water also noted that climate change also adds to risks in water supply and wastewater management including blue green algae on water bodies.

Historic England highlighted the impact that a changing climate can have on historic assets. Risks to heritage arise from extreme weather fluctuations, precipitation and flooding, and from unintended consequences of climate mitigation and adaptation measures.

Residents were also asked about potential place-based solutions to address the issues they have identified. There was a significant emphasis on physical measures like improved drainage, as well as some nature-based solutions (e.g. upstream wetland creation, tree planting, vegetation management). Residents recognise the importance of these measures being delivered by MKCC in partnership with external stakeholders, such as developers and water companies.

Anglian Water expressed interest in developing wind energy options at their sites to increase resilience to extreme weather events, for example through battery storage which provides back up energy if high winds bring down overhead powerlines.

Natural England's consultation response noted that in considering climate change adaption, the Local Plan should recognise the role of the natural environment to deliver measures to reduce the effects of climate change, for example tree planting to moderate heat island effects. In addition, factors which may lead to exacerbate climate change (through more greenhouse gases) should be avoided (e.g. pollution, habitat fragmentation, loss of biodiversity) and the natural environment's resilience to change should be protected. Natural England highlighted that Green Infrastructure and resilient ecological networks play an important role in aiding climate change adaptation.

2.6.4 Conclusions and recommendations

This section summarises how vulnerability, both in terms of socio-economic deprivation and the built environment, varies across Milton Keynes.

The use of geospatial data has facilitated a geographic 'deep-dive', to help identify particularly vulnerable social and transport infrastructure assets/facilities, as well as socio-economically vulnerable neighbourhoods. This analysis demonstrates a novel geospatial approach to considering neighbourhood vulnerability. The method has great potential to be expanded to cover a wider range of assets and hazards, but is influenced by data availability, and prioritisation.

With respect to the vulnerability of physical assets that are key for local communities, the geospatial approach has enabled the identification of specific vulnerable sites and assets. For example, there are areas along the railway routes in the city at Fenny Stratford that are exposed to fluvial flooding, as well as Milton Keynes Coachway. Some education facilities in the city are also exposed to flood risk, with Brooklands Farm Primary School and Cedars Primary School, both in Newport Pagnell, at risk from both fluvial and groundwater flooding.

The vulnerability of these schools to groundwater flooding is influenced by the presence or absence of critical assets (such as boilers) in basements. In terms of medical facilities and care homes, the Parklands Nursing Home in Woolstone and Burlington Hall in Woburn Sands are identified as the two most exposed to flood risk in the city.

In terms of socio-economic vulnerability, the areas with higher areas of deprivation are located in the city centre and the south of the city, as well as a pocket to the west. This socio-economic vulnerability data has been combined with flood and heat hazard data, to better understand how these factors intersect, to provide a socio-economic vulnerability lens to climate risk.

This has identified that the areas at-risk from fluvial and groundwater flooding broadly sit outside the areas at greatest levels of socio-economic deprivation, although there are particular risk 'hotspots' around Bletchley and New Bradwell. This evidence can help the New City Plan take a targeted approach to flood interventions in these areas that are both greatly exposed to the hazard and that have vulnerable communities with an assumed lower capacity to cope (based on the data).

This has been supported by the findings from the public consultation using the Commonplace platform. These insights broadly support the findings of the desk-based review, with towns like Stoney Stratford and Newport Pagnell being recognised by residents as key flood risk areas in the city. The consultation has also identified key community vulnerabilities, such as the risk flooding poses to residents reliant on using Redways for cycling to work.

The New City Plan has great potential to address the identified risks, by targeting neighbourhood-scale interventions in the most vulnerable areas of the city, and informing policy and planning criteria for new developments.

2.7 Air Quality

Although this assessment has concentrated on the climate impacts of the various Spatial Options, there are also wider environmental and health effects from these options. This includes the impacts on air pollution from the new buildings and associated transport, which has a wide range of health effects at all stages of life, including respiratory and cardiovascular diseases, cancer, birth defects, diabetes, and dementia. Air pollution also has a disproportionate impact on the young, elderly and those with existing health conditions, and is linked to inequalities in exposure and harm.

2.7.1 Methodology

MKCC is required, under the Local Air Quality Management framework, to have regard to the national air quality target and objectives, including:

- Annual average concentrations of Nitrogen Dioxide (NO_2), Particulate Matter (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$);
- Additional short term average concentrations for NO_2 and PM_{10}; and an exposure reduction target for $PM_{2.5}$.

These objectives are currently met in Milton Keynes, but there are health impacts below all these objectives and there are no safe levels (below which there is no harm to health) of PM_{10} and $PM_{2.5}$ so further improvements have health benefits.

In considering the Spatial Options, there was limited information on where the growth would be located, so it was not possible to model the full impact on air quality concentrations and population exposure. A full assessment has been carried out on the impact on emissions from the various spatial options, with further qualitative analysis and commentary provided on the potential impacts that these emissions changes would have on local concentrations, exposure and therefore health impacts.

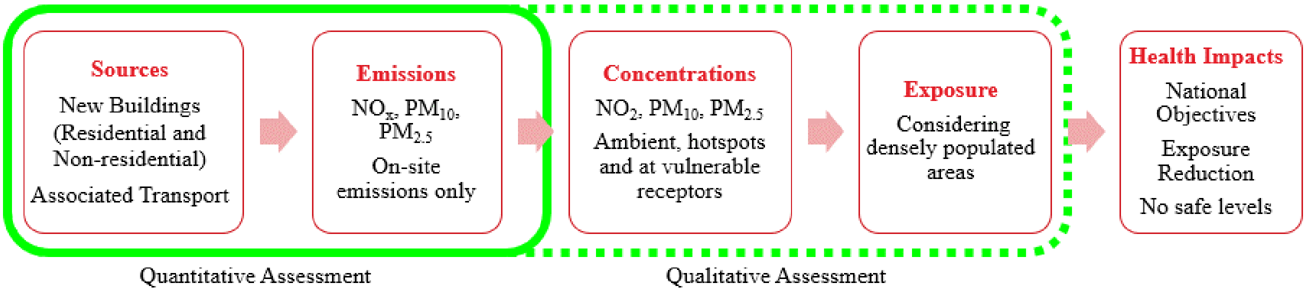


Figure 39: Scope of the air quality assessment for the Spatial Growth Options

The emissions assessment considered three key sources:

- For new residential buildings, gas use for heating is the main source of emissions, especially NO_x[9] emissions (PM_{10} and $PM_{2.5}$ emissions are minimal from gas combustion in boilers). As the requirement for new buildings to use ASHP instead of gas for heating and hot water from 2030, emissions will not increase after this time. ASHP have no onsite air pollution emissions, so the only emissions will be from the existing (2025-2029) gas fuelled properties;
- Gas use for heating is the main source of emissions for new non-residential buildings too. The spatial options propose moving from gas to electric powered in all new build from 2030; and
- The transport associated with the new residential and non-residential buildings has air pollution emissions of NO_x, PM_{10} and $PM_{2.5}$. Over time, there will be an increase in vehicle trips due to the new residential and non-residential buildings, but also efficiencies in the trips per capita due to traffic reduction programmes outlined in Section 2.4. There will also be reductions in air pollution from vehicle exhausts due to the increase in the use of EV as a proportion of the fleet. The air

[9] The air pollutant NO_2 has significant health impacts. When considering emissions, it is important to consider both direct NO_2 emissions and its precursor nitric oxide, NO, which rapidly oxidises in the air to form NO_2. NO_2 and NO are collectively known as NO_x.

pollution emissions are calculated for each vehicle type, at average speed, using recognised emission factors to 2050.

While electricity generation for power and electric vehicles does cause air pollution emissions (which vary depending on the type of power generation used), the emissions from this have a minimal impact on air quality in Milton Keynes and are considered as part of the background pollution discussed in the Baseline Report. This means that measures which improve the efficiency of buildings and reduce electricity use do not affect the air pollution emissions (with the exception of heat efficiency in the new gas fuelled buildings). This is part of the justification for setting more stringent fabric efficiency standards at the local level. If Government does not reverse the pushing back of the cut-off date for gas boilers, then demand reduction measures, facilitated by higher than Building Regulation fabric standards, will help to improve local air quality.

A qualitative assessment of concentrations and exposure is included, based on the emissions modelling, local air quality management work, feedback from the stakeholder workshop, and professional judgement. This also considers the current distribution of pollution, existing Air Quality Management Areas and other pollution hotspots, and vulnerable receptors (such as the Milton Keynes hospital).

Inputs and Assumptions

The air pollution emission assessment is largely based on the outputs of the buildings and transport modelling detailed above. More information and additional sources of data are set out in Table 9.

Table 9: Air Quality Parameters Matrix

Sector	Summary of Impacts	Rationale / assumptions
New residential buildings	Gas use for heating is the main source of emissions. Move from gas to ASHP for new build in 2030.	Informed by residential gas consumption, and heat and hot water demand data (from carbon modelling above). Using the National Atmospheric Emissions Inventory (NAEI[10]) emission factors for gas heating and gas hot water.
New non-residential buildings	Gas use for heating is the main source of emissions. Move from gas to electric for new build in 2030.	Informed by non-residential gas consumption, and land use split (from carbon modelling above) to estimate the gas use by commercial and public sector buildings. Using NAEI emission factors for gas in commercial and public sector buildings
Total vehicle trip numbers, split by vehicle type (including electric vehicles)	Increase in vehicle trips due to the new residential and non-residential buildings. Reduction in trips per capita due to efficiencies and traffic reduction programmes (see transport section). Increase in the use of electric vehicles.	Informed by vehicle trip numbers and length, by vehicle type (from transport modelling above). Using Government average speed estimates for Milton Keynes[11] (these were not split by A-roads, urban and suburban) Using NAEI (Emission Factor Toolkit, EFT v11[12]) emission factors for different vehicle types (per km). A requirement for electric vehicles was included at various points in the spatial options, and these were included explicitly. The emission factors for the UK fleet also assumes some electric vehicles under the business as usual spatial option.

[10] https://naei.beis.gov.uk/

[11] https://www.gov.uk/government/statistical-data-sets/average-speed-delay-and-reliability-of-travel-times-cgn

[12] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/

2.7.2 Analysis

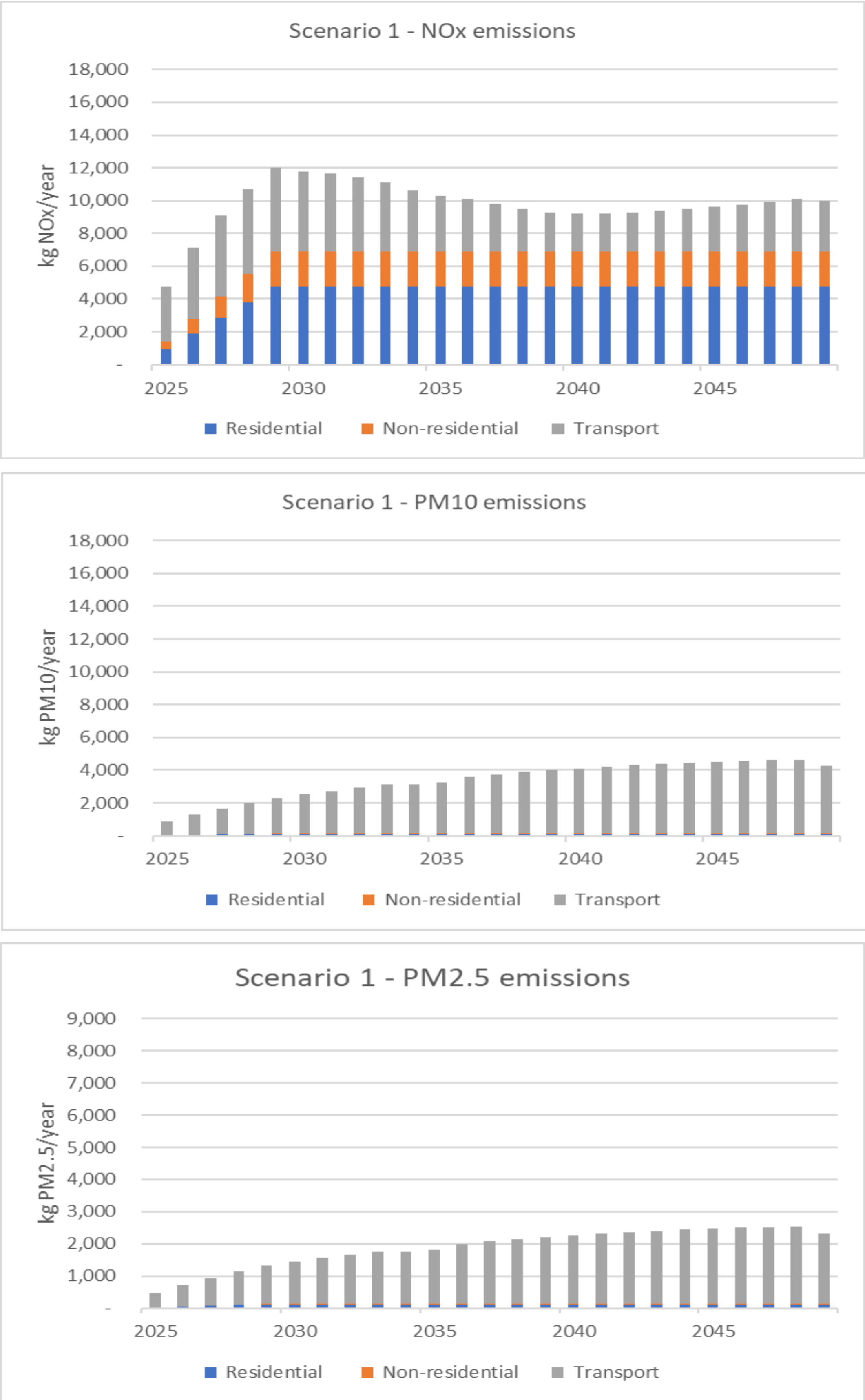


Figure 40: Air quality emissions – Spatial Option 1

Residential and non-residential buildings are a key source of emissions, where the new buildings use gas (which causes NO_x emissions and minimal PM_{10} and $PM_{2.5}$ emissions) until 2030 when they move to ASHP and electric, which have no local air pollution emissions. Therefore, the emissions increase with increasing buildings until 2030, then remain steady with no emissions from the additional buildings.

The transport emissions initially increase with increasing vehicles trips due to the new buildings. The NO_x emissions increase initially due to the introduction of gas boilers and transport, they then stop increasing from buildings as all future buildings are electric or ASHP, and reduce from most of transport due to the change to electric vehicles. There appears to be a second rise in the NO_X values, this is actually rising throughout the period, but is hidden until then; it is a result of the increase in non-electric transport, e.g. servicing trips. The NO_x emissions from transport then reduce as electric vehicles penetrate the vehicle fleet. The PM_{10} and $PM_{2.5}$ emissions from transport track more closely the increasing vehicle trips, as the emissions do not substantially reduce with the introduction of electric vehicles, due to tyre and brake wear emissions of PM_{10} and $PM_{2.5}$.

Spatial Option 2: Strategic Urban Extension

The trends for the various Spatial Options follow the same trends as above.

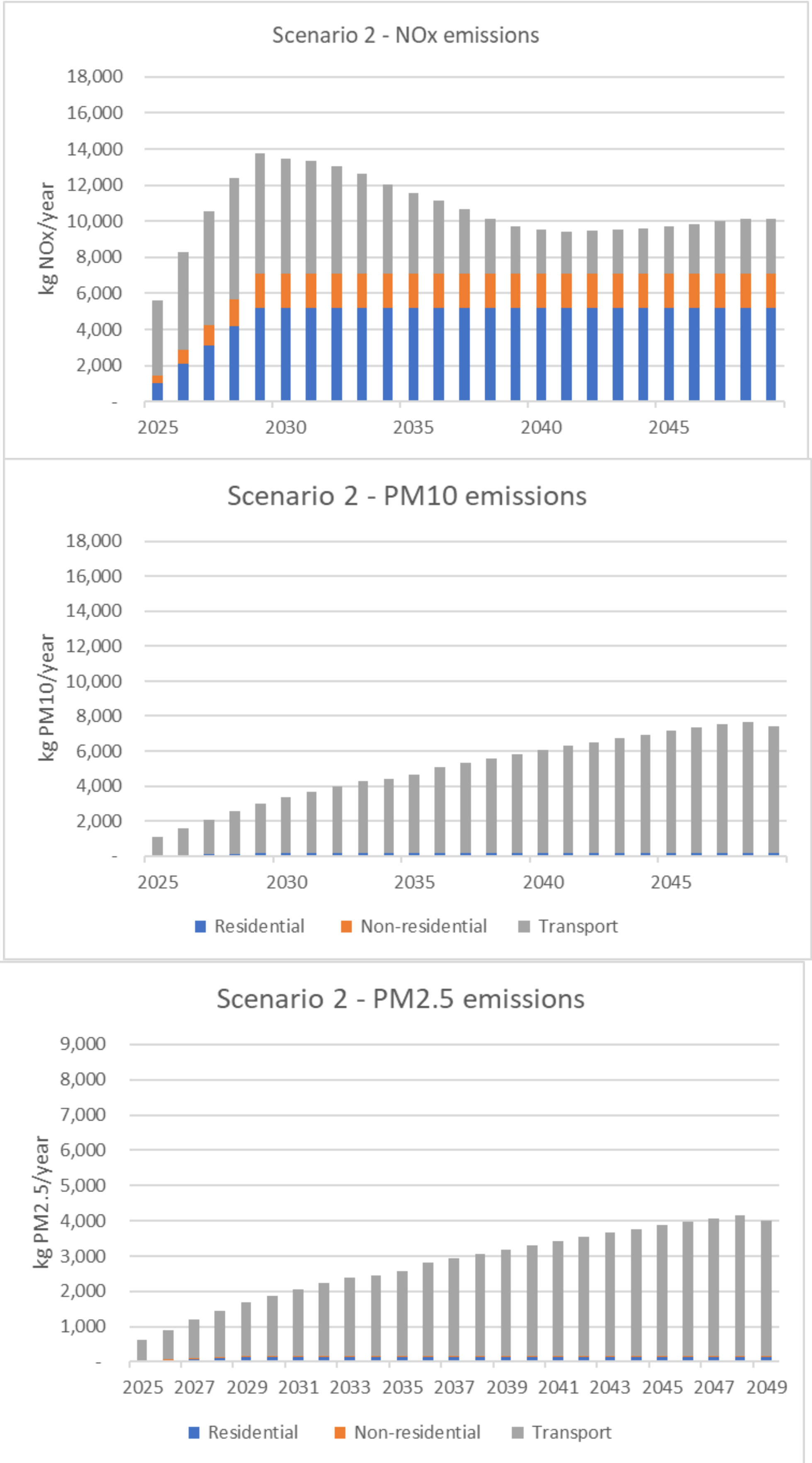
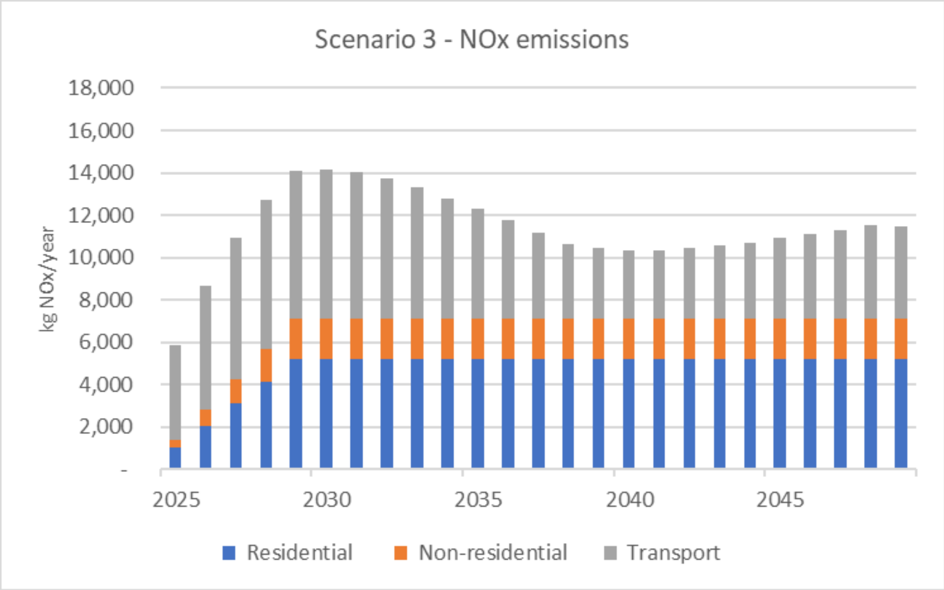
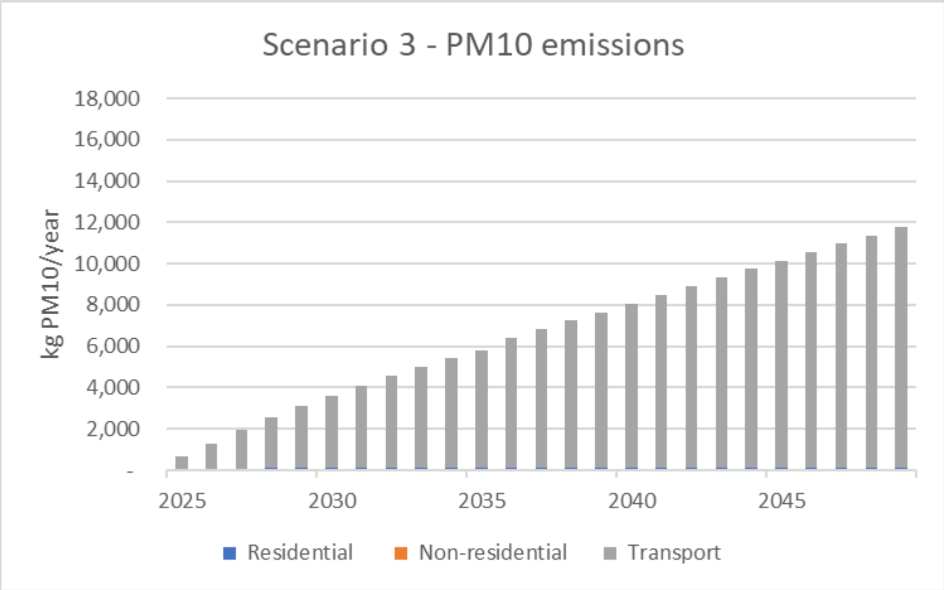


Figure 41: Air quality emissions – Spatial Option 2

Spatial Option 3: New Settlement





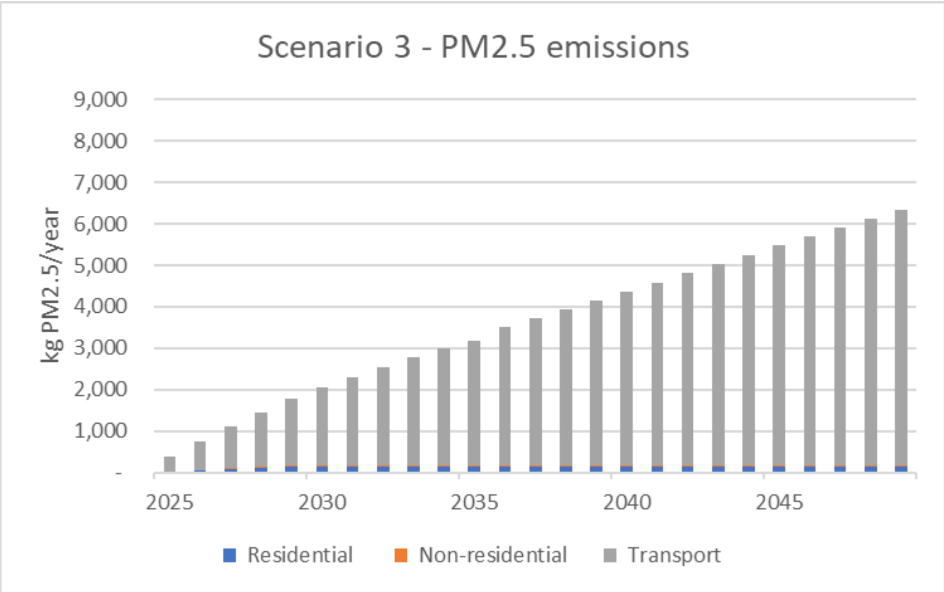
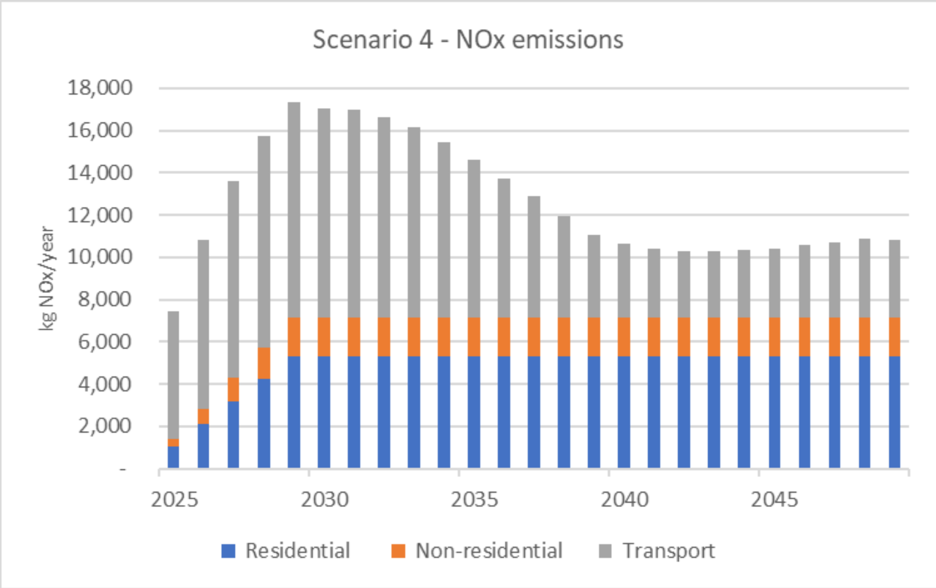
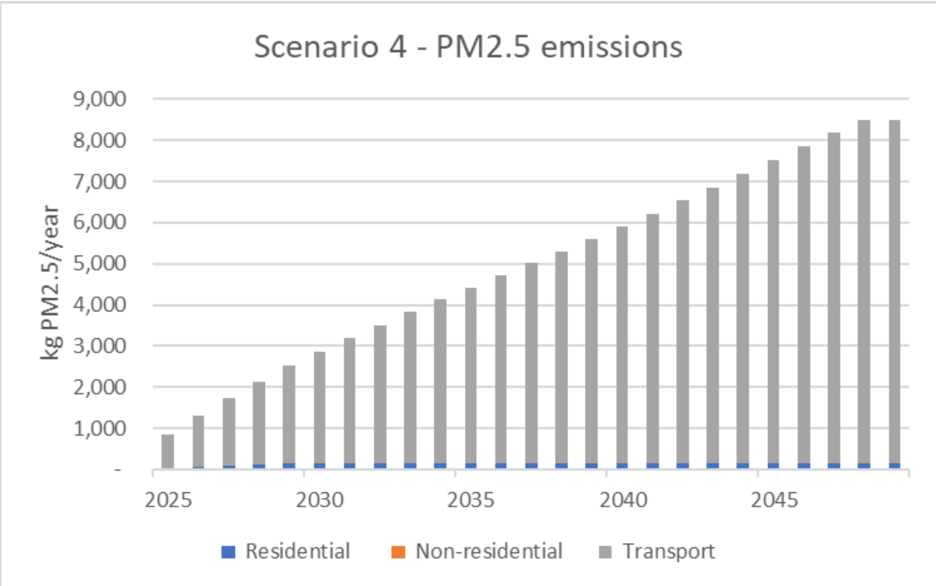


Figure 42: Air quality emissions – Spatial Option 3

Spatial Option 4: Rural approach





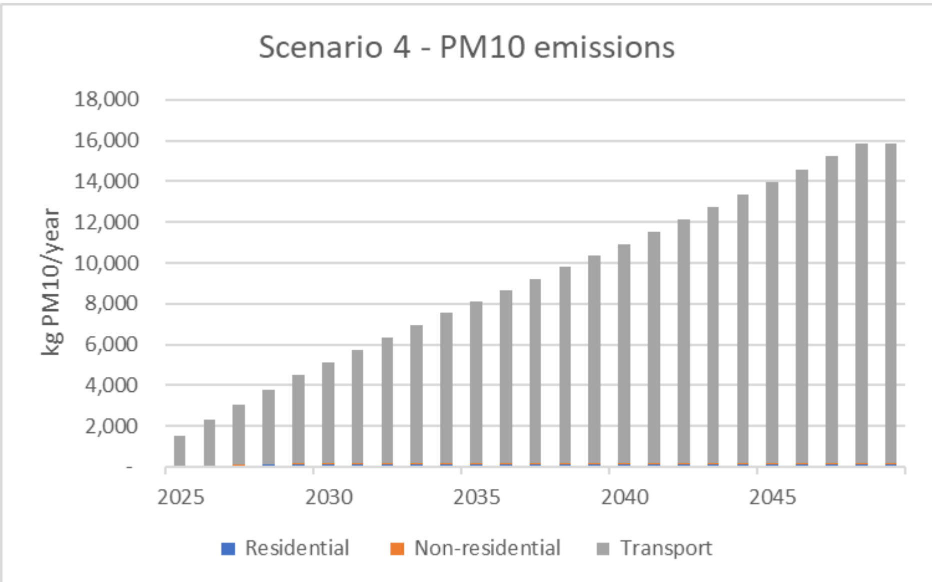


Figure 43: Air quality emissions – Spatial Option 4

The key sources of air pollution emissions are gas use in the new buildings (especially for NO_x emissions), and transport.

Buildings Emissions

The new residential and non-residential buildings use gas until 2030 when they move to ASHP and electric, which have no local air pollution emissions. The air pollution emissions from residential and non-residential buildings are from gas combustion (which causes NO_x emissions and minimal PM_{10} and $PM_{2.5}$ emissions), so follow the pattern of gas consumption. Therefore, the emissions increase with increasing buildings until 2030, then remain steady with no emissions from the additional buildings, however the locked in emissions from homes/buildings constructed with gas boilers remains.

When comparing the air pollution emissions from residential buildings for different Spatial Options, it can be seen that Spatial Option 1 Densification has slightly lower emissions and Spatial Option 4 Rural approach has slightly higher emissions than Spatial Option 2 Urban extension and Spatial Option 3 New Settlement. This is due to the lower floorspace (due to smaller apartment and houses) and gas consumption in Spatial Option 1 Densification and higher floorspace and gas consumption in Spatial Option 4 Rural approach, as described in **Section 2.2.**

For non-residential buildings, the opposite trend applies, as Spatial Option 1 Densification has the higher emissions, with Spatial Option 4 Rural approach causing less emissions. This is due to the higher non-residential floorspace and gas consumption in Spatial Option 1 Densification and lower non-residential floorspace and gas consumption in Spatial Option 4 Rural approach. The emissions for non-residential buildings are lower than residential buildings, due to higher number of residential buildings.

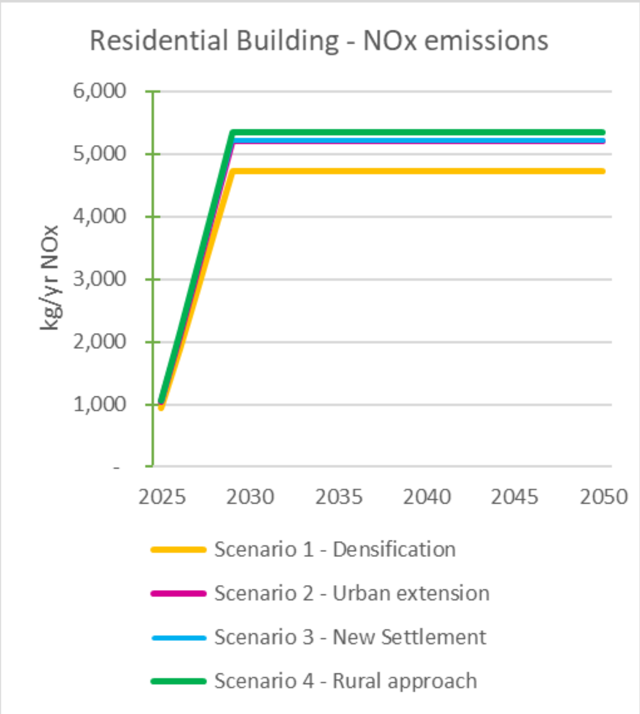


Figure 44: Residential Building NOx emissions

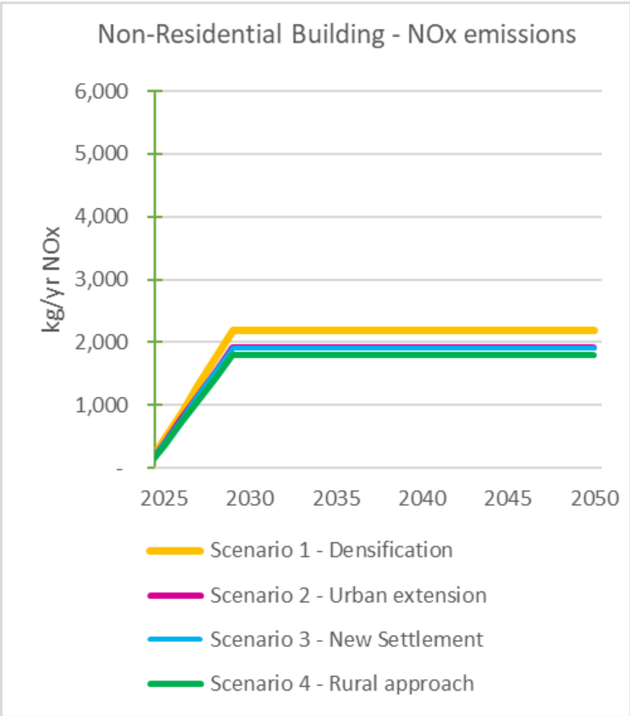


Figure 45: Non-Residential Building NOx emissions

Transport Emissions

Air pollution from transport is caused by exhaust emissions from engines and tyre and brake wear.

Transport emissions are affected by the number of vehicles and the emissions from each vehicle.

In these spatial options, transport emissions initially increase with the growing number of vehicles trips due to the new buildings. There are some minor efficiencies in the average emissions per vehicle over time, due to improvements in the UK fleet, and the penetration of electric vehicles, which reduce NO_x emissions, but have a less significant impact on PM_{10} and $PM_{2.5}$, as tyre and brake wear is a key source (and dependant on vehicle weight, which can be higher for electric vehicles).

The transport modelling also introduces more electric vehicles into the fleet, with the various vehicle types being electrified at different times, as set out in Section 2.4. The NO_x emissions from transport reduce as electric vehicles penetrate the vehicle fleet. The PM_{10} and $PM_{2.5}$ emissions from transport track more closely the increasing vehicle trips, as tyre and brake wear emissions of PM_{10} and $PM_{2.5}$ mean the introduction of electric vehicles do not substantially reduce total emissions.

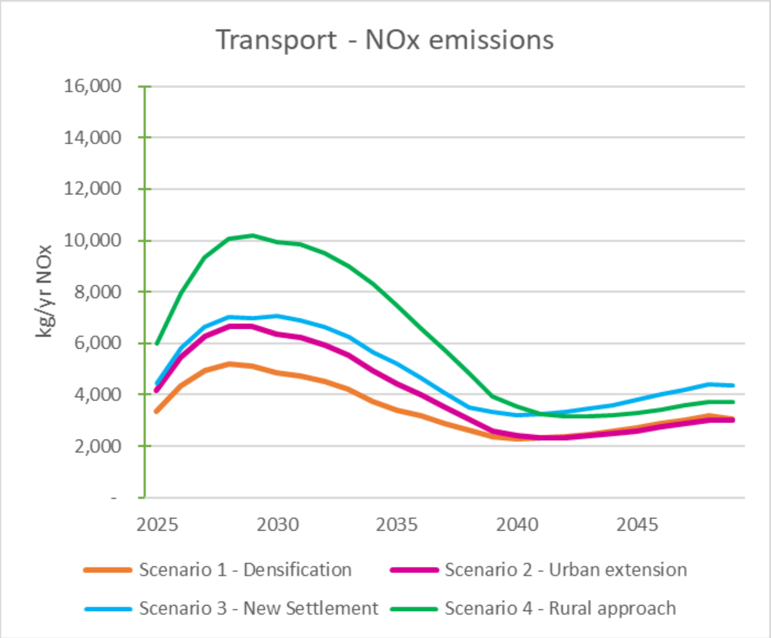


Figure 46: Transport NOx emissions

The NO_x emission trends for transport show the emissions tracking the increased vehicle numbers, then reducing due to the requirement for electric vehicles in the various categories. The higher vehicle trip numbers (measuring in total km) in Spatial Option 4 Rural approach is reflected in the higher NO_x emissions, and vice versa for Spatial Option 1 Densification until 2040. The NO_x emissions reduce significantly as electric vehicles are introduced in the different vehicle types.

Transport dominates the emissions of PM_{10} and $PM_{2.5}$ in all Spatial Options (as gas use is not a major source of these emissions) and these track the vehicle trip numbers, with some additional reductions due to improved vehicle technology and changes in the UK vehicle fleet.

The differences between the various Spatial Options mostly arise from the different trip generation for each option, as described in the transport modelling in Section 2.4.

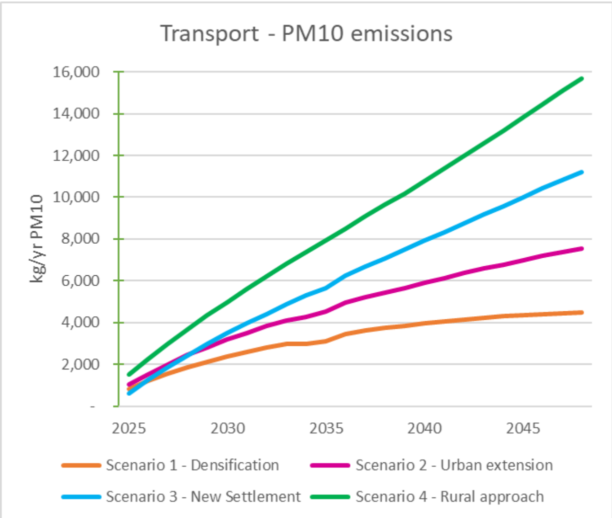


Figure 48: Transport PM10 emissions

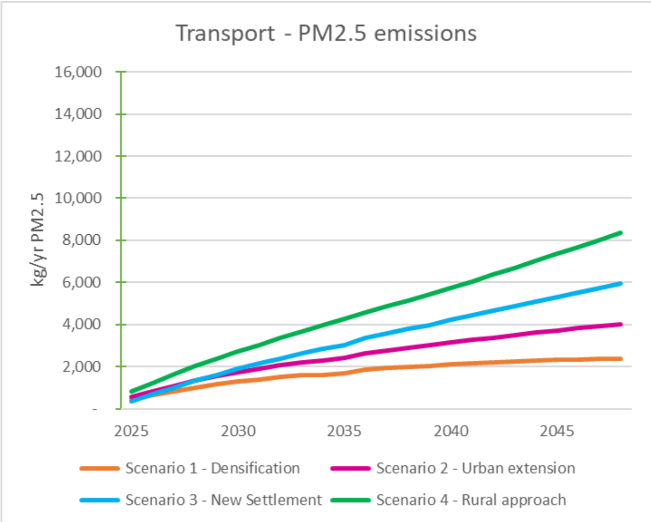


Figure 47: Transport PM2.5 emissions

In the absence of data on the local traffic speeds and how the trips associated with the different options split between A-road and smaller roads, the transport emissions were calculated on the basis of an average speed of 35 mph, from the Government's statistics[13] on average speed on local 'A' roads by local authority in

[13] CGN0503: Average speed on local 'A' roads in England: monthly and annual averages, https://www.gov.uk/government/statistical-data-sets/average-speed-delay-and-reliability-of-travel-times-cgn, Accessed October 2023.

England for 2022. A sensitivity analysis on this was carried out using the government's Local Air Quality Management Emission Factor Toolkit (EFT)[14]. The analysis established that:

- Emissions of PM_{10} and $PM_{2.5}$ would increase by less than 3.2% when reducing the speed from 35 mph to 20 mph;
- Emissions of NOx could be more affected, as emissions from heavy duty vehicles (buses, coaches and lorries) would approximately double as the speed was reduced, there would be a smaller increase in the emissions from cars (by up to 25%), the impact on vans and taxis would be less than 8% and motorcycles would have lower emissions at 20 mph than at 35 mph;
- The trends and conclusions in comparing the different spatial options are unlikely to be altered if a lower speed was used, as the spatial options with the highest trip rate (Spatial Option 4) is still likely have the highest emissions and the transport emissions from the spatial option with the lowest trip rate (Spatial Option 1) is still likely to have the lowest emissions.

As context, lower vehicle speeds do not always correlate with better air quality. An average speed of 20 mph could reflect congested traffic and stop start conditions, which would increase emissions, which may be reflected in the EFT. A 20mph zone, designed to reduce pollution, would aim to smooth traffic to reduce acceleration, and discourage vehicle traffic and encourage alternatives more generally.

Total Emissions

The overall trends in air pollution emissions show the balance of buildings and transport in NO_x emissions, and the dominance of transport emissions for PM_{10} and $PM_{2.5}$.

Spatial Option 4 Rural approach has the highest total emissions, as it has the highest vehicle trip numbers (in total km) and the highest residential gas use. Spatial Option 1 Densification has lowest overall emissions due to the lower trip numbers and residential gas use.

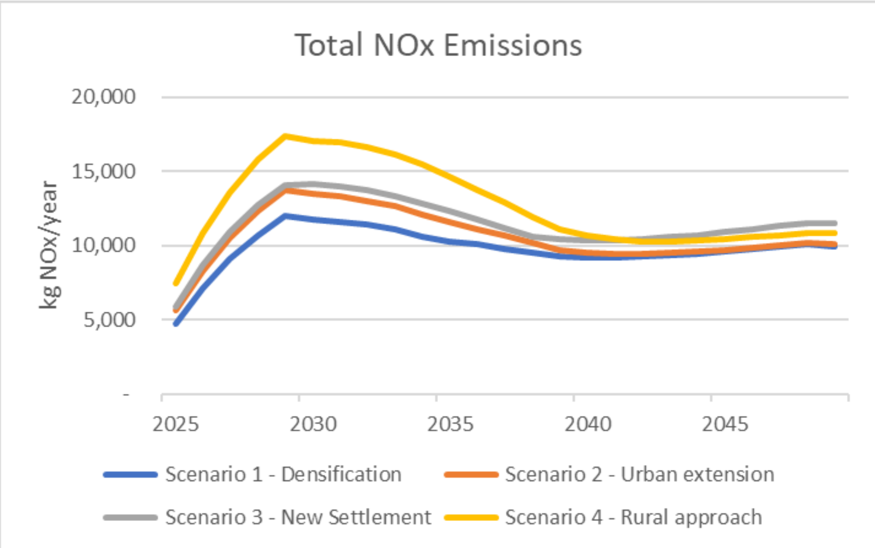


Figure 49: Total NOX emissions

[14] Department for Environment, Food & Rural Affairs (2023) Emissions Factors Toolkit. Available at: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/ [Accessed on 07/12/23]

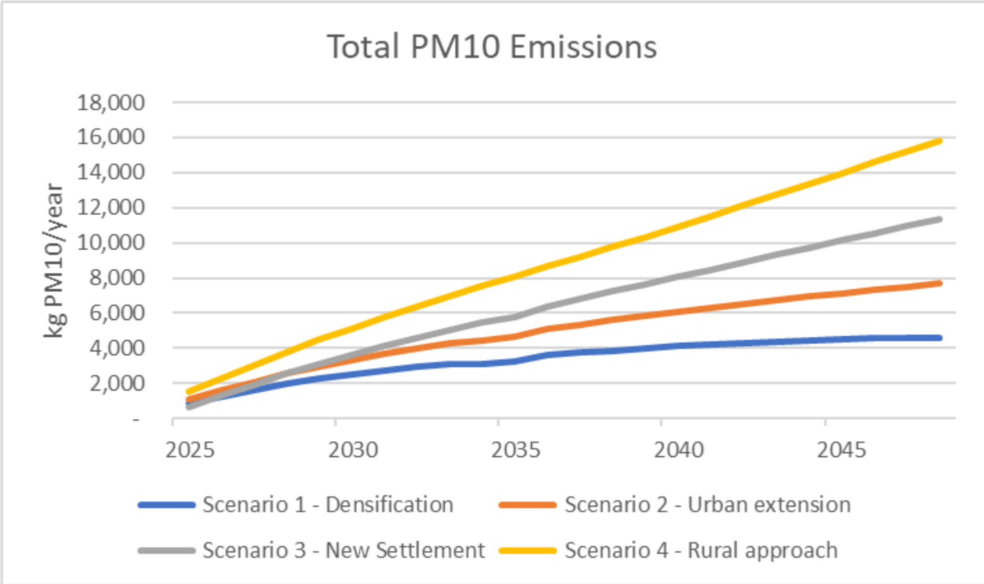


Figure 50: Total PM10 emissions

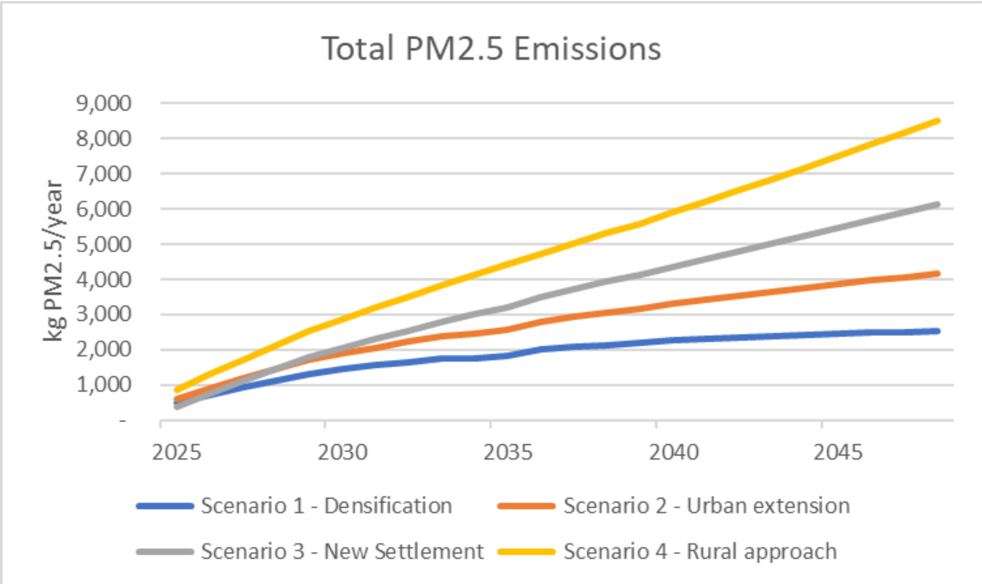


Figure 51: Total PM2.5 emissions

Air pollution impacts

When considering air pollution, it is important to refer to its impacts, in terms of concentrations (which have legal limits), and the impact on human health based on exposure to those concentrations, at general ambient levels, at existing hotspots and at locations with vulnerable populations.

Translating the impact of emissions onto environmental and health impacts is not simple and is subject to several factors.

- Emissions to concentrations is a non-linear relationship, and depends on dispersion, meteorology, atmospheric chemistry and background pollution levels;
- Emissions in densely populated areas are likely to cause more exposure than emissions in less populated areas;
- Emissions in areas of higher pollution (eg Air Quality Management Area) or more sensitive receptors are likely to have higher impacts on health; and
- Busy roads and junctions usually have higher levels of pollution than surrounding areas. Emissions from road transport are likely to increase pollution concentrations on busy roads.

There are number of key locations which have been considered in the qualitative assessment of impact. These include:

- The Olney Air Quality Management Area, which was declared in 2008 due to exceedances of the NO_2 annual average objective, but was revoked in January 2024 as air pollution has been within the objective for several years; this is within the area covered by Spatial Options 2 and 4;
- Milton Keynes Hospital, in the area covered by Spatial Option 1 Densification;
- Dense residential areas, especially where buildings are close to busy roads; the grid road system means that this may be less relevant for some major roads, due to separation of the sources (roads) and receptors (buildings such as homes and schools) by green infrastructure, but it may be relevant in some of the historic village centres and built up areas, which occur in all areas considered.

Spatial Option 1 Densification generally has the lowest increase in emissions, however these emissions occur in the town centre, where the population density is generally highest, and the existing concentrations are generally higher (with the exception of some road junctions elsewhere).

Spatial Options 2 and 4 may have an impact in Olney, where there was previously an Air Quality Management Area, due to historic breaches of the air quality objectives near a busy road junction.

Future development of sites allocated in the final New City Plan will need to look more closely at the site-specific impacts on air quality, to ensure that air pollution and health impacts are minimised.

2.7.3 Conclusions

An air quality assessment was undertaken to consider the impact on key pollutants for the various spatial options. The emissions were assessed in detail, building on the carbon assessment for residential and non-residential buildings and transport. Although there are we have not yet allocated specific sites within the draft New City Plan, the broad locations of the likely spatial options have been considered to assess concentrations. A commentary of the key issues for the potential spatial growth areas has also been provided.

NO_x emissions are predicted to be caused by the gas combustion in residential and non-residential buildings, and from road transport. This reduces as fossil fuels are replaced by electricity and renewable energy.

PM_{10} and $PM_{2.5}$ emissions are dominated by transport emissions, and closely tracks the vehicle trips (measured in total km travelled), this does not significantly reduce with the increased use of electric vehicles, due to tyre and brake wear emissions.

Spatial Option 1 Densification had the lowest overall emissions, due to lower gas use and lower trip rates. Spatial Option 2 Urban Extension has the second lowest overall emissions and Spatial Option 3 has the third lowest overall emissions due to the same metrics. Spatial Option 4 Rural approach had the highest emissions due to the same metrics.

The impacts on air quality and health are likely to be higher in the most densely populated areas, where there are residential properties and schools close to busy roads, and where there are vulnerable populations. More detailed assessment will be required to assess local impacts where further information on the geographical scope and location is available.

3. New Development Analysis

3.1 Introduction

This New Development Analysis chapter analyses the policy options for new development in Milton Keynes, in response to the technical evidence presented in Section 2 Spatial Option Analysis and best practice standards which are described in the separate Baseline Report.

The chapter considers:

- Renewable energy capacity: This section provides an assessment of the potential renewable power generation in Milton Keynes to increase local renewable energy capacity;
- Net zero carbon buildings: Framed by five future building typologies, this section presents technical building standards and potential policy options to achieve new builds of net zero carbon emissions;
- Sustainable design features: Accounting for the climate risk analysis and other best practice design considerations, this section presents potential policy options on sustainable design features and considerations for battery storage; and
- Green Infrastructure: This section presents a total of seven green roof and wall options, encompassing their merits for sustainability, cost and other factors.
- High-level cost estimates are provided for the future net zero building options and green roof and green wall options presented.

3.2 Renewable Energy Capacity

3.2.1 Introduction

This section provides an assessment of the potential renewable power generation in Milton Keynes to increase local renewable energy capacity, contribute to the decarbonisation of the MKCC administrative area and avoid emissions associated with new development and population growth.

At the same time, local renewable energy could be an opportunity for sustainable growth through new employment opportunities, upskilling/training of local communities and increased energy infrastructure resilience, while it delivers better air quality and energy security co-benefits.

The chapter sets out the methodology for assessing potential for commercial-scale on-shore wind and ground-mounted solar PV installations across Milton Keynes as well as commercial rooftop solar PV systems, reflecting information available at the current stage of plan making. It provides guidance to inform preferred sites, technologies, and policies to support the development of the New City Plan.

The findings and recommendations could be used within a wider framework approach to inform multi-criteria decision making and complement planning policies for net-zero target setting, decarbonisation interventions, changes of land use, future housing, and employment land areas.

A constraints-based approach was applied to determine opportunity areas for renewable and low-carbon technologies. Following discussions with MKCC, the renewable energy technologies considered in this assessment are:

- Rooftop (Roof-mounted) solar PV for existing and new buildings (commercial scale)
- Ground-mounted solar PV (commercial scale)
- Onshore wind (commercial scale).

3.2.2 Methodology & Limitations

Local geospatial data were used to assess renewable energy technologies subject to existing land uses and designations. As the New City Plan develops, future assessments may utilise the higher level of detail available to build a more accurate and detailed analysis.

High-level technical capacity for on-shore renewable energy (wind and PV) across Milton Keynes was estimated using benchmarks and geospatial data for the area. The analysis provided an indication of potential capacity across the MKCC administrative area. The overall potential for additional generation was calculated based on the assessment of total theoretical capacity for each technology.

Please note that a more detailed feasibility and techno-economic assessment, as well as consideration of grid connections and landscape impact, will be needed for any specific sites selected for renewable energy.

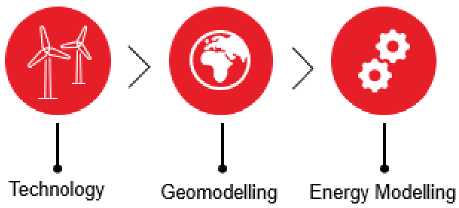


Figure 52: Three stage process in the site identification

3.2.2.1 Decentralised energy technologies

Three technologies have been considered in this assessment: roof mounted solar PV, ground mounted solar PV and onshore wind.

Engagement with stakeholders and the public throughout the development of this study has highlighted that there are other renewable technologies which could play a part in energy and heat generation in Milton Keynes, these include for example hydro power on the River Great Ouse and local heat generation from heat pumps.

The Canal and Rivers Trust specifically highlighted the opportunity for canal water to be used for heating and cooling of development adjacent to the canal, suggesting that sites such as Campbell Park North could be used as an exemplar for this technology.

The quantitative assessment in this section focusses on established technologies which have potential to generate the greatest amount of energy. Nevertheless, other technologies should be considered, and this will be covered further in Recommendations report for this study.

Roof-mounted solar PV

Solar PV panels have seen a big decrease in prices in recent decades due to economies of scale and manufacturing efficiencies. Various commercial solutions and products are available for ‘building integrated’ and rooftop PV systems. Modern applications can satisfy a range of aesthetic and installation requirements. Large commercial and industrial developments often have large roof areas available that can be utilised for electricity generation to use locally or sell to the grid.

Solar PV in the UK has a rather small load factor (approximately 10-11%) due to the hours of sunlight, as a result of the latitude and weather conditions. The load factors are the ratio of how much electricity is generated as a proportion of the total generating capacity (maximum theoretical potential). In general, southern areas of UK will have higher generation potential than northern areas.

Small scale rooftop PV (typically <3.5kW) uptake had been supported through feed-in tariff (FiT) schemes that paid for the electricity exported to the national grid. FiT has now been replaced with the Smart Export Guarantee (SEG) that enables individual consumers to receive payments from electricity suppliers for small scale PV generation.

Most importantly, rooftop PV capacity has been included in the specifications of the notional building that is used for compliance of new buildings with the UK building regulations (Part L, SAP10, 2021 Edition). The generation potential depends on the 1) available roof space, 2) orientation, 3) shading/exposure of the roof area. While solar PV is not mandatory to achieve compliance with the building regulations, they will help achieve the emissions and primary energy use target rates.

Policies and projections for electrification of heat and transport, advances in battery storage and the increase of grid electricity and gas unit prices drive the demand for solar PV systems. Solar PV is considered a viable investment with good payback periods and wider environmental benefits.

However, PV solar panels have embodied carbon emissions due to their raw materials and the carbon intensity of mining and manufacturing processes. Their lifespan is long but there are concerns regarding the carbon payback when this is assessed based on avoided emissions from grid electricity, especially as grid carbon intensity becomes very low.

The Town and Country Planning (General Permitted Development) (England) Order 2015 (as amended) permits solar PV to be installed on houses and flats subject to it not protruding by more than 0.2m above the plane of the wall or the roof slope, it not protruding above the highest part of the roof, and not involving a listed building or designated area. The Town and Country Planning (General Permitted Development etc.) (England) (Amendment) (No. 2) Order 2023 updated requirements so that roof mounted solar PV is now permitted in conservation areas subject to prior approval.

Rooftop solar PV can be also potentially integrated with green roofs, which are roofs on top of which vegetation is planted on a growing medium over a waterproofing membrane. They can have significant benefits such as:

- Promoting biodiversity;
- Improving roof insulation and therefore the energy efficiency of the building;
- Supporting rainwater management by reducing stormwater runoff;
- When in combination with PV panels, green roofs help to cool down the panel surroundings leading to an increase in the panel generation efficiency; and
- Improving the aesthetics of the roof.

On the downside, there are aspects of the green roofs that need to be carefully considered when approaching their design:

- Increasing the static load of the roof;
- More complexity associated with design and construction of the green roof layers;
- Maintenance associated with plant care, pruning, watering, and cleaning; and
- Higher upfront costs.

In summary, there is a great potential for these two technologies to work together and the realisation of a combined system will need to be evaluated on a case-by-case basis.

Ground-mounted solar PV

Using the same technology as rooftop PV, ground-mounted solar PV typically refers to commercial scale systems. In theory, the main restrictions to the capacity of these systems are suitable land availability, cost, and grid infrastructure.

Land availability will be influenced by existing land uses and habitat, heritage and landscape designations, orientation, topography, and terrain, surrounding landscape sensitivity and local infrastructure.

New solar PV capacity peaked in 2015, when 4.1GW out of a 6GW UK total new renewable energy capacity came from solar PV. In 2021, solar PV accounted for almost 10% of total UK renewable generation. The total generation from solar PV is smaller than Offshore, Onshore Wind and Bioenergy. Bioenergy has mainly grown due to conversion of coal to plant biomass (wood pellets) power plants.

There is currently a delay in connecting new capacity to the grid, associated with the high increase in renewable electricity generation projects. According to National Grid, the current pipeline of utility-scale solar project in the UK is ~14 GW, with almost 10 GW awaiting to be connected to the grid. National Grid is aiming to provide connection dates to 60% of the pipeline capacity within 12 months from their request. In order to speed up the connection process, National Grid is introducing a ‘queue management system’ which will require customers to meet various milestones during their connection journey and should release significant capacity from the queue. National Planning Practice Guidance (NPPG) on renewable and low carbon energy points out that "the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively"[15]. In the listed factors it is noted that large scale ground-mounted solar farms should be focused on previously developed and non-agricultural land, provided it is not of high environmental value. BRE planning guidance from 2013[16] suggests that ground-mounted large scale PV installations should ideally "utilise previously developed land, brownfield land, contaminated land, industrial land or agricultural land preferably of classification 3b, 4 or 5". Ground maintenance will be required as vegetation will need to be managed. If planned carefully, solar PV sites can be used for grazing to control vegetation and there are examples that have been developed to function as nature reserves for endangered species of flora and fauna[17].

Regarding financial drivers for solar power developments, solar PV farms with capacity >5MW qualify for the Contracts for Difference (CfD) scheme[18], further explanation of which is set out below. Installations with capacity <5MW can benefit from the SEG to receive payments from electricity suppliers for the electricity exported to the grid.

Onshore wind power

Onshore wind power is an established technology that in 2021 had the largest share of installed capacity among onshore renewable energy technologies[19] in the UK. The electricity generation output of wind power installations is significantly influenced by local factors and weather conditions. Local topography (and thermal effects), wind speeds and flow profiles affect the wind turbine performance as measured with the wind load factor. In general, onshore wind in the UK has high load factors and the London and Southeast area where Milton Keynes is located show a 26.8 % average between 2014 – 2022[20].

Onshore wind and solar PV projects used to be supported by the Renewable Obligation (RO) and later the CfD (>5MW capacity) scheme. The CfD scheme is an effort to incentivise large scale renewable energy investments by setting an agreed fixed price – the strike price. The strike price is agreed in contracts with 15 years duration. When the market rate for electricity falls below this threshold, generators are paid the difference from a fund. Generators pay back to the fund when the market rate is higher than the fixed price. The contracts are awarded in auctions where the bids define the strike prices.

In general, solar PV and onshore wind have been very cost-effective, established technologies that were considered to require little government support. They were excluded from CfD auctions from 2015 until 2019. In the last auction they had been allocated a relatively small budget and a capacity cap in the CfD scheme with the main support focus shifting towards offshore wind. The average strike price for onshore wind was around 42 GBP/MWh[21]. All onshore wind projects awarded in the scheme were in Scotland. The combination of increasing CAPEX costs, increasing electricity prices, a low strike price, economic and supply chain uncertainty make it difficult to predict how the investments in these technologies will evolve.

In the case of onshore wind farms, early community engagement is important to avoid local opposition and mitigate any impact the wind farm may have on residents. Complaints are often associated with noise levels, TV signal reception issues, visual and landscape impact. There is also potential environmental impact to local habitats and wildlife. On the pros, the land surrounding wind turbines can still be used for farming and grazing animals. Local communities could benefit from low carbon, affordable electricity and even participate in the investment through community co-ownership models.

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15 Department of Levelling Up, Housing and Communities, Guidance on Renewable and low carbon energy. Particular planning considerations for hydropower, active solar technology, solar farms and wind turbines. Published 18 June 2015. Available at: https://www.gov.uk/guidance/renewable-and-low-carbon-energy#particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines

16 BRE, 2013, Planning guidance for the development of large scale ground mounted PV systems. Available at: https://files.bregroup.com/solar/KN5524_Planning_Guidance_reduced.pdf . Last accessed 13 July 2023.

17 See for example case studies in Solar Energy UKs, Ecological trends on Solar Farms report, available at: solarenergyuk.org/resource/solar-habitat-a-look-into-ecological-trends-on-solar-farms-in-the-uk.

18 Grimwood G.G., Mawhood B., Sutherland N., 2022, Large solar farms, CDP 2022/0052, House of Commons Library, UK: London. Available at : https://researchbriefings.files.parliament.uk/documents/CDP-2022-0051/CDP-2022-0051.pdf

19 Digest of UK Energy Statistics (DUKES) 2022, Chapter 6: renewable sources of energy. Available at: https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes. Last Accessed: 13 July 2023.

20 BEIS Feed-in Tariff annual regional wind load factors. Available at: https://www.gov.uk/government/publications/quarterly-and-annual-load-factors

21Wind Europe, UK awards almost 11 GW in biggest-ever national renewables auction (7 July 2022), Available at: https://windeurope.org/newsroom/news/uk-awards-almost-11-gw-in-biggest-ever-national-renewables-auction/ . Last Accessed: 13 July 2023

Microgrids in rural areas

The New City Plan should also consider the opportunity to create local and small-scale renewable energy systems, particularly in rural areas, that could serve local demand, such as microgrids. Microgrids can promote renewable energy usage, given that land suitable for solar, wind or small-scale hydropower is usually available in rural areas. Microgrids also improve the energy access for remote communities where traditional grid infrastructure is lacking, supporting essential services and businesses.

At the same time, implementing an energy generation system that can potentially operate autonomously off-grid, improves the reliability and independency of the electricity supply within remote areas that could be prone to power outages. Producing and consuming energy in the same location significantly reduces losses due to power transmissions, consequently improving the energy efficiency of the whole system. Realising microgrids in rural locations creates opportunities both in terms of new jobs and attraction of new economic activities in those areas.

Community Energy in Milton Keynes

Community energy is a development of the distributed energy concept and can be described as an integrated approach to meet the energy demand of a local community from renewable sources. Community energy covers aspects of collective action to reduce, purchase, manage and generate energy.

These projects have an emphasis on local engagement, local leadership and control, and the local community benefiting collectively from the outcomes. Community-led action can often tackle challenging issues around energy, with community groups well placed to understand their local areas and to bring people together with common purpose. There are many examples of community energy projects across the UK, with at least 5,000 community groups undertaking energy initiatives in the last five years.

Wolverton Community Energy operates in Milton Keynes. The organisation is non-profit, investing back profits within the local Wolverton area and the wider MKCC area, with a focus on fuel poverty. They fund their capital expenditures by offering opportunities to investors that are looking for commercial rates of return but want to make a difference to the local community, with 25 years of guaranteed revenue. The Wolverton community is consequently supplied with electricity at a stable price and can avoid price fluctuation due to external conditions.

Wolverton Community Energy is also strongly involved in energy efficiency and retrofit programmes that range from informative campaigns for tenants to providing energy assessment and managing LED lighting or building insulation projects.

They have a track record of seven completed projects for solar PV energy generation, with 16 different arrays and an overall peak power installed of 350 kWp. The community is also involved in a feasibility study for the Agora regeneration plan: this involves a solar PV installation opportunity of ~200kWp and integration in a microgrid with Air Source Heat Pumps (ASHPs) and batteries for 100 planned homes.

The Wolverton Community’s primary focus has been rooftop solar PV on both residential and commercial buildings, but solar farm feasibility studies are also in their pipeline. They have carried out heat source assessment, looking at river and ground sources for heat pumps but the preliminary results have shown unsuitability for a potential installation.

3.2.2.2 Geomodelling criteria

Based on the planning and viability considerations for each technology as described in the previous section, a series of land use constraints and exclusion criteria were used to estimate the suitable land for onshore wind power and ground-mounted solar PV as well as the suitable rooftop area for rooftop PV.

Roof-mounted solar PV

The rooftop solar generation potential has been estimated considering both existing and planned non-domestic buildings. In particular, four sets of non-domestic buildings have been identified:

- Existing
- Within Spatial Options (developed by Arup)
- Within Current Local Plan

- Within Future Local Plan (Call for Sites)

Existing non-domestic buildings within Milton Keynes boundaries have been identified at an individual building level by means of data cross-checking between the following databases:

- OS MasterMap Topography Layer
- OS AddressBase Core

The building footprint information is included within MasterMap Topography Layer while within AddressBase Core each building is classified by its typology. In the Ordnance Survey products, all buildings have a Topographic Identifier (TOID), a code that allows unequivocal identification of buildings. Data cross-checking has been used to associate each non-domestic building with their footprint. Assuming a flat roof for all non-domestic buildings, the total rooftop area has been calculated.

In order to estimate the total rooftop area for non-domestic buildings within the Spatial Options, the 'Total Employment Land Mid Scenario' from the HEDNA 2022 report has been used. The Mid Scenario includes a breakdown of building typologies with associated building area. The use class has been used to identify the non-domestic buildings suitable for rooftop PV installation and consequently the total rooftop area available.

The Current Local Plan and New City Plan (Call for Sites) have been developed by MKCC and submitted to Arup in the form of GIS compatible data. Within the plans, all the sites are classified by typology of use which allows us to identify all the non-domestic sites. In this case, the information was not available at an individual building level and therefore assumptions have been made in terms of Building-to-Site ratio, which represents the ratio between the area occupied by the building's footprint on the total area of the site. In particular, a scenario with a 20% ratio and a scenario with a 40% ratio were applied.

For all the four non-domestic building datasets, the net available roof area to host PV panels was calculated by using the following assumptions:

- 30% roof area reduction due to panel spacing and access and maintenance clearances;
- 50% reduction due to shading; and
- 20% reduction due to optimism bias.
- As a result, the ratio between net and gross available rooftop area is 28%.

Ground-mounted solar PV

The land suitable for ground-mounted PV installation was calculated by applying exclusion areas within the MKCC boundary. A full list of land constraints has been developed and listed within Table 10 below.

Table 10: Constraints used to evaluate the Ground Mounted Solar PV and Onshore Wind potential.

Data	Rationale
Ramsar sites	Land designations excluded based on the following: Conservation of Habitats & Species Regulations 2010 Wildlife and Countryside Act 1981 National Planning Policy Framework (NPPF) Natural Environment and Rural Communities Act
Special Protected Areas (SPAs)	
Special Areas of Conservation (SACs)	
Special Site of Scientific Interest (SSSI)	
Areas of Outstanding Natural Beauty (AONB)	
National Parks	
National Nature Reserves	
Local Nature Reserves	
England Green Belt	

Data	Rationale
Agricultural Land Category (ALC) Grade 1-2-(3)	Excellent (Grade 1) and Very Good (Grade 2) quality agricultural land are unsuitable for ground-mounted PV and onshore wind installations based on the following policies: A Green Future: Our 25 Year Plan to Improve the Environment NPPF Town and Country Planning (Development Management Procedure (England) Order) (DMPO) 2015 NPPG for the Natural Environment
Ancient & Priority Habitats Woodland	The Natural England and Forestry Commission 'standing advice' is that ancient woodlands are defined as irreplaceable habitats with natural and heritage value. They have equal protection in the NPPF for all UK nations.
World Heritage Sites, Scheduled Monuments	World Heritage Sites are landmarks or areas of international importance designated by UNESCO. Land designations excluded in line with: - NPPF The Convention Concerning the Protection of World Cultural and Natural Heritage National Heritage Act 1989 Ancient Monuments and Archaeological Areas Act, 1979
Ministry of Defence (MOD) territories	Unsuitable land for ground-mounted and onshore wind installations
Greenspaces (Parks, gardens, cemeteries, recreational spaces, etc)	Greenspace data covers areas such as allotments, cemeteries, playing fields and public parks. These land uses already hold significant natural and public value so are not best suited for ground mounted solar PV.
Urban / Built up areas	Planning portal guidance for standalone solar equipment (not on a building) states it should be sited, so far as is practicable, to minimise its effect on the amenity of the area. Typically, a 20m buffer zone is allocated around urban areas to also minimise the impact of shading from buildings (based on Arup project experience). Certain academic studies consider greater distance from urban areas an important factor as it can reduce competition with urban development and avoids the 'not-in-my-backyard' opposition from residents (Castillo et al., 2016; Janke, 2010). Planning Permission: Stand-alone solar equipment (panels not on a building but within the grounds of a house or a block of flats) - Solar panels - Planning Portal All Urban/Built up areas comprehensive of Existing and Planned buildings have been excluded.
All Inland Waters	Industry best practice suggests that although potentially suitable for floating solar PV, a minimum distance of 10m from surface water bodies to ground-mounted PV arrays should be considered as a good practice measure to account for potential water body overflow, and to minimise impact on the water body in terms of contaminants, noise and vibration during construction.
All Woodland	Woodlands are not suitable land for developing ground solar PV due to the existing habitat and potential presence of species protected under the following: Conservation of Habitats & Species Regulations 2017 Wildlife and Countryside Act 1981 NPPF

Industry best practice and policy recommendations state a buffer should be applied to certain land uses when conducting site selection studies for ground solar. The minimum distance stated was 10m from surface waters and roads, and 20m from urban areas.

In order to account for potential constraints adjacent to, but outside, the Milton Keynes boundary, a buffer of 20m has been applied to ensure minimum distances are always kept.

Subsequently, a more conservative scenario and a less conservative scenario for suitable land estimation have been developed by using the Flood Maps and ALC 3 as additional exclusion criteria:

- Scenario 1 (Conservative): excluding Flood areas from river, sea, surface water and ALC 3; and
- Scenario 2 (Less conservative): including Flood areas from river, sea, surface water and ALC 3.

By applying the exclusion criteria within Table 1 and considering buffer zones, the suitable land has been identified and the ground-mounted PV theoretical capacity and electricity generation potential calculated.

Onshore wind power

To identify opportunities for onshore wind turbines within Milton Keynes, the number of wind turbines that could reasonably fit within the suitable land was estimated. These estimations were based on industry “typical” turbine sizes, i.e., the Vestas 3MW wind turbine, which has a rotor diameter of 100 m and a hub height of ~100 m. The suitable land was estimated by excluding the land areas based on the geomodelling exclusion criteria as described in the previous section3.2.2.2. Land in proximity to major settlements was excluded using a 600m buffer distance. Land around main roads was also excluded using a buffer distance based on the assumed hub height of the turbines.

Subsequently, a more conservative scenario and a less conservative scenario for suitable land estimation have been developed by using the Flood Maps and ALC 3 as additional exclusion criteria:

Scenario 3 (conservative): Excluding Flood areas from river, sea, surface water and ALC 3; and

Scenario 4 (less conservative): Including Flood areas from river, sea, surface water and ALC 3.

Onshore wind turbines are optimally spaced between 7 and 15 rotor diameters apart; therefore, the land footprint for each turbine was determined assuming a spacing of 10 rotor diameters (e.g. rotor diameter of 100m would mean each turbine requires a 1000m x 1000m (1.0 km2) footprint). The suitable land area was overlayed with a relevant grid that represented the spacing of the turbines on land. This was used to estimate the number of turbines which could fit into the available area.

The NOABL Wind Speed Database[22] was used for the preliminary assessment of wind speeds at 45m height, with a grid resolution of 1km^2.

This dataset was originally commissioned by BERR (Department for Business Enterprise & Regulatory Reform) and generated by the Hadley Center. It is based on data collected between 1975 and 1985 and it does not account for local topography and local surface impact (such as trees) on the wind speeds.

It is considered however that it is suitable for preliminary, high-level assessments as suggested in the Renewable and Low-carbon Energy Capacity Methodology for the English Regions[23]. Based on that methodology the wind speed limit requirement for onshore wind is 5m/s at 45m above ground level (i.e. consider areas with wind speed at and above 5m/s).

22 NOABL wind speeds mapped by RenSMART, Available at https://www.rensmart.com/Maps, Last Accessed 06 Oct 2023.

23 SQWenergy (commissioned by DECC and CLG) (2010) Renewable and low-carbon energy capacity methodology for the English Regions, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/226175/renewable_and_low_carbon_energy_capacity_methodology_jan2010.pdf

As shown in Figure 53, the average wind speed within the Milton Keynes area ranges between 5.6m/s and 7m/s, exceeding the 5m/s threshold at 45m above ground and therefore can be considered suitable for wind energy generation.

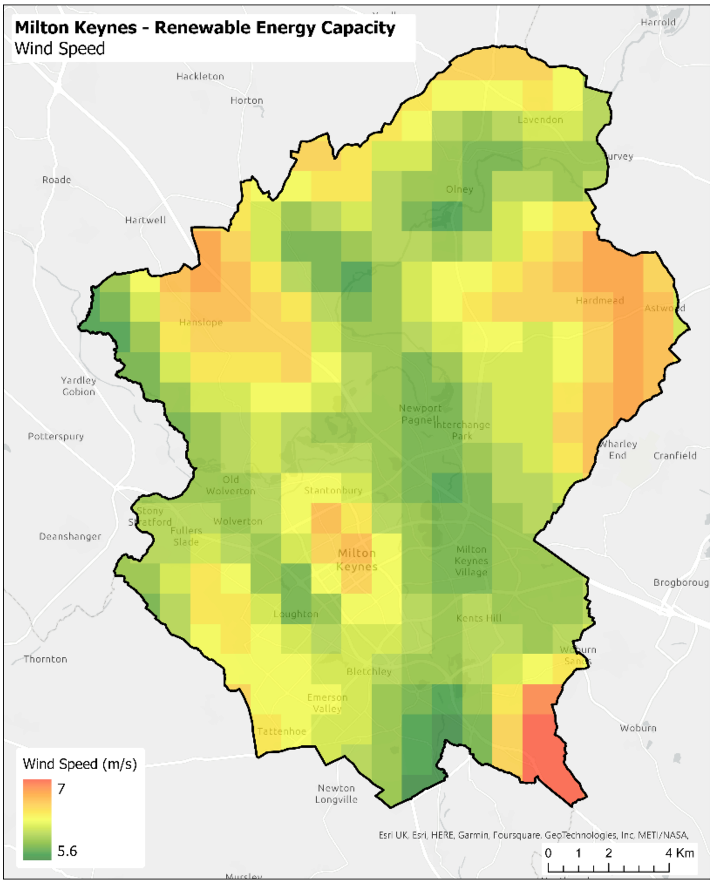

Figure 53: NOABL wind speed database output with 1km2 grid resolution for the area of Milton Keynes.

Wind direction at Milton Keynes is primarily distributed towards North-West / West-North-West as shown by the wind rose in Figure 54, obtained from the Cranfield EGTC Weather Station in Milton Keynes.

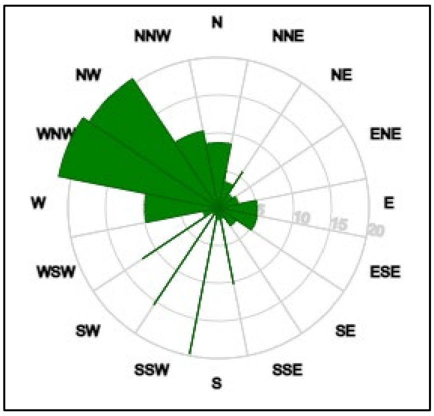

Figure 54: Wind rose from Cranfield EGTC Weather Station, Milton Keynes City Council.

3.2.2.3 Energy modelling

Roof-mounted solar PV

The net available rooftop area of the non-domestic buildings' datasets, as estimated in Section 3.2.2.2, is used as input for the rooftop PV capacity assessment. Industry Standard figures complemented by Arup internal benchmarks have been assumed for the calculation. A full list is provided below:

- PV panel assumed is a typical commercial panel with the following specifications[24]:
- Dimensions of 1700mm by 1000mm, area of 1.7m^2
- Nominal maximum power of 340W
- PV panel is installed at a 15°degree slope on flat roofs
- PV panel orientation is assumed as follows:
- 25% East facing
- 25% West facing
- 50% South facing
- System losses are at 14%, representing losses in cables, power inverters, dirt and loss of power due to aging of the panels
- Yearly specific PV energy production (kWh/kWp) in the Milton Keynes area has been calculated via PVGIS tool[25] assuming panel orientation, slope and system losses as per above, with a final output of 863 kWh/kWp
- Optimism bias factor of 20% has been assumed.

The number of panels that could suitably cover the net rooftop area of non-domestic buildings and consequently the total PV power installed (MW) and total annual energy produced (GWh) is calculated by using the assumptions and specifications listed above.

Ground-mounted solar PV

The land areas identified by the geospatial modelling as suitable for ground-mounted solar PV are used as input for the ground-mounted PV capacity assessment.

Industry Standard figures complemented by Arup internal benchmarks have been assumed for the calculation. A full list is provided below:

- Solar farm power density in UK can range from 0.5MW/ha to >1.0MW/ha. Industry-based standard value of 0.7MW/ha is assumed, accounting for spacing between PV panel arrays, access and maintenance allowance and installation clearances, shading[26];
- PV panel is installed at a 20°degree slope on flat land to minimise shading between panel arrays;
- PV panel orientation is assumed as 100% South-facing;
- System losses are at 14%, representing losses in cables, power inverters, dirt and loss of power due to aging of the panels;
- Yearly specific PV energy production (kWh/kWp) in the Milton Keynes area has been calculated via PVGIS tool assuming panel orientation, slope and system losses as per above, with a final output of 968 kWh/kWp; and
- Optimism bias factor of 20% has been assumed.
- The total PV power installed (MW) and total annual energy produced (GWh) is calculated by using the total suitable land together with the assumptions and specifications listed above.

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24 Rooftop PV panel datasheet. Available at: https://www.canadiansolar.com/wp-content/uploads/2019/12/Canadian_Solar-Datasheet-HiKu_CS3L-P_EN.pdf

25 European Commission, EU Science Hub, PVGIS (Photovoltaic Geographical Information System), SOLAREC Action, JRC Renewable Energies Unit for Geographical Assessment of the Solar Energy Resource. Available at: https://re.jrc.ec.europa.eu/pvg_tools/en/.

26 Planning and solar farms. Available at: https://researchbriefings.files.parliament.uk/documents/CDP-2023-0168/CDP-2023-0168.pdf

Onshore wind power

The total number of turbines for each scenario that have been identified within the Geomodelling section are used as input to assess the potential electricity generation from onshore wind.

Industry Standard figures complemented by Arup internal benchmarks have been assumed for the calculation. A full list is provided below:

- Wind turbine assumed is a typical Vestas turbine with a power rating of 3MW[27]; and
- Load factor, representing the ratio between the actual output and the maximum theoretical output of a turbine, is assumed 26.8% as per London & Southeast area average between 2014 – 2022[28].

The total onshore wind power installed (MW) and total annual energy produced (GWh) is calculated by using the total number of turbines together with the assumptions and specifications listed above.

Integrated solution for onshore renewables

The methodologies for ground-mounted PV and onshore wind capacity estimation, as described above, are looking at the two technologies as if they were to be installed alternatively on the same suitable land in a "non-cumulative" way. However, the land usage could be optimised by integrating the two technologies together on the same suitable land, in a way that the final installed power could be increased cumulatively.

For the purpose of this analysis, cumulative and non-cumulative scenarios have been evaluated for the two onshore renewable technologies.

Within the non-cumulative scenario, it was considered that each land field area identified as suitable for both ground-mounted solar PV and onshore wind has an equal probability to be used for each technology. This means that the total power potential for each technology is not cumulative for the area of study as some suitable land field areas will be overlapping.

Within the cumulative scenario, it was considered that ground-mounted solar PV and onshore wind can be integrated and installed together within the same suitable land. To enable that, the following considerations have been used for the estimation of the total power potential:

- Average annual shading of the wind turbine rotor and tower over the ground-mounted PV panels, including flickering of the wind turbines blades as they rotate; and
- Clearance around wind turbine for assembly/replacement operations of components.

In summary, in order to enable wind turbine installation on the same land as ground-mounted PV, and therefore obtain a final cumulative installed power of the two technologies, a proportion of panels will need to be sacrificed to make space for the turbines and at the same time, the wind turbine shading will compromise some of the panels' efficiency.

3.2.3 Results

The local electricity generation is a high-level estimation based on the potential capacity according to land area calculations, relevant industry benchmarks and resource potential. Actual generation would be dependent on a more detailed, technical site-specific study, planning considerations, landscape impact, grid connections and engagement with relevant stakeholders.

The total renewable energy potential in Milton Keynes in conjunction with energy storage, load/demand matching and low carbon electricity from the grid could help reduce emissions drastically and facilitate sustainable growth with combined financial and health benefits for the local communities.

It should be noted that the total generation potential does not usually mean that peak and hourly demand can be met by local renewable energy systems alone. The matching of load and demand will affect any local storage capacity requirements and the amount of electricity still used from the national grid. Decentralised

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27 Vestas wind turbine datasheet. Available at: https://www.vestas.com/content/dam/vestas-com/global/en/sustainability/reports-and-ratings/lcas/LCA_V903MW_version_1_1.pdf.coredownload.inline.pdf

28 BEIS Feed-in Tariff annual regional wind load factors. Available at: https://www.gov.uk/government/publications/quarterly-and-annual-load-factors

energy generation with local storage and use will increase the energy resilience of the communities and it will enable cost optimisation based on the grid electricity prices, demand and available supply.

When considering integration of batteries with roof-mounted PV systems in non-domestic buildings, despite the advantages of peak shaving, load shifting and energy supply resilience described above, considerations around capital costs, space requirements and maintenance needs also to be taken into account on a case-by-case basis. Those will eventually establish the project techno-economic feasibility.

In addition to this, the annual energy production factor from solar in the UK is relatively low. The base electrical demand from the non-domestic buildings served could generally be higher than the electricity generated by the panels, reducing the usage of batteries and consequently, their benefits.

3.2.3.1 Roof-mounted solar PV

The geospatial analysis has identified the potential suitable rooftop area for PV panel installation in existing and planned non-domestic buildings. By applying the calculation methodology and assumptions described in the energy modelling Section 2.3, the final power capacity and generation potential for rooftop PV have been calculated. Results are presented in Table 2 for the 20% building-to-site ratio scenario for Local Plans and Table 3 for the 40% building-to-site ratio scenario.

Table 11: Rooftop PV potential of existing and planned buildings in Milton Keynes with 20% building-to-site ratio for Local Plans.

Dataset	Rooftop area	Rooftop area available for PV	Rooftop PV capacity	Annual rooftop PV generation
	m2	m2	MWp	GWh/yr
Current Local Plan (20% building-to-site ratio)	308,000	86,300	17.3	14.9
New City Plan (Call for Sites, 20% building-to-site ratio)	2,970,000	831,000	166.0	144.0
Spatial Options (HEDNA)	37,900	10,600	2.1	1.8
Existing non-domestic buildings	4,690,000	1,310,000	262.0	227.0
Total	8,000,000	2,240,000	448.0	387.0

Table 12: Rooftop PV potential of existing and planned buildings in Milton Keynes with 40% building-to-site ratio for Local Plans

Dataset	Rooftop area	Rooftop area available for PV	Rooftop PV capacity	Annual rooftop PV generation
	m2	m2	MWp	GWh/yr
Current Local Plan (40% building-to-site ratio)	616,000	173,000	34.5	29.8
New City Plan (Call for Sites, 40% building-to-site ratio)	5,940,000	1,660,000	332.0	287.0
Spatial Options (HEDNA)	37,900	10,600	2.1	1.8
Existing non-domestic buildings	4,690,000	1,310,000	262.0	227.0

Dataset	Rooftop area	Rooftop area available for PV	Rooftop PV capacity	Annual rooftop PV generation
	m2	m2	MWp	GWh/yr
Total	11,300,000	3,160,000	632.0	545.0

Fossil fuel-free new developments are expected to have a significant amount of electricity demand met by local renewable generation. The advantage of new developments is that building density and layout can be decided at an early design stage to maximise the rooftop solar PV installed capacity.

3.2.3.2 Ground-mounted solar PV

The geospatial analysis has identified the potential suitable land area for ground-mounted PV within Milton Keynes. By applying the calculation methodology and assumptions described in the energy modelling Section 1.2.3, the final power capacity and generation potential for ground-mounted PV have been calculated. Scenarios 1 and 2 of the suitable land have been developed as described in Section 1.2.2.

In addition, the proximity to existing substations has been evaluated through a 'land-to-substation' distance parameter (km) and visualised via a heatmap. Industry practice shows that 3 kilometres is generally a threshold above which network distribution losses and cable length become excessive and do not ensure an energy efficient and economical connection to the grid.

Only the location of existing substations has been considered within this study. Energy generation plants can also have a dedicated substation to be designed and built with the energy centre upon a detailed technoeconomic assessment.

The vast majority of the MKCC administrative area is served by the National Grid while very limited areas at the council boundaries would fall under UKPN. Distribution Network Operator's (DNO)s Network Capacity Maps have been used to identify the location of all the substations[29] that a renewable energy generation plant in Milton Keynes would potentially use to connect to the grid. Substations falling outside of the Council boundaries have been also taken into account; given their location falls at a distance > 3km from the suitable land identified, they do not impact the findings.

Results are shown within Figure 55 for Scenario 1, which exclude Flood Map zone for rivers, surface water and ALC 3 from the suitable land and Figure 56 for Scenario 2 which includes Flood Map zone for rivers, surface water and ALC 3 within the suitable land.

29 National Grid's and UKPN's Network Capacity Map. Available at: https://www.nationalgrid.co.uk/our-network/network-capacity-map-application and https://ukpowernetworks.opendatasoft.com/pages/network-infrastructure-usage-map/howto

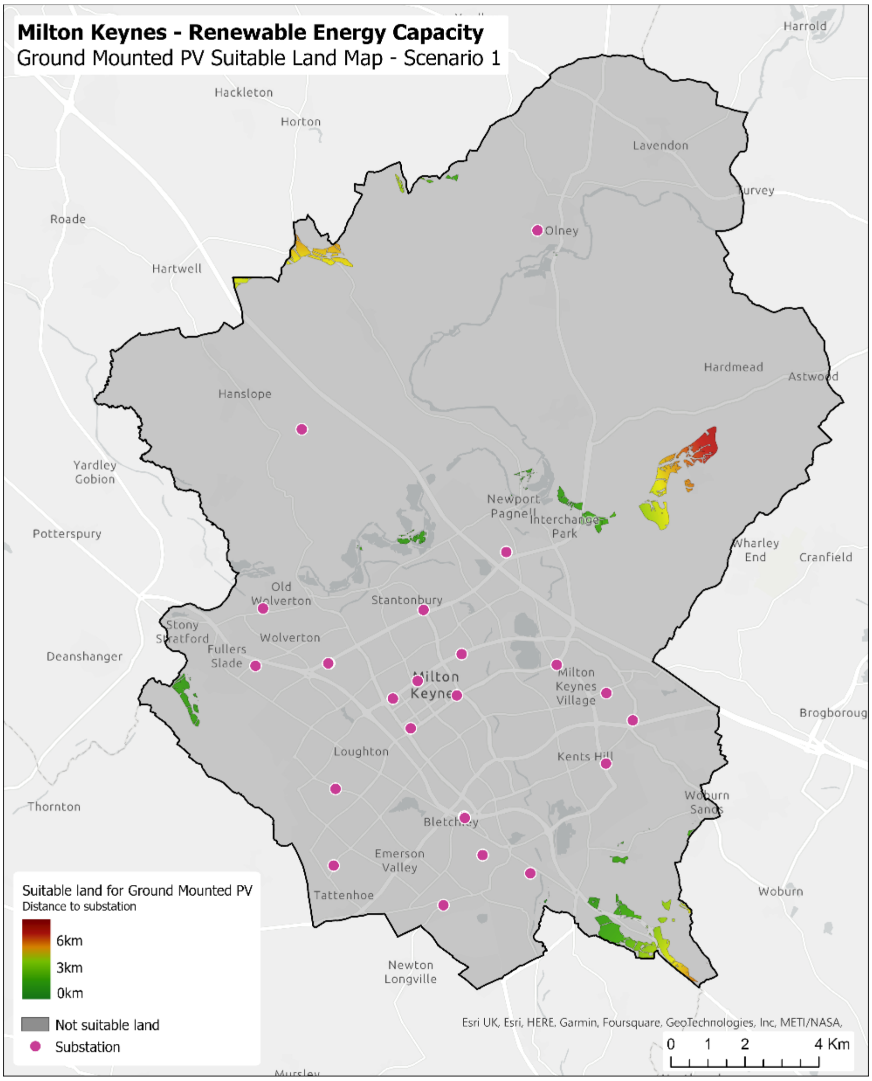


Figure 55: Ground-mounted solar PV potential suitable land Scenario 1, excluding flood map zones from rivers, surface water and ALC 3

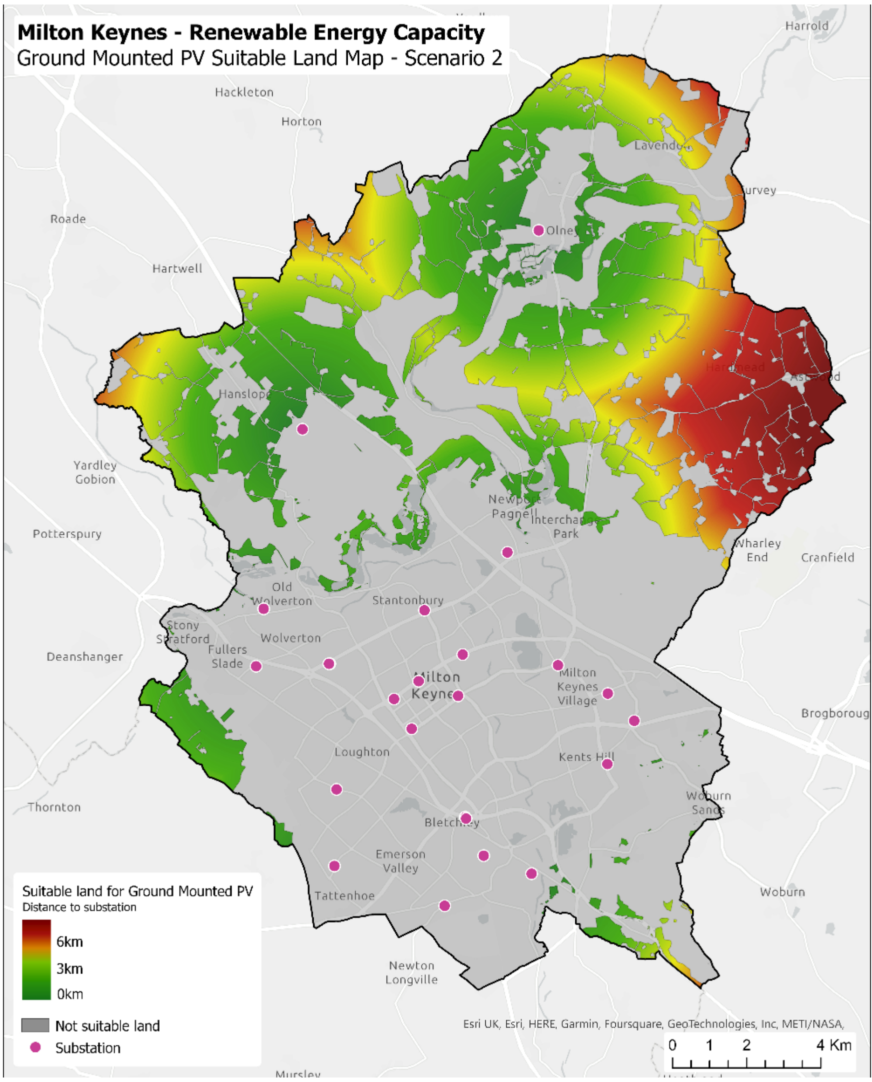


Figure 56: Ground-mounted solar PV potential suitable land Scenario 2, including flood map zones from rivers, surface water and ALC 3

The following information is shown within the Figure 55 and Figure 56 heat maps:

- 'Grey area': land considered unsuitable for ground mounted PV installation.
- 'Magenta dots': the existing substation location.
- 'Green-yellow-red area': land considered suitable for ground mounted PV installation, colour-coded according to the distance from existing substations, in particular:
    - 'Green' < 3km distance
    - 'Yellow' 3km < distance < 4.5km
    - 'Red' > 4.5km distance.

Total power capacity and energy generation results are presented in Table 13. As expected, excluding Flood zones and ALC 3 leads to a reduction of the total ground-mounted PV generation potential.

Table 13: Ground-mounted solar PV potential capacity and generation.

Suitable land	Suitable land area	Solar power capacity installed	Annual energy generated
	km2	MW	GWh/yr
Scenario 1	3.9	217	211
Scenario 2	107.0	6’000	5’810
Scenario 1’ (consider only land at a distance < 3km from existing substations)	1.4	78	75
Scenario 2’ (consider only land at a distance < 3km from existing substations)	36.0	2’020	1’960

As discussed previously, a ground-mounted PV farm to be located at a distance of > 3km from an existing substation would require a dedicated substation to be built. For these reasons, within Table 13, Scenario 1’ and Scenario 2’ are presented as subsets of Scenario 1 and Scenario 2 respectively; in this instance, only the suitable land at a distance < 3km from substations is used to compute the power capacity and annual energy generation.

It is also noteworthy that the suitable land across the different scenarios will likely be further reduced when considering the visual impact from the effect of glint and glare on the landscape, on neighbouring uses and aircraft safety during the planning process.

3.2.3.3 Onshore wind power

The suitable land areas identified for wind power and ground-mounted solar PV technologies will overlap largely as they have used the same exclusion criteria with the only variation being different buffer zones. By applying the calculation methodology and assumptions described in the energy modelling Section 3.2.2.2, the final power capacity and generation potential for onshore wind has been calculated based on the final number of wind turbines that can be hosted within the suitable land. Two scenarios, Scenario 3 and Scenario 4, have been developed as described in Section 3.2.2.2.

The proximity between wind turbines and substations has been evaluated following the same logic and methodology described within the ground-mounted PV Section.

Results are shown within Figure 57 for Scenario 3, which exclude Flood Map zone for rivers, surface water and ALC 3 from the suitable land and Figure 58 for Scenario 4 which includes Flood Map zone for rivers, surface water and ALC 3 within the suitable land.

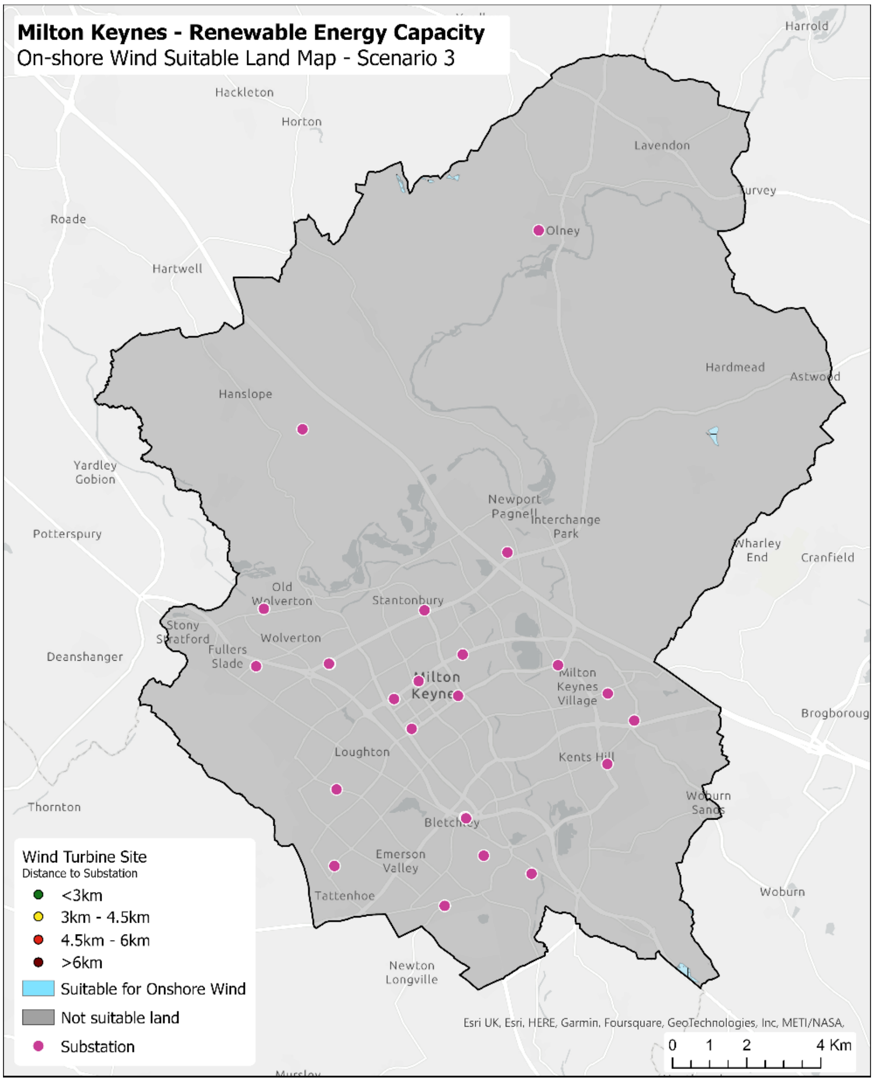


Figure 57: Potential for onshore wind power installations, Scenario 3. Siting of wind turbines (3MW) in the case of suitable land area with exclusion of flood map zones from rivers, surface water and ALC 3.

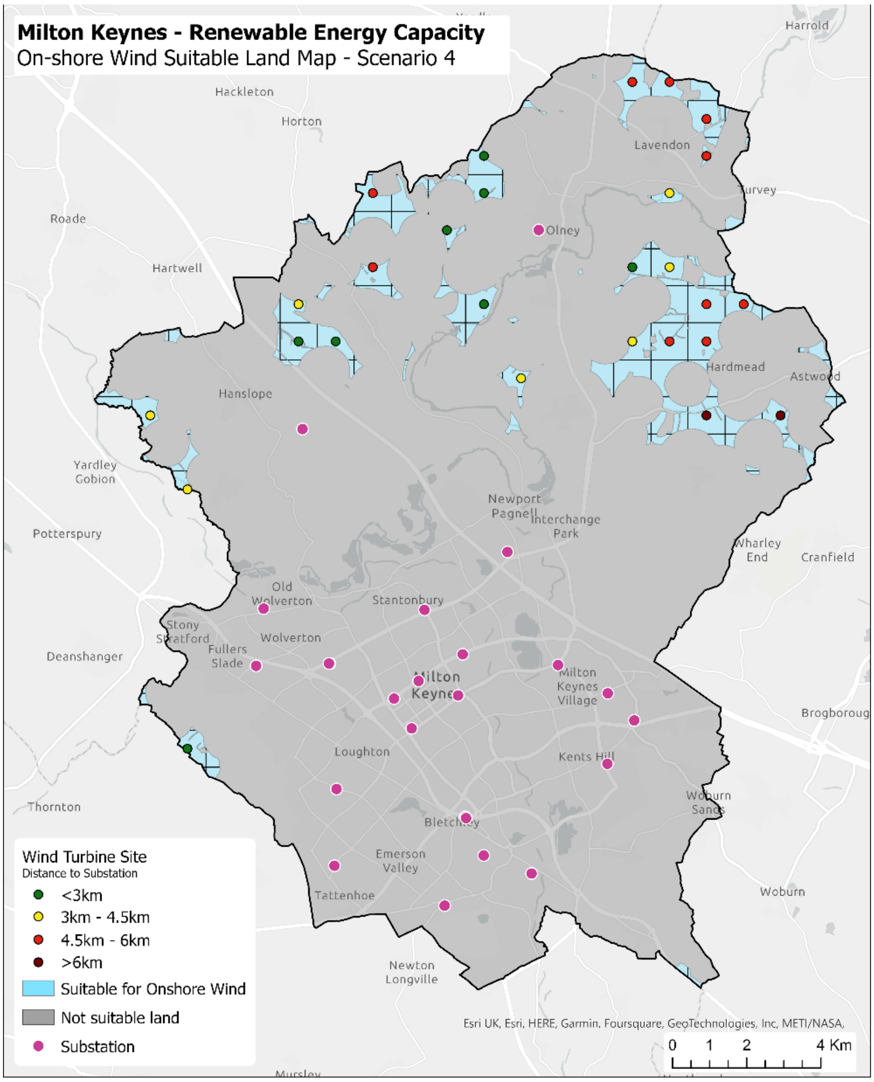


Figure 58: Potential for onshore wind power installations, Scenario 4. Siting of wind turbines (3MW) in the case of suitable land area with inclusion of flood map zones from rivers, surface water and ALC 3.

The following information are shown within the Figure 57 and Figure 58 heat maps:

- ‘Grey area’: land considered unsuitable for wind turbine installation;
- ‘Magenta dots’: the existing substation location;
- ‘Light-blue area’: land considered suitable for wind turbine installation;
- Color-coded dots, representing the (single) wind turbine location, according to the distance from existing substations:
  - ‘Green’ < 3km distance
  - ‘Yellow’ 3km < distance < 4.5km
  - ‘Red’ > 4.5km distance.

Total power capacity and energy generation results are presented in Table 14. By excluding flood zones and ALC 3, there is no land considered suitable for wind turbines installation.

Table 14: Onshore wind power capacity potential and generation.

Suitable land	No. of turbines based on available land	Onshore wind power capacity installed		Annual energy generated
	-	MW		GWh/yr
Scenario 3	0	0		0
Scenario 4	27	81		190
Scenario 4' (consider only turbines at a distance < 3km from existing substations)	8	24		56

As discussed within Section 3.2.2.2, for an onshore wind farm to be located at a distance of > 3km from an existing substation would require a dedicated substation to be built. For these reasons, within Table 14, Scenario 4' is presented as a subset of Scenario 4; in this instance, only the suitable land at a distance < 3km from substations is used to calculate the power capacity and annual energy generation.

It is also noteworthy that the number of wind turbines may be reduced further due to additional restrictions regarding landscape sensitivity and planning considerations. Wind turbines could also be integrated with agricultural and farming activities and be sited on the same land; this is generally not suitable for ground-mounted solar PV farms that can be potentially only used for grazing.

3.2.3.4 Combined Ground-mounted PV and onshore wind

As described above, it is possible to integrate solar and wind onshore technologies together on the same suitable land following consideration of shading and clearances around turbines. By applying the methodology described within Section 3.2.2.2, the ground-mounted PV area has been reduced to account for wind turbines colocation and results are presented across the two scenarios. Given results of Table 14 and the absence of suitable land for wind turbine within Scenario 3, only Scenario 2 and 4 have been considered. Table 15 reports the ground-mounted PV area reduction and consequent power capacity and energy generation.

Table 15: Ground-mounted solar PV potential capacity and generation, reduced to account for wind turbines colocation.

Suitable land	Suitable land area	Solar power capacity installed	Annual energy generated
	km2	MW	GWh/yr
Scenario 2a	106.7	5'980	5'790
Scenario 2'a (consider only land at a distance < 3km from existing substations)	35.9	2'010	1'950

Generation potential from 'reduced' ground-mounted PV and co-located onshore wind turbines have been combined together in Table 16, which reports the cumulative scenarios. By combining solar and wind technology together it is possible to maximise the renewable energy generation within the Milton Keynes area. Table 16 figures have been obtained by combining the power capacity and annual energy generation figures of Table 15 with the ones of Table 14.

Table 16: Ground-mounted solar PV and onshore wind colocation potential capacity and generation.

Suitable land	Solar & wind combined power capacity installed	Annual solar & wind combined energy generated
	MW	GWh/yr
Scenario 2b	6’060	5’980
Scenario 2’b (consider only land at a distance < 3km from existing substations)	2’040	2’010

3.2.3.5 Results comparison

The annual generation potential results obtained across the three renewable energy technologies analysed have been related to the following Milton Keynes specific figures:

- Milton Keynes forecasted electricity consumption, estimated to reach 1’689 GWh/yr in 2031
- Milton Keynes household typical electricity consumption, reported as 2’737 kWh/yr in 2021
- The final summary of results in relation to consumption figures of Milton Keynes is shown within Table 17.

Table 17: Summary of Renewable Energy Generation in Milton Keynes.

	Total annual energy produced	Percentage of total Milton Keynes demand met	Number of households supplied
	GWh/yr	%	-
Rooftop PV on non-domestic buildings (20% building-to-site ratio for city plans)	387	23%	141’000
Rooftop PV on non-domestic buildings (40% building-to-site ratio for city plans)	545	32%	199’000
Scenario 1 (ground-mounted PV more conservative scenario)	211	12%	77’000
Scenario 2 (ground-mounted PV less conservative scenario)	5’810	344%	2’123’000
Scenario 1’ (consider only land at a distance < 3km from existing substations in Scenario 1)	75	4%	27’000
Scenario 2’ (consider only land at a distance < 3km from existing substations in Scenario 2)	1’960	116%	716’000
Scenario 3 (onshore wind more conservative scenario)	0	0%	0
Scenario 4 (onshore wind less conservative scenario)	190	11%	69’000
Scenario 4’ (consider only turbines at a distance < 3km	56	3%	20’000

	Total annual energy produced	Percentage of total Milton Keynes demand met	Number of households supplied
	GWh/yr	%	-
from existing substations in Scenario 4)			
Scenario 2b (colocation of ground mounted PV and onshore wind)	5’980	354%	2’185’000
Scenario 2’b (consider only land at a distance < 3km from existing substations in Scenario 2b)	2’010	119%	734’000

Table 17 shows that ground-mounted solar alone in scenarios which include ALC 3 and flood areas (Scenarios 2 and 2’) could potentially meet and exceed the totality of the Milton Keynes electricity demand in 2031. This result is to be seen in conjunction with other considerations: the suitable land for ground-mounted PV will likely be further reduced when considering the visual impact from the effect of glint and glare on the landscape, on neighbouring uses and aircraft safety during the planning process. The solar parks’ feasibility would also be dependent on a more detailed, technical site-specific study, planning considerations, landscape impact, grid connections and engagement with relevant stakeholders.

Colocation of wind turbines within the same suitable land designated for ground-mounted PV is applicable in the “less-conservative” scenarios only (Scenarios 2b and 2’b). Integrating the two technologies leads to a contained increase of the total generation potential of around 3%.

The current housing stock in Milton Keynes is 123’264 units (June 2023[30]). Considering results in Table 17, the electricity generated from rooftop PV on non-domestic buildings would potentially be able to fulfil the electricity demand from all the existing Milton Keynes households.

In summary, rooftop PV, ground mounted PV and onshore wind technologies can be considered as concurrent to the total renewable electrical energy generation. This study shows that the three renewable technologies analysed within this study could potentially meet the total electricity demand within the MKCC area in 2031.

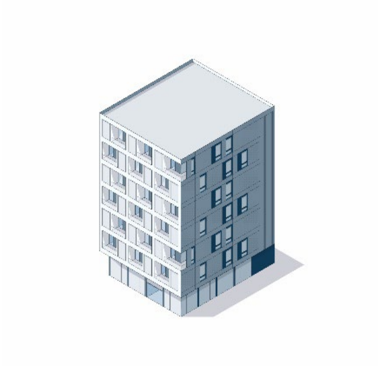
30 Milton Keynes Housing Statistics. Available at: https://www.milton-keynes.gov.uk/your-council-and-elections/statistics/housing-statistics#:~:text=Housing%20stock%20in%20the%20borough,in%20MK's%20urban%20areas%20%3D%20105%2C321

3.3 Net Zero Carbon Buildings

3.3.1 Five future building typologies

Building specifications are presented for each typology based on current Building Regulations, Future Homes Standard and a high-ambition case represented with the LETI guidance requirements. RIBA Good Practice (2021), RIBA 2030 Climate Challenge, LETI guidance and Passive House targets for energy use have been included where available to inform the decision on the level of energy performance requirements above Building Regulations and the pace of the transition aspired to in future planning requirements. In terms of energy performance, there are no differences expected between the market sale and affordable housing options for the selected 2-bedroom flat typology. High performance affordable housing should make it easier for tenants/homeowners to heat to achieve comfort and cheaper to run overall.

Figure 59: Two bedroom flat typology (market)



Typical type and GIA

2 Bedroom (3-4 people) 69 – 80m^2

Design measures

- Rooftop PV and/or building integrated PV if feasible and viable.
- Green roofs in areas with high urban heat intensity – flooding risks
- Building level measures – Central ASHP – thermal storage if feasible
- External seasonal shading to protect from overheating.
- Indicative Form factor (heat loss, external surface area / Treated Floor Area) ≤ 3 (or as low as possible)

LETI guidance

EUI = 35 kWh/m^2.yr (excluding renewable energy contribution) | Space Heating demand: 15 kWh/m^2.yr | Hot water demand : 10 kWh/m^2.yr | Embodied carbon = 300 kgCO$_2$e/m^2 (200 kgCO$_2$e/m^2 incl. sequestration)

RIBA Good Practice (2021)/ Reference

EUI < 60 kWh/m^2.yr (including renewable energy contribution, no gas boilers) | Potable water : 110 l/p/day | Embodied carbon

RIBA 2030 challenge

EUI < 35 kWh/m^2.yr (including renewable energy contribution) | Potable water : < 75 l/p/day | Embodied carbon < 625 kgCO$_2$e/m^2

Passive House

Primary EUI ≤ 60 kWh/m^2.yr | Heating demand = 15 kWh/m^2.yr | Hot water demand : 25 l (@60ºC)/p/day | Embodied carbon : encourages “optimisation”

CRREM

EUI = 55 kWh/m^2.yr

Building specifications

	Future Homes Standard (2025, Consultation) – Min standards	LETI Guidance
External Walls	U = 0.26 W/(m^2.K)	U = 0.13 – 0.15 W/(m^2.K)
Floors	U = 0.18 W/(m^2.K)	U = 0.08 – 0.10 W/(m^2.K)
Roofs	U = 0.16 W/(m^2.K)	U = 0.10 – 0.12 W/(m^2.K)
Windows	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Doors	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Air tightness (@50Pa)	8.0 m^3/(h.m^2)	<1.0 m^3/(h.m^2)

Figure 60: Three bedroom semi-detached typology (market)

Typical type and GIA

3 Bedroom (4-6 people) 86 - 110m^2

Design measures[31]

-
- Consideration of orientations for solar gains and rooftop PV.
- ~3.5kWp rooftop PV capacity and battery storage provisions (“battery ready”)
- Seasonal shading to avoid overheating.
- Building form – compactness: Surface area to volume (A/V ratios ≤ 0.7m2/m3)
- Indicative Form factor (heat loss, external surface area / Treated Floor Area) ≤ 3 .

LETI guidance

EUI = 35 kWh/m^2.yr (excluding renewable energy contribution) | Space Heating demand: 15 kWh/m^2.yr | Hot water demand : 10 kWh/m^2.yr | Embodied carbon = 300 kgCO_2e/m^2 (200 kgCO_2e/m^2 incl. sequestration)

RIBA Good Practice (2021)/ Reference

EUI < 60 kWh/m^2.yr (including renewable energy contribution, no gas boilers) | Potable water : 110 l/p/day | Embodied carbon

RIBA 2030 challenge

EUI < 35 kWh/m^2.yr (including renewable energy contribution) | Potable water : < 75 l/p/day | Embodied carbon < 625 kgCO_2e/m^2

Passive House

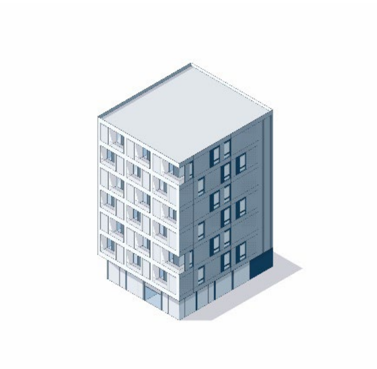
Primary EUI ≤ 60 kWh/m^2.yr | Heating demand = 15 kWh/m^2.yr | Hot water demand : 25 l (@60ºC)/p/day | Embodied carbon : encourages “optimisation”

Building Specifications

	Future Homes Standard (2025, Consultation) – Min standards	LETI Guidance
External Walls	U = 0.26 W/(m^2.K)	U = 0.13 – 0.15 W/(m^2.K)
Floors	U = 0.18 W/(m^2.K)	U = 0.08 – 0.10 W/(m^2.K)
Roofs	U = 0.16 W/(m^2.K)	U = 0.10 – 0.12 W/(m^2.K)
Windows	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Doors	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Air tightness (@50Pa)	8.0 m^3/(h.m^2)	<1.0 m^3/(h.m^2)

[31] BRE – Passivhaus primer: Designer’s guide available from https://passivehouse-international.org/upload/BRE_Passivhaus_Designers_Guide.pdf

Figure 61: Two bedroom flat typology (affordable)



Typical type and GIA

2 Bedroom (3-4 people) 65 - 80m^2

Design measures

- ≤ 12 affordable dwellings in one block (exemption for areas with density much higher than average).
- "tenure blind" developments. Design and materials used and amenity provided should be characteristic of the rest of development.
- Other measures as in "market sale" typology.

LETI guidance

EUI = 35 kWh/m^2.yr (excluding renewable energy contribution) | Space Heating demand: 15 kWh/m^2.yr | Hot water demand : 10 kWh/m^2.yr | Embodied carbon = 300 $kgCO_2e/m^2$ (200 $kgCO_2e/m^2$ incl. sequestration)

RIBA Good Practice (2021)/ Reference

EUI < 60 kWh/m^2.yr (including renewable energy contribution, no gas boilers) | Potable water : 110 l/p/day | Embodied carbon

RIBA 2030 challenge

EUI < 35 kWh/m^2.yr (including renewable energy contribution) | Potable water : < 75 l/p/day | Embodied carbon < 625 $kgCO_2e/m^2$

Passive House

Primary EUI ≤ 60 kWh/m^2.yr | Heating demand = 15 kWh/m^2.yr | Hot water demand : 25 l (@60ºC)/p/day | Embodied carbon : encourages "optimisation"

Building specifications

	Future Homes Standard (2025, Consultation) – Min standards	LETI Guidance
External Walls	U = 0.26 W/(m^2.K)	U = 0.13 – 0.15 W/(m^2.K)
Floors	U = 0.18 W/(m^2.K)	U = 0.08 – 0.10 W/(m^2.K)
Roofs	U = 0.16 W/(m^2.K)	U = 0.10 – 0.12 W/(m^2.K)
Windows	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Doors	U = 1.6 W/(m^2.K)	U = 1.0 W/(m^2.K)
Air tightness (@50Pa)	8.0 m^3/(h.m^2)	<1.0 m^3/(h.m^2)

Figure 62: Small office typology

Typical type and GIA

Small office space ≤1,000m^2

Design measures

- BREEAM Outstanding or similar certification (e.g. WELL)
- Sourcing 100% renewable electricity by 2030.
- LED lighting where possible.
- Low Global Warming Potential (GWP) refrigerants.
- Rooftop PV / battery storage.
- Green roofs in areas with high urban heat intensity – flooding risks.
- External/internal shading and low carbon design features.
- Features that allow to repurpose it easily if use changes in the future.
- Mixed use developments where viable/applicable.
- EV charging provision.
- Cycle storage and shower facilities/ changing rooms.
- Low form factor, low carbon design, procurement of materials with sustainability certifications where possible.

General office space – small offices

LETI guidance

EUI = 55 kWh/m^2.yr (excluding renewable energy contribution) | Space Heating demand: 15 kWh/m^2.yr | Embodied carbon = 350 $kgCO_2e/m^2$ (250 $kgCO_2e/m^2$ incl. sequestration)

RIBA Good Practice (2021)/ Reference

EUI < 90 kWh/m^2.yr (including renewable energy contribution) and/or DEC C (65) and/or NABERS Base build 5 | Potable water : 16 l/p/day | Embodied carbon 1,180 $kgCO_2e/m^2$

RIBA 2030 challenge

EUI < 55 kWh/m^2.yr (including renewable energy contribution) and/or DEC B (40) and/or NABERS build 6 | Potable water : < 10 l/p/day | Embodied carbon < 750 $kgCO_2e/m^2$

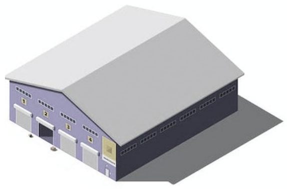
CRREM

EUI = 90.4 kWh/m2.yr

Building specifications

	Future Buildings Standard (2025, Consultation) – Min standards	LETI Guidance
External Walls	U = 0.26 W/(m^2.K)	U = 0.12 – 0.15 W/(m^2.K)
Floors	U = 0.18 W/(m^2.K)	U = 0.10 – 0.12 W/(m^2.K)
Roofs	U = 0.18 W/(m^2.K) (flat) / U = 0.16 W/(m^2.K) (pitched)	U = 0.10 – 0.12 W/(m^2.K)
Windows	U = 1.6 W/(m^2.K) or Rated Band B	U = 1.0 – 1.2 W/(m^2.K)
High-usage entrance doors Doors	U = 3.0 W/(m^2.K)	U = 1.2 W/(m^2.K)
Air tightness (@50Pa)	8.0 m^3/(h.m^2)	<1.0 m^3/(h.m^2)

Figure 63: Warehouse typology



Typical type and GIA

Warehouse (Storage/Distribution/light industrial use) > 1,000m^2

Design measures[32]

- BREEAM Outstanding
- Sourcing 100% renewable electricity by 2030
- LED lighting where possible
- Low Global Warming Potential (GWP) refrigerants.
- Daylight provision and daylight linking controls.
- Zonal heating controls.
- Rooftop PV / battery storage / on-site renewable generation where feasible.
- Features that allow to repurpose it easily if use changes in the future.
- (British Retail Consortium (BRC) Energy Efficiency and Carbon Reduction in retail warehousing. https://brc.org.uk/media/682079/energy-efficiency-in-warehousing.pdf)
- tbc

Warehouse – logistics/storage/light industrial

LETI guidance

EUI = 55 $kWh/m^2.yr$ (excluding renewable energy contribution) | Space Heating demand: 15 $kWh/m^2.yr$ | Embodied carbon = 350 $kgCO_2e/m^2$ (250 $kgCO_2e/m^2$ incl. sequestration)

RIBA Good Practice (2021)/ Reference

EUI < 90 $kWh/m^2.yr$ (including renewable energy contribution) and/or DEC C (65) and/or NABERS Base build 5 | Potable water : 16 l/p/day | Embodied carbon 1,180 $kgCO_2e/m^2$

RIBA 2030 challenge

EUI < 55 $kWh/m^2.yr$ (including renewable energy contribution) and/or DEC B (40) and/or NABERS build 6 | Potable water : < 10 l/p/day | Embodied carbon < 750 $kgCO_2e/m^2$

CRREM

Refrigerated distribution EUI = 65 $kWh/m^2.yr$

Non-refrigerated distribution EUI = 26.5 $kWh/m^2.yr$

Building specifications

	Future Buildings Standard (2025, Consultation) – Min standards	LETI Guidance
External Walls	U = 0.26 W/(m^2.K)	U = 0.12 – 0.15 W/(m^2.K)
Floors	U = 0.18 W/(m^2.K)	U = 0.10 – 0.12 W/(m^2.K)
Roofs	U = 0.18 W/(m^2.K) (flat) / U = 0.16 W/(m^2.K) (pitched)	U = 0.10 – 0.12 W/(m^2.K)
Windows	U = 1.6 W/(m^2.K) or Rated Band B	U = 1.0 – 1.2 W/(m^2.K)
High-usage entrance doors Doors	U = 3.0 W/(m^2.K)	U = 1.2 W/(m^2.K)
Air tightness (@50Pa)	8.0 $m^3/(h.m^2)$	<1.0 $m^3/(h.m^2)$

In this analysis, the five building typologies described above have been selected to represent the local development trends and align with Housing and Economic Development Needs Assessment (HEDNA) recommendations on domestic and non-domestic development needs.

[32] Example measures - British Retail Consortium (BRC) Energy Efficiency and Carbon Reduction in retail warehousing. https://brc.org.uk/media/682079/energy-efficiency-in-warehousing.pdf

The residential building typologies were selected based on the housing mix of permitted developments in Milton Keynes from 2019/20 to 2022/23 financial years. The results were compared and aligned with the latest HEDNA recommendations for housing and population growth in the area. The record of permitted developments provides a breakdown of the number of different house types and tenure for all major developments approved in a financial year. Data from the last four years provides a representative sample for the identification of new development types and the current local market trends in the housing sector.

The quarterly reported entries have been aggregated and clustered into “Developers for sale” and “Affordable Housing”. For each category the percentage of total developed houses was calculated for each building type. For example, 1,2,3+ bedroom flats (BF) or 1-5+ bedroom houses (BH). In this four-year period there were 16,294 plots permitted for development. Affordable housing was reported to be around 27.5% of the annual total major developments in the last two years. The target for affordable housing is 31% per major application. However, this difference is likely explained by outline applications, prior notifications and legacy reserved matter schemes which were granted permission in line with a previous Local Plan which had lower affordable housing requirement.

Planning use classes for non-domestic buildings were adopted from the HEDNA recommendations. The economic development assessment has concluded that warehouses for light industrial, storage and distribution (area >1,000m^2) (Use Class B2 & B8) and small office space (Use Class E, Commercial, Business and Services) should be the focus of new development.

The typical floor areas for each typology were based on the Technical housing standards – nationally described space standard, the floor space in English homes report by the DLUHC, the UK Valuation Office Agency (VOA) and real estate market reports.

3.3.2 Review of net zero requirements

This section sets out best practice industry standards. A review of relevant best practice policy in respect of net zero buildings and sustainable design features is set out in the separate Baseline Report.

Context for net zero building standards

Taking a ‘no regrets’ approach to construction, the priority for decarbonising buildings should be the reduction of energy demand and consumption. This shall ensure that there are no utility bills’ cost increases, and comfort and indoor environmental quality are achieved to support health and wellbeing of the residents. The ‘no regrets’ approach is consequently interpreted into a ‘fabric first’ approach with focus on construction elements and design strategies to reduce heat/cooling demand as much as possible.

The following sub-sections present best practice standards which aim to decarbonise buildings and associated priorities for heating and cooling. A review of relevant legislation is contained in the Baseline report.

Review of best practice industry standards

Current UK industry bodies are calling for a whole-building approach considering all stages of the life cycle of buildings and setting ambitious targets for energy use intensity (EUI, kWh/m^2/yr), space heating demand and low-carbon energy supply with on-site renewable energy systems. The EUI accounts for the annual energy consumption (energy used) per square meter of building floor area. Low EUI corresponds to low energy consumption. Fossil-fuel free homes with on-site solar PV generation and electricity storage have been showcased as the optimal solution to achieve low EUI, reduce risk of increasing utility bills for occupants due to electrification of heating, and maximise benefits associated with indoor environment quality and comfort.

Best current industry practice in buildings energy performance and effective decarbonisation come from Royal Institute of British Architects (RIBA), Passivhaus and the Low Energy Transformation Initiative (LETI).

LETI is a voluntary network of over 1,000 built environment professionals that are working to facilitate the transition of the construction industry and the built environment towards a net zero carbon path. LETI targets have been widely acknowledged for the high ambition and aspirational targets for domestic and non-domestic buildings sectors.

Table 18: LETI Energy use intensity targets[33]

Residential	Non-Domestic (new build office)	Non-Domestic (Schools)
35 kWh/m^2/yr	55 kWh/m^2/yr	65 kWh/m^2/yr

Passivhaus adopts an early passive design approach to minimise heating and cooling loads and achieve comfortable conditions. It follows a whole-building design approach with high thermal specifications for fabric and windows, independent quality assurance, increased air tightness and mechanical ventilation with heat recovery systems.

RIBA has considered the design and construction stages and introduced the 2030 Climate Challenge. The 2030 Climate Challenge sets a series of voluntary targets to reduce operational energy, embodied carbon, potable water use, health, and wellbeing. These targets are set out in Table 19 below.

Table 19: RIBA Current (2021) Good Practice for new build projects[34]

	Domestic/ Residential	Non-Domestic (new build office)	Non-Domestic (Schools)
Operational Energy	60 kWh/m^2/y (GIA) no gas boilers	90 kWh/m^2/ (GIA) and/or DEC C(65) and/or NABERS Base build 5	75 kWh/m^2/y (GIA)
Embodied Carbon	LETI Band D 1000 kgCO_2e/m^2	LETI Band D 1180 kgCO_2e/m^2	LETI Band D 870 kgCO_2e/m^2
Potable Water Use	110 l/p/day	16 l/p/day	3m^3/pupil/year

3.3.2.1 Net zero building policy packages

Building on the introduction to the study's building typologies (Section 3.3.3.1) and industry standards (Section 3.3.2), this section present opportunities for net zero buildings and policy options for achieving this.

Decarbonisation opportunities

The Carbon Risk Real Estate Monitor (CRREM)[35] is a tool, developed with EU and Laudes Foundation funding, that monitors the transition of real estate assets to net zero. The CRREM Decarbonisation Target Tool aims to evaluate the stranding risk due to climate change and offers the possibility to assess energy and emissions reduction pathways aligning to the Paris Agreement (COP21) 1.5ºC global warning target. The stranding risk is the risk of an asset becoming obsolete earlier than expected or lose market value because of the net zero transition of different industry sectors.

The methods used for the decarbonisation pathways align with the Science Based Targets initiative (SBTi) requirements for science-based decarbonisation pathways and target setting. The tool includes a grid decarbonisation projection for countries globally and it calculates the benchmarks for different regional sectors – such as UK dwellings, UK warehouses etc. Assets above the benchmark values are "stranded" – in risk of early obsolescence. CRREM follows a "whole building approach" that accounts for the total landlord and tenant emissions.

In this analysis, the latest CRREM targets for UK dwellings, offices, and warehouses in 2025, 2030 and 2035 were assessed to inform the level of ambition required from developers to achieve reduction of buildings energy consumption and emissions while at the same time reduce stranding risks in their portfolios and aligning with science-based decarbonisation pathways for the relevant building sectors.

[33] https://www.leti.uk/_files/ugd/252d09_3b0f2acf2bb24c019f5ed9173fc5d9f4.pdf

[34] https://www.architecture.com/about/policy/climate-action/2030-climate-challenge

[35] Carbon Risk Real Estate Monitor (CRREM), Available from https://www.crrem.eu/

Table 20: CRREM energy use and GHG emissions intensity targets for UK building sectors.

	Energy use intensity (kWh/m^2.yr)			GHG Emissions intensity (kgCO_2e/m^2.yr)		
	2025	**2030**	**2035**	**2025**	**2030**	**2035**
Multi-family residential (flats)	103.1	72.7	55.0	17.8	10.1	4.8
Offices	166.7	122.7	90.4	32.8	19.3	9.5
Warehouses (refrigerated)	108.5	84.0	65.0	19.1	10.6	4.9
Warehouses (non-refrigerated)	47.7	35.6	26.5	9.3	5.5	2.7

The CRREM EUI and GHG emissions intensities have been considered in combination with LETI, RIBA and Passivhaus recommendations to define the EUI targets for the five different building typologies in the final planning policy requirements.

Energy performance targets and buildings systems

A series of worked examples was developed to support the argument for high energy performance targets for new dwellings and non-residential buildings and demonstrate the implications of compliance calculation methodologies (such as SAP) on building design decisions. All building typologies in the worked examples are assumed to comply with current Building Regulations and, as a constant, use the same construction specifications. To clarify, the "notional" building energy performance metrics in SAP are a function of several design aspects and have not been calculated for building typologies in Milton Keynes as part of this report.

The worked examples are based on simplified hand calculations and assumptions to facilitate discussion. Any results and conclusions are generic and transferable to non-residential buildings. The estimated costs for heating do not include the standing charges and are based on the unit price in the previous and current versions of SAP. The actual cost is calculated based on an average unit price assumption for England in December 2023[36].

An overview of the estimated metrics and the comparison among energy system design choices is shown in Table 21, taking a notional semi-detached dwelling as an example typology This example includes 'PV', also referred to as solar panels. For the avoidance of doubt, solar thermal systems have not been considered in the worked examples.

Table 21: Impact of building design choices to energy metrics in the worked examples*

	Gas boiler, no PV (House A)	Heat pump, no PV (House B)	Electric panels, no PV (House C)	Gas boiler, 3.1 kWp PV (House D)	Heat pump, 3.1kWp PV (House E)
Floor space area, m^2	93	93	93	93	93
Heating demand, kWh/year	8,200**	8,200	8,200	8,200	8,200
Energy Use Intensity (EUI), kWh/m^2	136	69	126	119	36

[36] Ofgem (2023) Energy price cap, Available from https://www.ofgem.gov.uk/energy-price-cap. Last Accessed 30/11/2023.

	Gas boiler, no PV (House A)	Heat pump, no PV (House B)	Electric panels, no PV (House C)	Gas boiler, 3.1 kWp PV (House D)	Heat pump, 3.1kWp PV (House E)
Total Primary Energy, kWh_{PE} /year	15,549	9,649	17,562	12,508	5,089
Electricity generation (local use), kWh/year	0	0	0	1519	3038
Electricity generation (export), kWh/year	0	0	0	1519	0
Total emissions (energy related), tCO_2e	2.4	0.9	1.6	2.0	0.5
SAP Cost for heating (consumption based), £/year	£332	£483	£1,352	£332	£483
Actual Cost estimate for heating (consumption based) £/year	£629	£802	£2,247	£629	£802

*The worked examples are based on a new semi-detached house with $93m^2$ floor area. The heating demand was assumed to be 8,200kWh, annual electricity consumption of 3,500kWh and estimated energy use intensity (EUI)=~136kWh/m^2. **Based on the assumption that new builds will have lower heating demand than existing dwellings.

Fossil fuel-free buildings

The new metrics and factors used for compliance with Building Regulations favour electric heat pumps, which can achieve very high efficiencies in comparison to gas boilers and electric panel heaters.

In terms of energy related emissions, new dwellings with air source heat pumps (ASHP) in the worked examples are expected to have ~60% less emissions than dwellings with gas boilers. The use of electric panel heaters will result in higher emissions in comparison with ASHP but will still perform better (regarding emissions) than gas boilers.

Energy Use Intensity (EUI) calculations are not required for compliance, but it is a metric that allows direct comparison of the energy performance between different building systems (i.e. fabric + services). EUI represents the total energy consumption of the dwelling, including unregulated energy use (e.g. from appliances). Recommended EUI for net-zero dwellings is in the range of 35-40kWh/m^2. In the examples in this section, it is only House E with the ASHP, solar panels and battery storage that has an EUI value near this level of energy use.

The total primary energy, which is a metric required for compliance now, is again lower with the use of ASHP systems than gas boiler heating systems. Electric panel heaters perform worse than gas boilers but the results between the two heating systems are comparable.

The role of solar panels in new building developments

The "notional" building specification includes a PV system. Based on Approved Document L, for houses, the nominal installed capacity (kWp) should be 40% of ground floor area including unheated areas / 6.5; for flats, the nominal installed capacity is 40% of dwelling floor area / (6.5 x number of floors in block)[37].

In this example, the "notional" semi-detached dwelling would include a PV system of (0.40 x 50 m^2) / 6.5 = 3.1 kWp installed capacity.

As shown in Table 21, the performance metrics for House D (gas heating + PV) would change. For simplicity, it has been assumed that the PV generation is not used to displace loads from the gas boiler as it is expected that typical installations will be high efficiency combi-boilers (e.g. there is not a hot water storage tank with immersion heaters or secondary electric heating and hot water systems). Taking an example industry benchmark, it is assumed that the smart export guarantee (SEG) tariff rate is 15 p/kWh[38] exported to the grid. It is also assumed that there is no battery storage (local or communal) and half of the electricity generated by PV is used locally with the other half being exported to the grid. This assumption on PV generation is set for the purposes of the worked example, rather than being based on empirical data. This is based on the expectation that, without battery storage, it will not be possible to match the PV generation with the dwelling loads over extended periods of time; there may also be a mismatch in generation and demand. For example, maximum PV generation will likely be at noon – early afternoon in summer when the dwellings may not have high electricity demand for heating and lighting.

This example shows the role that Building Regulations will have into the electrification of heating in new buildings. House D in this example (gas heating + PV) will still have higher energy use intensity, primary energy consumption and carbon emissions than House B (ASHP, no PV). Assuming the House D performance as shown above has the same performance as the notional building, House B with the ASHP in the example would achieve a 20% reduction in the total primary energy consumption without any PV systems. In terms of emissions, House B (ASHP) will also achieve a 55% emissions reduction in comparison with House D emissions.

The inclusion of the PV system in the "notional" building in combination with the building fabric performance specification means that new buildings with gas heating systems will either need to have some renewable energy capacity installed or the developers will have to reduce the primary energy demand rate by further reducing the heating demand, through additional air tightness, design and better performance than the minimum specification building elements. This will also make the economic case for ASHP stronger, as any cost avoided with the selection of a gas boiler instead of a ASHP will likely have to be invested in other measures.

Regarding running costs, SAP cost factors indicate that the cost for heating will be lower for House D (gas heating + PV) than House B (ASHP, no PV). A 3.1 kWp PV system in Milton Keynes could potentially generate 3,000 kWh electricity annually, which is almost 85% of the assumed total electricity consumption of House D. Such PV system would require ~16 m^2 of unshaded roof area with southeast-southwest orientation (15deg azimuth angle[39], and 35deg roof angle assumed). At £2,000[40] to £3,260[41] (different assumptions may apply on preliminary, access costs and discounts) for 1 kWp installed, the total capital cost would be around £6,200 to £10,100 per dwelling (without including economies of scale, trade discounts and developer's subcontractor pricing, preliminaries etc).

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[37] UK government. Building Regulations 2010. Approved Document L, Conservation of fuel and power, Volume 1: Dwellings, 2021 edition incorporating 2023 amendments. Table 1.1 Summary of notional dwelling specification for new dwelling pp.12.

[38] Example reference with summary of SEG tariffs for suppliers. Greenmatch (2024) How much do solar panels in the UK cost? 2024 prices. Available at: https://www.greenmatch.co.uk/blog/2014/08/what-is-the-installation-cost-for-solar-panels. Last Accessed: 18 February 2024.

[39] The azimuth is a term that refers to the orientation of the panels. It is the angle of the solar panels relative to the South (0 degrees is South).

[40] Example references: 1) DESNZ (2023) Official Statistics. Solar photovoltaic (PV) cost data. Available at: Solar photovoltaic (PV) cost data - GOV.UK (www.gov.uk), 2) Federation of Master Builders (2024) Solar panel costs in the UK. Available at: Solar panel costs in the UK | 2024 solar panel prices (fmb.org.uk), 3) Greenmatch (2024) How much do solar panels in the UK cost? 2024 prices. Available at: https://www.greenmatch.co.uk/blog/2014/08/what-is-the-installation-cost-for-solar-panels. Last Accessed: 18 February 2024.

[41] See Tables 24-25 of cost analysis below.

New residential developments with an EUI = 35-40 kWh/m²

The worked example for the dwelling with the ASHP and without any PV generation (EUI = 69 kWh/m^2) shows that the EUI could be reduced almost by 50% with the transition from gas boilers (EUI = 136 kWh/m^2) to heat pumps, assuming better building fabric performance has been achieved, as specified by the Approved Document L (Part L) 2021 edition incorporating 2023 amendments. It is assumed that local PV generation used in the dwelling is included in the EUI calculation, whereas electricity export to the grid is excluded. It is noted that LETI guidance excludes renewable energy contribution from the EUI targets, whereas RIBA 2030 Challenge targets include both grid and renewable electricity consumption.

The semi-detached dwelling in the example has a floor area of 93m^2. To reduce the EUI from 69 kWh/m^2 to 36 kWh/m^2, additional electricity consumption reductions of around 33 kWh/m^2 x 93 m^2 = 3,070 kWh electricity would be needed. In Milton Keynes, assuming optimum azimuth[42] and slope of the panels, the 3,040 kWh could be generated by a 3.1 kWp PV system, with an approximate roof surface requirement for installation of 16 m^2 and a cost of around £6,200.

House E in Table 21 shows the results for the case study with ASHP + solar panels and local use of the PV output. The generated electricity will not match the household demand for large periods of time[43]. The PV output can be directed to a hot water cylinder (typically installed with the heat pump), to a battery in the house/car or to a decentralised energy system with demand variation and local/communal storage in the future.

To achieve an EUI= 35 -40 kWh/m^2 the solution promoted is to install ASHP, and ~3kW PV capacity with battery storage of sufficient capacity to store the excess electricity and use it in the house when required, for example during peak demand periods. All buildings will still be connected to the grid, for example with grid-tie island battery systems that can manage the loads with the use of the grid, local generation, or the battery and charge the battery with excess electricity from the PV when available or by the grid when unit prices are preferable. Such type of systems will increase the CAPEX considerably more than the £6,200 cost for the PV panels alone.

Achieving net-zero (ready) for non-residential buildings

Achieving net zero for non-residential buildings requires exploration of multiple pathways. The opportunities for interventions will first be guided by the development use class(es), location and size. This will then enable consideration of appropriate building specifications and associated heating, cooling, and hot water systems that optimise passive design, efficient ventilation strategies, and a “fabric first” approach.

In general, interventions for non-residential buildings will take the form of increased fabric insulation, air tightness improvements, high-efficiency lighting and cooling, electrification of heating systems where feasible (such as reversible heat pumps), increased heat recovery from mechanical ventilation, and rooftop solar PV installations (potentially with battery storage). Site developments with mixed uses should assess the potential for site-wide solutions that could improve the technical and economic viability of solar PV and heat pump installations.

By integrating an appropriate selection of these interventions, new office buildings should aim for EUI=55 kWh/m^2/yr (RIBA 2030 Climate Challenge). Retail and light industrial buildings should aim for EUI=65 kWh/m^2/yr.

For medium to large scale developments, the most efficient solution to decarbonise heat within neighbouring developments would likely be via low carbon district heating networks, as highlighted as an opportunity through the densification approach in Spatial Option 1 (see section 2.3.2). These networks will likely require public investment and public-private sector partnerships to fund and deliver the necessary infrastructure at pace and scale. Additionally, the opportunities for roof-mounted solar PV on non-residential buildings will be particularly important for decarbonising energy supply, as identified in section 3.2.

[42] The azimuth is a term that refers to the orientation of the panels. It is the angle of the solar panels relative to the South (0 degrees is South).

[43] As discussed in previous sub-section, this is based on the expectation that, without battery storage, it will not be possible to match PV generation with dwelling loads over extended periods of time; there may also be a mismatch in generation and demand. For example, maximum PV generation will likely be at noon – early afternoon in summer when the dwellings may not have high electricity demand for heating and lighting.

3.3.3 Net zero policy options

The best practice review of Local Plan policies and the industry standards that they incorporate (see section 6 of the Baseline report) have been used to synthesise potential policy options in minimum, medium and maximum tiers. These options are summarised in Table 22 below.

These are given further consideration in Recommendations report, produced as the next stage of this study.

Table 22: Overview of result from the Net Zero Policy Options Review

	Minimum policy option	Medium policy option	Maximum policy option
Requirements	Major residential development		
Legal	Current Building Regulations (Parts L [1], F, O and S [2])	FHS 2025	FHS 2025
Non-statutory best practice	N/A	LETI Target for Operational Energy – Total Energy Use Intensity (EUI) of 35 kWh/m^2 /yr (GIA) excl. renewable generation.	FHS 2025 LETI Target for Operational Energy – Total Energy Use Intensity (EUI) of 35 kWh/m^2 /yr (GIA) Estimate and minimise unregulated carbon emissions. Monitoring of key metrics for first five years of occupation [3]. Use latest net zero technology, including digital [4].
Energy efficiency/ operational carbon	Plan:MK policy: Submit Energy & Climate Statement. 2025 Future Homes Standard: Assumed at 55 kWh/m^2 /yr (GIA) – EPC B equivalent.	Energy & Climate Statement to demonstrate how net-zero carbon targets would be met, in accordance with the energy hierarchy. RIBA 2030 Operational Energy – Total Energy Use Intensity (EUI) of 35 kWh/m^2 /yr (GIA) incl. renewable generation.	Detailed energy statement to show how net-zero carbon target will be met using energy hierarchy, decentralised energy provision and residual met through on-site or community renewables scheme LETI Target for Operational Energy – Total Energy Use Intensity (EUI) of 35 kWh/m^2 /yr (GIA) excl. renewable generation.
Wider sustainability targets	No equivalent requirement in Plan:MK. BREEAM Outstanding: Less than top 1% of UK new builds BREEAM Excellent: Top 10% of UK new builds	3-star HQM score for new build	4-star HQM score for new build
Whole lifecycle carbon	No equivalent requirement in Plan:MK.	RIBA 2025 (LETI Band C) Design Target for residential development (<800 kgCO_2e/m^2)	RIBA 2030 (LETI Band B) Design Target for residential development (<625 kgCO_2e/m^2) Provide details of whole life-cycle carbon emissions, if >100 dwellings [5].
On-site renewables	No equivalent requirement in Plan:MK.	25% of future annual electricity use from on-site renewables	25% of future annual electricity use from on-site renewables

	Minimum policy option	Medium policy option	Maximum policy option
Carbon offsetting	Plan:MK policy: Contribute to offset fund, where on-site emissions target cannot be met.	Provision for carbon offsets, where on-site emissions target cannot be met. E.g. S106 contribution towards the LPAs offsetting fund.	No provision for carbon offsets.
		Fossil fuel free by 2030	Fossil fuel free by 2027
Requirements	Major non-residential development		
Legal		Current Building Regulations (Parts L and F)	Current Building Regulations (Parts L and F)
Non-statutory best practice		FBS 2025	FBS 2025
Energy efficiency/ operational carbon	Plan:MK: Submit Energy & Climate Statement. Estimated at 160 kWh/m^2 /yr (GIA) for existing offices with cooling	Energy & Climate Statement to demonstrate how net-zero carbon targets would be met, in accordance with the energy hierarchy. RIBA 2025 Operational Energy – Total Energy Use Intensity (EUI) of 75 kWh/m^2 /yr (GIA) incl. renewable generation.	Energy & Climate Statement to demonstrate how net-zero carbon targets would be met, in accordance with the energy hierarchy. LETI Target for Operational Energy – Total Energy Use Intensity (EUI) of 55 kWh/m^2 /yr (GIA) excl. renewable generation.
Wider sustainability targets	No equivalent requirement in Plan:MK. BREEAM Outstanding: Less than top 1% of UK new builds BREEAM Excellent: Top 10% of UK new builds	BREEAM 'Excellent' standards.	BREEAM 'Outstanding' standards.
Whole lifecycle carbon	No equivalent requirement in Plan:MK.	RIBA 2025 (LETI Band C) Design Target for non-residential development (<970 $kgCO_2e/m^2$)	RIBA 2030 (LETI Band B) Design Target for non-residential development (<750 $kgCO_2e/m^2$) Provide details of whole life-cycle carbon emissions, if >100 sqm (GIA)
On-site renewables	Plan:MK: 20% on-site renewable energy required.	25% of future annual electricity use from on-site renewable	25% of future annual electricity use from on-site renewables
Carbon offsetting	Plan:MK: Contribute to offset fund, where on-site emissions target cannot be met.	Provision for carbon offsets, where on-site emissions target cannot be met. E.g. S106 contribution towards the LPAs offsetting fund.	No provision for carbon offsets.

	Minimum policy option	Medium policy option	Maximum policy option
		Fossil fuel free from 2030	Fossil fuel free from 2025

3.3.4 Cost analysis of preferred policy options

Introduction and Methodology

This section provides a comparison between baseline and future building design, aligning with our maximum scenario for net zero building. The assumptions for the cost analysis are based on the U-values in Figures 48 and 49 for residential development (uplift from notional building level to LETI standard) - this has been transposed to Table 23 for residential development and Table 22 for non-residential development.

Table 23: Assumptions for residential properties

Typology	Baseline u-value	Future u-value
Flats	External walls: 0.18 $W/m^2.K$ Windows: 1.2 $W/m^2.K$ Roofs: 0.16 $W/m^2.K$	External walls: 0.14 $W/m^2.K$ Windows: 0.9 $W/m^2.K$ Roofs: 0.11 $W/m^2.K$
Semi-detached dwellings		

Table 24: Assumptions for non-residential buildings

Category	Element	Units	Baseline	Uplift	Baseline	Uplift
			Office		Small warehouse / light industrial	
Fabric	External walls	W/m²K	0.13	0.12	0.18	0.12
	Roof	W/m²K	0.12	0.1	0.15	0.1
	Ground floor	W/m²K	0.12	0.1	0.15	0.1
	Doors	W/m²K	1.8	1.2	1.6	1.2
	Glazing	W/m²K	1.41	1	1.6	1
	Glazing	-	0.5 / 0.37	0.3	0.4	0.3
	Air tightness	m³ / h.m² @ 50Pa	4.6	2-3	5	2-3
HVAC	Heating	-	Gas fired boiler with radiators	Reversible heat pump	Electric radiators / panel heaters	Electric radiators / panel heaters
	Cooling	-	Multi-split AC / VRF	Reversible heat pump	N/A	N/A
	Ventilation	-	Natural ventilation	Mixed mode throughout (SFP<1.1w/l/s, HR > 90%)	Extract	Extract

Costings have been calculated for the five archetypes introduced in Section 3.3.1: apartments, semi-detached housing, detached housing, offices and industrial units. We have assumed that there will be no difference in interventions between the “market” and “affordable” flats.

Costs have been calculated using industry published data and internal benchmarked data of projects of a similar nature. This data is from a combination of sources, built up from individual rates with on-costs applied. A combination of information from previous projects that Arup have costed, quotations received and industry standard priced books such as SPONS have been used to build up costs that are then calculated back to £ per unit. As a result, it is not possible to simply link an itemised cost with a single source of reference data.

The feasibility nature of this study means the feasibility design detail is equivalent to RIBA Stage 0 Strategic Definition. It is prudent to allow an estimate sensitivity tolerance of +/- 50%.

It should be acknowledged that factors such as commencement of construction, procurement route, tendering strategy and construction contract, as well as contracting businesses, development size, site location, market conditions and building methodology, will all influence costs and are currently unknown at this stage. Costs are inclusive of main contractor preliminaries, overheads and profits and include allowances for risk. Costs have been made based on new build developments only and are not applicable in alternative scenarios. These costs should not be used during procurement or tendering activities or to determine project or business commercial targets.

For the purpose of preparing a comparison, assumptions have been made regarding the unit sizes, glazed ratios of external walls, heating output requirements and PV generation potentials. It is the case that these assumptions will not be reflective of all developments and therefore, costs are to be considered as an indicative guide only for discussions on development of planning scenarios and for input into the Whole Plan Viability Study to support preparation of the New City Plan. For example, where heat generation for apartment buildings has been costed on the basis of individual heat pumps, alternative more centralised methods may be used depending on the development design.

Of further note, costs relating to Archetype 1 (Apartments) should be considered as a partial representation. It is notable that costs per apartment would be calculated across a wider development in real terms. This would significantly impact the cost per m² as shown, dependent on the intervention. Overall, it would be anticipated that the cost per apartment would be reduced, reflecting economies of scale and more efficient methods of construction. Furthermore, in the instance of heat generation, it is the likelihood that more development centralised systems may be used as an alternative to individual ASHP's. This would likely also lower the cost per kW requirement.

Archetype 3 (Office) has been based on a design reflective of a standalone, two-storey building. Costs relating to Archetype 4 (Industrial) have also been built-up on a similar basis. It should be noted the construction methodology utilised will vary between developments due to locality, purpose and design preference. The construction methodology will impact the extent of each intervention and therefore, costs per m² / kW.

Cost assumptions and exclusions

For all cost estimates, the following assumptions and exclusions apply.

Cost assumptions

1. All relevant systems will be shut-off prior to any work being completed on that system.
2. Allowance for protection to works areas, plant and equipment being retained, will be required.
3. There is no requirement for any extraordinary site investigations.
4. The contractor's preliminaries reflect a single phase programme.
5. The contractor's overheads and profit is based on the likely cost of the main contractor's head office setup, administration proportioned to each contract and reasonable profit.
6. A client risk allowance has been included to allow for design development, unforeseen works during construction, client change during design and construction, and any other client risks, to a reasonable extent.
7. Allowance has been made within estimates for builder's work in connection with services, such as forming holes, fire resistant stopping and making good surfaces disturbed during the works.
8. It is assumed there are no requirement for structural alterations associated with the works such as alterations to risers, structural enhancements to roofs and adjustments to openings for glazing.

9. Allowance has been made within estimates for offloading and positioning of central plant and equipment.
10. Due to the level of design information available at the time of preparing this report, these costs should be considered with a tolerance of +/- 50%.
11. An allowance for main contractor overheads and profits have been included within the costs. No consideration to the tendering method used has been made and it should be noted that this will impact costs.
12. The costs contained within this report should be considered indicative only and be used as a guide for future discussions surrounding the design development of these elements and use in the Whole Plan Viability Study at the plan-making stage. These costs should not be used during procurement or tendering activities or to determine project or business commercial targets.
13. Where interventions require existing materials and/or components of a system to be adjusted, such as the insulation within a composite wall system, the type of system is still appropriate.

Exclusions

1. Costs are reflective of Q1 2024 prices. No allowance has been made for tender or construction inflation beyond the base date.
2. Specific risk items that maybe associated with design changes.
3. Allowances for abnormals following site surveys / investigations and ground conditions such as works associated with archaeological findings.
4. Allowance for Other Development / Project Costs. It is noted that the Whole Plan Viability Study will consider the cost impact of other design requirements.
5. Allowances for general or special planning conditions, if required. It is noted that the Whole Plan Viability Study will consider the cost impact of planning obligations.
6. Any attempt to estimate the client's procurement and tendering methods.
7. Costs for decanting personnel for any reason associated with the delivery of the project works.
8. No contamination / remediation strategy report is present at the time of producing this order of cost estimate, an allowance has not been included for the removal and investigation, management, removal or disposal of hazardous contaminated materials / substances including asbestos.
9. Site specific limitations arising from listed building status, or other statutory building requirements.
10. Any archaeological investigations, wildlife mitigation measures and other extraordinary site investigation works, and the like.
11. Does not include for physical restrictions or limitations in accessing site.
12. VAT has been excluded from costs.
13. Battery storage associated with PV panel electricity generation is excluded.
14. Structural works associated with interventions, including those to the roof, are excluded.
15. Costs associated with permissions and road closures required for cranage / access.

Feasibility Findings

Feasibility findings will differ between developments and developers, and as such will be required to be considered on a case-by-case basis. Nonetheless, these costings and policy recommendations are provided with sufficient confidence to be utilised within viability testing as required at the plan-making stage.

Initial findings suggest enhanced insulation to external walls and roof based on the same design and construction yields minimal financial impact for Archetypes 1 – 3. Alternative construction methodologies designed to achieve relevant u-values for Archetypes 4 – 5 indicate a larger financial impact, though this would vary depending on the design of units.

Glazing upgrades assume an upgrade from double to triple glazing to achieve improved u-values. The resultant cost impact reflects increased material costs associated with glazing improvements. The impact of this on the feasibility of projects would vary from design and developments across the archetypes, depending on project values and glazing proportions.

The most significant impact on feasibility can be seen on the PV, and subsequent battery storage installations and heat generation. PV and batteries panels are compared against no installations and therefore demonstrate a more significant cost impact. These initial costs need to be considered against the operational cost savings that can be made before making a financial decision. Heat generation for dwellings has been assessed on ASHP compared to the installation of electric boilers on Archetypes 4 and 5. The perceived value will be dependent on the purpose of the development and the ownership of operational costs. Initial findings suggest PV installations and alternative heat generation will have the most significant impacts on feasibility.

Tables 24 to 27 below set out the cost findings of the proposed interventions. Costs should be read in conjunction with the corresponding comments shown in the cost assumptions and exclusions in Section 3.3.5 below.

The cost assessment for Archetypes 3 and 4 have been based on a previous carbon study. The previous study similarly provided an overview of the extra over costs for improving the performance of specific construction elements for different building typologies, such as: building fabric, HVAC systems and Low and Zero Carbon (LZC) Technologies. The methodology of translating the costs from this study, into applicable costs for Milton Keynes, involved rebasing the costs with a location factor and then uplifting the costs to match the base date of the Milton Keynes estimate.

It should be acknowledged that measures to improve air tightness are typically building specific and therefore challenging to identify and cost in a modelling scenario. For Archetypes 3 and 4, air tightness costs have been calculated based on a percentage of the fabric intervention costs only.

All costs are inclusive of materials, labour and necessary tools, plant and equipment to install the products and systems. Costs also include for testing and commissioning, as necessary, builders' works in connection with mechanical and electrical installations, contractor preliminaries, overheads and profit, as well as allowances for professional fees and risk.

Table 25: Cost findings Archetype 1 - Apartments

Archetype 1 – Flats **70 m² Assumed GIA (m²)** **753 ft² Assumed GIA (ft²)**				
Ref	Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Future [£ GBP]
1.	Insulation to external walls	m²	530	540
2.	Glazing	m²	870	1,280
3.	Roof insulation	m²	340	360
4.	PV installations	kW	0	3,260
5.	Heat generation	kW	240	1,980

Table 26: Cost findings Archetype 2 – Semi-detached houses

Archetype 2 – Semi-detached houses 85 m² Assumed GIA (m²) 915 ft² Assumed GIA (ft²)				
Ref	Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Future [£ GBP]
1.	Insulation to external walls	m²	530	540
2.	Glazing upgrades	m²	870	1,280
3.	Roof insulation	m²	340	360
4.	PV installations	kW	0	3,260
5.	Heat generation	kW	240	1,980
6.	Battery Storage	kWh	0	1,420

Table 27: Cost findings Archetype 3 – Offices

Archetype 3 – Office 770 m² Assumed GIA (m²) 8,288 ft² Assumed GIA (ft²)				
Ref	Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Future [£ GBP]
1.	Fabric	m²	270	490
1a.	External walls	m²	-	10 [uplift]
1b.	Roof insulation	m²	-	30 [uplift]
1c.	Ground floor insulation	m²	-	30 [uplift]
1d.	External doors	m²	-	0 [uplift]
1e.	Glazing upgrades	m²	-	100 [uplift]
1f.	Air tightness	m²	-	40 [uplift]
2.	Heat generation	kW	Excluded	Excluded
3.	PV installations (£/ GIFA)*	m²	20	160

Note the £/unit for the PV installations is £/GIFA (Gross Internal Floor Area) for the office archetype.

Table 28 Cost findings Archetype 4 – Industrial

Archetype 4 – Industrial 324 m² Assumed GIA (m²) 3,488 ft² Assumed GIA (ft²)				
Ref	Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Future [£ GBP]

Archetype 4 – Industrial 324 m² Assumed GIA (m²) 3,488 ft² Assumed GIA (ft²)				
1.	Fabric	m²	130	300
1a.	External walls	m²	-	30 [uplift]
1b.	Roof insulation	m²	-	30 [uplift]
1c.	Ground floor insulation	m²	-	20 [uplift]
1d.	External doors	m²	-	0 [uplift]
1e.	Access doors	m²	-	10 [uplift]
1f.	Glazing upgrades	m²	-	50 [uplift]
1g.	Air tightness	m²	-	40 [uplift]
2.	Heat generation	kW	Excluded	Excluded
3.	PV installations (£/ GIFA)*	m²	10	310

Note the £/unit for the PV installations is £/GIFA (Gross Internal Floor Area) for the industrial archetype.

The rates shown in the sub-categories for the fabric interventions are the cost uplifts only.

Estimating costs of sustainability certifications

The policy options make reference to two industry recognised sustainability certification frameworks:

- HQM (Home Quality Mark) for residential development; and
- BREEAM (Building Research Establishment Environmental Assessment Methodology) for non-residential development, both hosted by the BRE Group.

The costs associated with these certification frameworks include:

- Administrative fees, as per the latest iteration of the BREEAM Fee Sheet FS036
- Accredited assessor fees, which our sustainable building specialists estimate at ⩾£40,000 for major development. These vary according to:
    - The target rating. This will determine the Assessors' requisite involvement in the design process. For higher ratings, Assessor involvement is stipulated from an early stage (e.g. RIBA Stages 1 or 2).
    - The number of typologies within a development. Each typology design will require consideration by the Assessor.
- Construction cost uplift, as indicated in Tables 24 – 27 above.

3.4 Sustainable design features policy options

3.4.1 Introduction

With a focus on residential developments, policy options have been developed in minimum, medium and maximum tiers. These options have been shaped by a best practice review of Local Plan policies and the climate risk analyses. These options are summarised in Table 28 below.

It is noted that these options do not account for reservoir flood risk, as this was judged to be low risk in the climate risk assessment of the spatial options.

The preferred policy options for each theme will be presented in the Recommendations report.

Table 29: Residential Sustainable Design Feature Policy Options

	Minimum policy option	Medium policy option	Maximum policy option
Mitigating overheating[1]	Plan:MK policies look to ensure well designed and high-quality places, that are of appropriate size and scale, this is largely from a design perspective, rather than climate change.	Orientation of buildings to be considered, to take advantage of solar gain and minimise heat loss. Consider form of building, to create more efficient heating and cooling.	New buildings shall be designed and positioned to take advantage of solar shading, thermal mass, heating and ventilation. This should include use of tree planting to create external natural shading, and external louvres where appropriate. Integrate internal blinds or shutters with openable windows in each habitable room of each building. Consider use of appropriately coloured materials in areas exposed to direct sunlight.
Fluvial Flood Resilience	Plan:MK requires development in areas at risk of flooding to account for fluvial flooding in a site-specific Flood Risk Assessment.	Where required, a site-specific Flood Risk Assessment should demonstrate how design has addressed and appropriately mitigated against current fluvial flood risk from the River Great Ouse and its tributaries, the canals and any interaction between the watercourses, as assessed in the Strategic Flood Risk Assessment.	Where required, a site-specific Flood Risk Assessment should demonstrate how design has addressed and appropriately mitigated against current and future fluvial flood risk (including climate change) from the River Great Ouse and its tributaries, the canals and any interaction between the watercourses, as assessed in the Strategic Flood Risk Assessment. Different solutions can be used to mitigate flood risks e.g. raising floor levels, having these independently verified, raising electrics above a certain level. The most appropriate solution will be determined on a case by case basis and secured via planning condition/other agreement.
Surface Water Flood Resilience	Plan:MK requires development in areas at risk of flooding to account for surface water flooding in a site-specific Flood Risk Assessment. Plan:MK: Incorporate surface water drainage system and reduce flooding to the lowest possibility.	Meet current Plan:MK requirement for site-specific Flood Risk Assessment. Meet current policy requirements and reduce runoff rates down to greenfield runoff rates.	Meet current Plan:MK requirement for site-specific Flood Risk Assessment. Developments should achieve greenfield runoff rates, with multifunctional green drainage features being utilised over grey.

	Minimum policy option	Medium policy option	Maximum policy option
Groundwater Flood Resilience	Plan:MK requires development in areas at risk of flooding to account for groundwater flooding in a site-specific Flood Risk Assessment.	Meet current Plan:MK requirement for site-specific Flood Risk Assessment. Ensure finished floor levels are at least 300mm above estimated flood level, based on the latest Strategic Flood Risk Assessment for Milton Keynes and the site-specific Flood Risk Assessment prepared for the proposal. Ensure doors, windows and other openings are at least flood resistant to 600mm above estimated flood level, based on the latest Strategic Flood Risk Assessment for Milton Keynes and the site-specific Flood Risk Assessment prepared for the proposal.	Meet current Plan:MK requirement for site-specific Flood Risk Assessment. Ensure finished floor levels are at least 300mm above estimated flood level, accounting for climate change, based on the latest Strategic Flood Risk Assessment for Milton Keynes and the site-specific Flood Risk Assessment prepared for the proposal. Ensure doors, windows and other openings are at least flood resistant to 600mm above estimated flood level, accounting for climate change, based on the latest Strategic Flood Risk Assessment for Milton Keynes and the site-specific Flood Risk Assessment prepared for the proposal. The most appropriate solution will be determined on a case by case basis and secured via planning condition/other agreement.
Public Health	Plan:MK: Provide new green infrastructure or contribute to enhancement and strengthening of existing GI to provide wellbeing benefits through access to nature.	Nature Green and Blue Infrastructure Study contains recommendations for how accessible GI should be.	Nature Green and Blue Infrastructure Study contains recommendations for how accessible GI should be.
Biodiversity Net Gain	Maintain and protect biodiversity Where possible, provide a measurable net gain	As per Environment Act, minimum 10% BNG.	.Minimum 10% BNG and 20% where possible. 20% required on previously developed sites and strategic sites.
Electric Vehicle Charging	New residential developments will be required to provide 1 charging point to each dwelling.	As per Approved Document S, min. charging points of either: Number of associate parking spaces. Number of dwellings that car park serves	Provision in line with Approved Document S, with additional specification of charging point (minimum Mode 4) subject to viability testing.

3.4.2 Cost analysis of Electric Vehicle Charger Units

As one of the sustainable design measures proposed in section 3.4.1 and as a relatively new intervention to be delivered at scale, we provide estimated EV charger unit costs for each Archetype below.

Table 30: EV Charger Costs

Archetype 1 – Apartment				
Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Advanced [£ GBP]	Comments
EV Chargers – 7kW	No.	0	£2,870	Baseline scenario assumes no installation of EV Chargers. For the advanced scenario, the EV Charging capacity has been assumed at 7kW of a wall mounted charger. No upgrades to the existing electrical supply or additional distribution boards have been allowed. Costs are inclusive of main contractor preliminaries at 15% and OH&P at 8%. An additional risk allowance of 10% has been allocated to this intervention. This rate is an uplift to new builds and therefore does not include for backfilling or covering of the cabling trenches. An allowance has been made for wall signage and wheel stoppers.
Archetype 2 – Semi-detached house				
Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Advanced [£ GBP]	Comments
EV Chargers – 7kW	No.	0	£1,400	Baseline scenario assumes no installation of EV Chargers. For the advanced scenario, the EV Charging capacity has been assumed at 7kW of a wall mounted charger. No upgrades to the existing electrical supply or additional distribution boards have been allowed. Costs are inclusive of main contractor preliminaries at 15% and OH&P at 8%. An additional risk allowance of 10% has been allocated to this intervention. This rate is an uplift to new builds and therefore does not include for backfilling or covering of the cabling trenches.
Archetype 3 – Office				
Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Advanced [£ GBP]	Comments
EV Chargers – 22kW	No.	0	£4,300	Baseline scenario assumes no installation of EV Chargers. For the advanced scenario, the EV Charging capacity has been assumed at 22kW. No upgrades to the existing electrical supply or additional distribution boards have been allowed. Costs are inclusive of main contractor preliminaries at 15% and OH&P at 8%. An additional risk allowance of 10% has been allocated to this intervention. This rate is an uplift to new builds and therefore does not include for backfilling or covering of the cabling trenches. An allowance has been made for wall signage and wheel stoppers.
EV Chargers – 50kW	No.	0		

Archetype 4 – Industrial				
Description	Unit	Cost per 'Unit' Baseline [£ GBP]	Cost per 'Unit' Advanced [£ GBP]	Comments
EV Chargers – 22kW	No.	0	£4,300	Baseline scenario assumes no installation of EV Chargers. For the advanced scenario, the EV Charging capacity has been assumed at 22kW. No upgrades to the existing electrical supply or additional distribution boards have been allowed. Costs are inclusive of main contractor preliminaries at 15% and OH&P at 8%. An additional risk allowance of 10% has been allocated to this intervention. This rate is an uplift to new builds and therefore does not include for backfilling or covering of the cabling trenches. An allowance has been made for wall signage and wheel stoppers.
EV Chargers – 50kW	No.	0		

3.4.3 Considerations for battery storage

Energy storage is extremely important for ensuring the grid system resilience by performing four different functions:

1. Matching the grid electricity supply to the demand within seconds;
2. Frequency regulation and maintenance of the stability and safety of the grid;
3. Enabling energy to be harvested when available and stored for consumption at a more convenient time; and
4. Providing a buffer source for use in case of emergencies.

In particular, batteries have characteristics that make them ideal for grid energy management applications:

5. Fast Acting: batteries can deliver power almost instantaneously on demand;
6. Bi-directional Energy Flow: batteries can deliver stored energy or absorb surplus energy just as quickly; and

7. Scalable: a wide range of energy storage technologies are available so that batteries can be optimised for both power delivery and storage capacity and scaled from small portable containerised units to multi-MW installations.

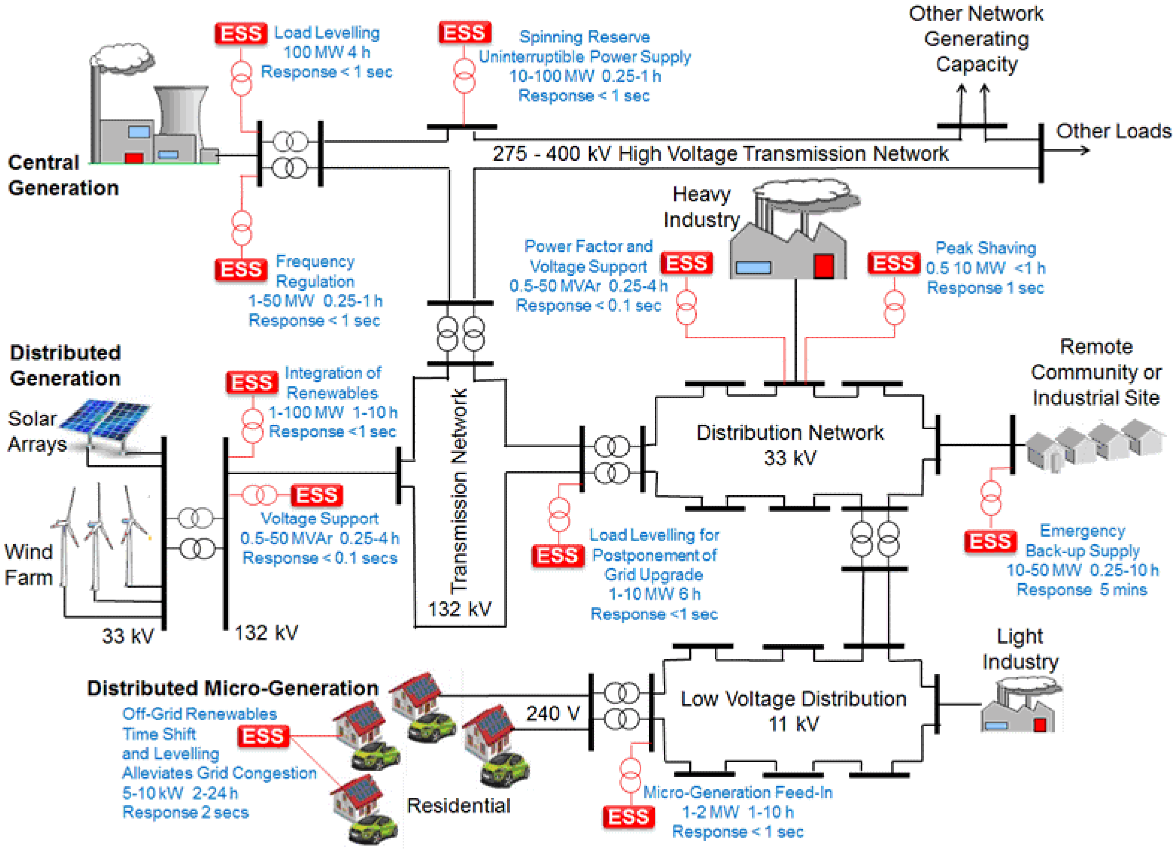

Figure 64: Example deployment of batteries within the transmission and distribution network

Figure 64 shows how batteries energy storage systems (BESS) can be deployed and integrated within the electricity network of a council such as Milton Keynes, from generation to transmission and distribution, by performing the four different functions described above.

The availability of renewable resources such as wind and solar is variable and related to the weather, the time of day and the period of the year. The variability of the resources affects the physical operation of the modern grid, resulting in increased difficulties in matching the supply to the demand. However, a mix of renewables, combined with energy storage can provide a secure provision of electricity and heat.

One of the key aspects of this process is the load shifting: the practice of changing the pattern of energy supply so that the generation of energy for consumption during the hours of peak demand is shifted to off-peak periods. This can be achieved by using battery energy storage coupled with an energy supply management system and allows greater use of the more efficient base load generating assets as well as the storage of intermittent energy generated by renewable sources such as wind and solar.

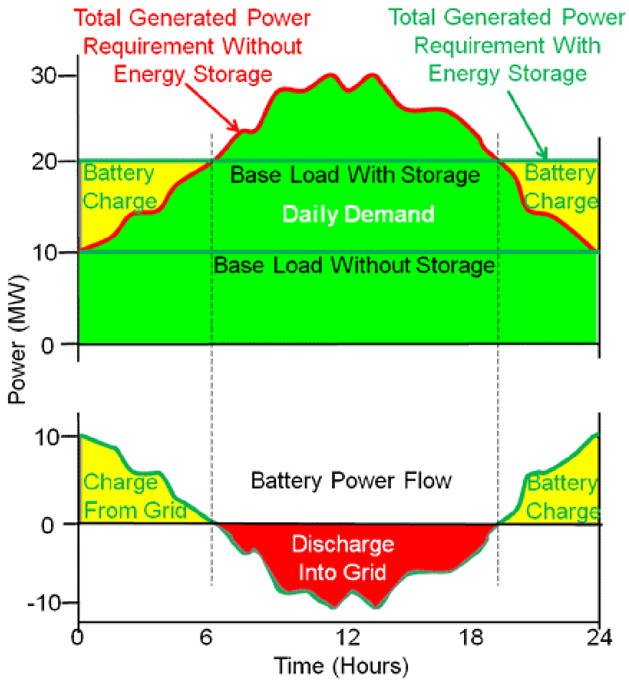

Figure 65: Load levelling and peak shaving[44]

Figure 65 shows the principle of peak shaving, in which demand for immediate generating capacity during the short periods of peak demand can be supplied from stored energy. During periods of low demand, the excess capacity produced via renewable sources such as wind and solar can be used to charge the battery and during periods of high demand the battery is discharged into the grid augmenting the base load generator's capacity to supply the peak demand. In this way, energy storage can remove the need for costly load following generators.

Despite all these advantages, battery storage can have drawbacks as follows:

- They can be expensive and complex to install and operate, depending on the type, size, and quality of the battery:
- They can have environmental and safety issues (such as thermal runaway) that need to be considered carefully;
- Battery storage can face technical and regulatory barriers. Battery installation should be carefully planned.

As of today, batteries for grid energy management applications have usually a discharge time of 1 to 2 hours, with a total capex that ranges from £300-500k / MWh. Typical footprint of the whole BESS (battery energy storage system) plant spans between 15-25 sqm/MWh.

In summary, batteries coupled with an energy supply management system are key to an effective utilisation of wind and solar energy sources to ensure the energy demand of all the users within a council such as Milton Keynes is always met.

It is recommended that MKCC engage with the relevant stakeholders on both the renewable energy production side and the battery energy storage systems side. This will ensure opportunities to create synergies towards the net zero objective are identified.

A more detailed technical and economic feasibility study would benefit from the availability of hourly energy consumption and generation data, both measured and projected.

MKCC could undertake a data collection exercise aimed at gathering hourly demand profiles from buildings within the Local Authority boundaries, starting from publicly owned ones. Data collected would ideally be

[44] "Battery and Energy Technologies, Grid Scale Energy Storage Systems – Load shifting". Available at: https://mpoweruk.com/grid_storage.htm

from buildings of different typology, such as residential, commercial, educational, industrial, in a way that the data can be representative for the whole building stock.

Once available, those will need to be combined with hourly renewable energy generation profiles that can serve as a benchmark for MKCC.

The same data collection would need to be carried out on the generation side: Wolverton Community Energy could be involved in the process and the opportunity of obtaining operational data from their renewable energy systems could be investigated.

By analysing the demand and generation profile together, it would be possible to identify with a higher level of confidence the magnitude of the mismatch between them and estimate the BESS requirements that would maximise the usage of renewable energy sources.

Market research on the best BESS services provider available in the area to assist the Milton Keynes council would also be recommended.

3.5 Green Infrastructure (GI)

3.5.1.1 Introduction

As set out in the MK Nature, Green and Blue Infrastructure Strategy (August 2023) (NGBI Strategy), Milton Keynes has an extensive network of green and blue infrastructure spaces and features that provide a wealth of social, economic and environmental benefits.

It is well known that grasses, plants and trees can help mitigate climate change by sequestering atmospheric carbon as they grow and store it in their biomass and within the soil. The amount of carbon annually sequestered is dependent on the types, size, health, and species of planting, re-wilding and habitat creation, protection of soil resources during construction, and correct soil reinstatement during landscape design and management. GI can also help reduce CO_2 emissions from energy use in buildings. This is reflected in Indicator 7 (Green and nature-based solutions) in the Sustainable Urban Framework in the separate Baseline Report.

The term GI is sometimes used as an umbrella term that encompasses blue infrastructure, which refers to lakes, ponds, rivers, canals, and other waterways. Combining green and blue spaces is seen as an effective way of providing a natural solution to common climate change challenges including air pollution, stormwater and the urban heat island effect. GI and blue infrastructure can provide many benefits such as reducing and/or slowing the amount of surface water that is fed into traditional drainage systems and reducing the risk of flooding in storm events. If designed well, blue-green infrastructure can also improve the amenity of an area and provide multi-functional spaces for local communities.

3.5.1.2 GI Principles

Natural England has published a Green Infrastructure Framework[45] which is recognised in the NGBI Strategy. The Framework includes a series of principles and standards with supporting information for England. The 15 principles are intended to provide a baseline for different organisations to develop stronger green infrastructure policy and delivery. The principles also cover the Why, What and How to do good green infrastructure.

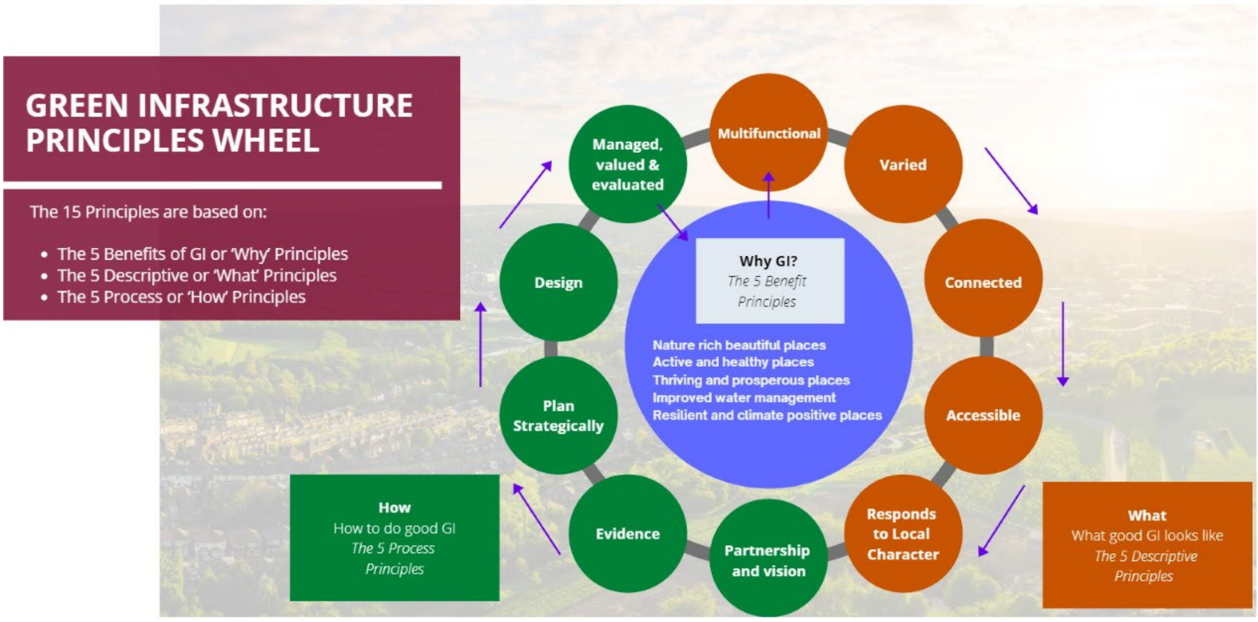

Figure 66: Green Infrastructure Principles Wheel (extracted from Natural England's Green Infrastructure Framework, 2023)

For example, 'Principle How 4' covers the design of GI and is about understanding an area's landscape character to create 'well-designed, beautiful, and distinctive places.' The supporting text for 'Principle How

[45] Green Infrastructure Framework – Principles and Standards for England (January 2023) Natural England

4' refers to the GI Mapping Database[46] included within Natural England's Green Infrastructure Framework as well as published character assessments and management plans for statutory designated landscapes, as key sources for gathering information on the baseline and understanding the relative importance of different elements. The supporting text states that:

"There should also be a strong relationship between GI design and sustainability. This can be through ensuring good practice in construction and that materials used minimise impacts and maximise benefits, particularly in terms of climate change. Substitution of carbon heavy materials such as concrete for lower impact, locally produced, products, can make a long-term difference and should form part of the design thinking. This should be considered at the master planning stage, as well as at the detailed design, to ensure that early decisions do not preclude opportunities for more sustainable approaches."

Natural England's consultation response highlighted the importance of a strategic approach to infrastructure, suggesting it should be incorporated into the Local Plan as a strategic policy area, supported by appropriate detailed policies and proposals to ensure effective provision and delivery.

The NGBI Strategy includes, as Figure 67, Natural England's process diagram for using the Green Infrastructure Framework, as replicated below. It is intended to enable the development of informed and comprehensive GI related policy and strategy that is based on the Natural England Green Infrastructure Principles, Standards and data, which can be built on to address and respond to local needs and opportunities.

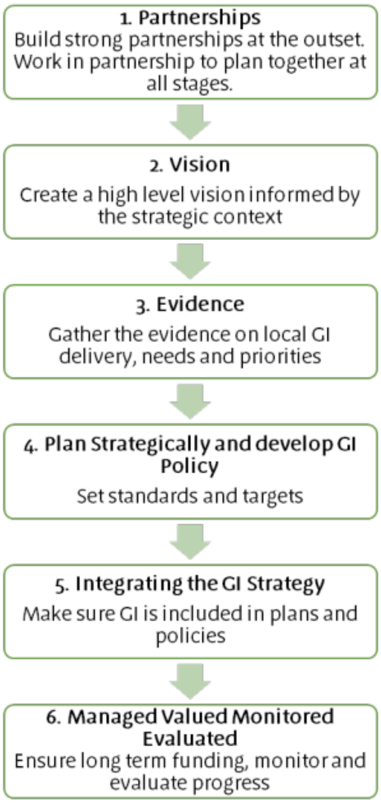

Figure 67: Overview of process of using the GI Framework to develop GI strategies and local policy (extracted from the NGBI Strategy, 2023)

The NGBI Strategy sets out that MKCC are following the principles, standards and associated guides within Natural England's' GI Framework when preparing design policies for the New City Plan.

It is clear from a review of recently adopted Local Plans (in the separate Baseline report) and those in the early stages of preparation that GI will continue to become a core thread running through plans. Some are included direct references to Natural England's GI standards whilst others are loosely following their approach.

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[46] Green Infrastructure Mapping Database, Available at: https://designatedsites.naturalengland.org.uk/GreenInfrastructure/Map.aspx

3.5.2 Green Roofs and Walls

3.5.2.1 Introduction

Green roofs and green walls play a crucial role in enhancing the sustainability and resilience of urban environments. Serving as integral components of green infrastructure, these features contribute significantly to mitigating the adverse effects of urbanisation. For new development, they provide additional opportunities to mitigating urban heat island effects, and improving air quality and contribute to biodiversity, enhancing the wider landscape and ecology along with gardens, parks, street trees, and waterbodies. Their functions in natural insulation and reducing energy consumption are key to helping buildings achieve Net Zero objectives.

This section explores the value of different types of green roof and wall interventions to help MKCC, developers and property owners evaluate the best approach to green walls and roofs in their projects. It is not intended to provide design specification for green roofs and walls, which will need to be developed separately to suit each specific building and location.

For the purposes of this evaluation, the following assumptions have been made:

- Based on the five Building Typologies outlined in Section 3.3.1 of this report, residential apartment blocks, semi-detached housing and office buildings are the only structures considered. Other structures such as car parks, cycle shelters, deck landscapes, bin/substation enclosures, screens or other ancillary structures are excluded;
- Fire hazard for green roofs and green walls on buildings greater than 18m in height or over 7 storeys should refer to Fire Performance in Green Roofs and Walls (2013) or latest edition; and
- Retrofitting to existing buildings are not part of this study.

This section draws upon published documents and best practice guidance including the following:

- The GRO Green Roof Code; Green Roof Organisation (GRO); 2021 (amended 2023) https://www.greenrooforganisation.org/downloads/
- GRO fire risk guidance document; Green Roof Organisation (GRO), 2018 https://www.greenrooforganisation.org/downloads/
- Green Roof Guidelines; Landscape Development and Landscaping Research Society e.V. (FLL); 2008 https://shop.fll.de/de/downloadable/download/sample/sample_id/44/
- Sustainable Design and Construction Supplementary Planning Guidance, London Plan; Mayor of London; 2011 https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Sustainable%20Design%20%26%20Construction%20SPG.pdf
- Living Roofs and Walls; Technical Report: Supporting London Plan Policy; Greater London Authority; 2008 https://www.london.gov.uk/sites/default/files/living-roofs.pdf

Evaluation Framework

Seven types of green roofs and green walls have been selected as most appropriate for the five Building Typologies defined by in Section 3.2.1: 2-bedroom flats (market), 3-bedroom semi-detached (market), 2-bedroom flats (affordable), small offices with a gross floor area<1000m^2, and warehouses with a gross floor area>1000m^2:

- Thin Substrate Green Roof
- Medium-depth Green Roof
- Deep Substrate Green Roof
- Biodiverse Green Roof
- Ground-based Green Wall
- Green Wall System with Elevated Planters
- Modular Living Wall System.

Each type has been evaluated in terms of its benefits and cost.

Four measurable benefits have been identified that respond to Milton Keynes policy focus on water management, biodiversity and climate resilience:

- **Public Health**: Views and immersion in nature have been shown in studies to reduce stress in people and therefore have a positive impact on public mental health. This category includes the visual amenity value as well as access to nature. In addition, they could provide opportunity of food production which engages local communities also has social benefits.
- **Microclimate**: Appropriately designed Green Roof & Green Walls can reduce both surface and ambient temperatures, helping to mitigate Urban Heat Island (UHI) Effect which will be exacerbated by climate change. The air quality in our cities is a major health issue. Green roof and green wall, when selected and placed appropriately, can help reduce PM2.5 & PM10 levels by deposition on flora and subsequent sedimentary deposition within the plant medium itself. Green walls can reduce noise reverberation by up to 10dB.
- **Climate resilience**: Surface runoff in cities is a major source of urban flooding. With climate change more intense rain events are expected which will exacerbate this problem. Green Roof & Green Walls could act as a stormwater attenuation, reducing and slowing down the excess water entering the offsite drainage systems. The plant medium and the vegetation layer itself store additional water volumes, which at a later stage are slowly released into environment by evapotranspiration.
- **Biodiversity**: Green roofs and green walls could enhance biodiversity in different spatial scenarios through diverse habitat creation that increases the health and resilience of these natural systems, supporting a greater variety of species and the provision of valuable ecosystem services.
- The evaluation of whole-life cost has been based on the following:
- **Capital Investment**: This includes cost to design a fully functional system taking into consideration of roof insulation, drainage, structural loading, planting design and so on. In addition, the procurement for all components such as planters, substrates, supporting systems.
- **Installation**: All green roof and green wall have loading implication on the buildings. The structural may be required to be strengthened which requires more materials or more expensive construction than the buildings without these systems. The assembly of green roof and green wall requires different levels of labour depending on complexity of the system.
- **Maintenance**: Maintenance are key to the longevity of the green roofs and green walls even some systems are more self-sustaining than the others. The operation requires inspection and monitoring of system integrity and plant and habitat health. The variety of incorporated plants could have a great impact on the maintenance frequency and activities.

The unit cost based on general principles is provided in Section 3.5.3 below.

3.5.2.2 Green roof and green wall types

Table 31 and Table 32 below summarise the benefits and costs associated with each green roof and wall intervention respectively.

Table 31: Green roof types evaluation matrix

Green Roof types	Benefits – Public Health	Benefits – Microclimate	Benefits – Climate Resilience	Benefits – Biodiversity	Cost – Capital Investment	Cost - Installation	Cost - Maintenance
Thin Substrate Green Roof	Limited	Limited	Limited	Limited	Low	Low	Low

Medium-Depth Green Roof	Fair	Good	Fair	Good	Medium	Medium	Medium
Deep Substrate Green Roof	Good	Good	Good	Good	High	High	High
Biodiverse Green Roof	Fair	Fair	Fair	Excellent	Medium	Low-Medium	Low

Table 32: Green wall types evaluation matrix

Green Wall types	Benefits – Public Health	Benefits – Microclimate	Benefits – Climate Resilience	Benefits – Biodiversity	Cost – Capital Investment	Cost - Installation	Cost - Maintenance
Ground-based green wall	Limited	Limited	Fair	Limited	Low	Low	Low
Green wall system with elevated planters	Fair	Fair	Good	Good	Medium - High	High	Medium
Modular living wall system	Good	Good	Medium	Good	High	Medium - High	High

The following section provides the general principles and associated evaluation for each type of roof and wall. The images provided help to illustrate the approach, design quality and ideas that the policy should aspire to.

3.5.2.3 Thin substrate green roof

This is a type of green roof on a thin layer of growing medium with typical thickness between 80 to 150mm, which aims to establish a largely self-sustaining and naturalistic plant community, typically with species such as sedums and/or hardy wildflower herbaceous mixes. These green roofs are also known as ‘extensive’ green roofs.

Figure 68: Thin substrate green roof (with raised beds) at YMCA, Milton Keynes © The Green Project

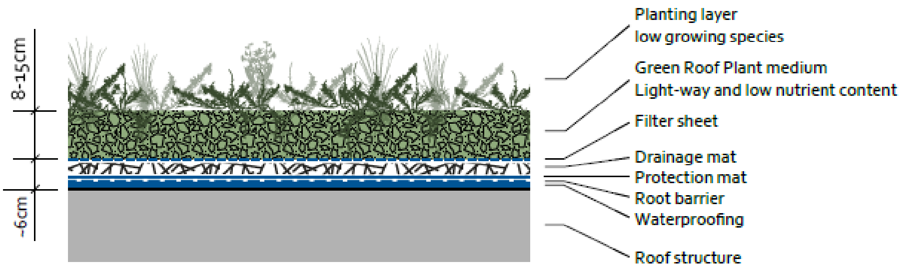

Figure 69: Thin substrate green roof typical section

Table 33: Thin substrate green roof evaluation

Benefits: Public Health	• Generally not accessible to the public. • Plants are limited to hardy grass and/or sedum, not visually appealing.
Benefits: Microclimate	• Due to the shallow depth and low planting layer limited ability to reduce ambient temperature. • The capacity in evaporated cooling and thermal mass insulation are limited in building energy performance.
Benefits: Climate Resilience	• Retention of rainfall runoff in planting medium and the drainage layer is lowest compared to other types of green roof.
Benefits: Biodiversity	• Low variety of hardy plants provides limited food source or refuge for birds or insects.
Cost: Capital Investment	• Proprietary products widely available. • The system is simple with affordable components.
Cost: Installation	• Light weight (typically less than 250kg per m^2 saturated density). • Suitable for roofs with pitch less than 45°, anti-slip systems should be used for pitch over 15°. • The installation is straightforward for competent building contractor, no special skills required.
Cost: Maintenance	• A minimum of 2-4 visual maintenance inspections per year should be carried out. • Cutting back and removal of dead vegetation in late winter will maintain species diversity. • Encourage the establishment of a largely self-sustaining and naturalistic plant community.

Medium Depth Green Roof

Sometimes referred to as 'Semi-extensive', this type of green roof consists of a deeper growing medium layer of approximately 100mm-300mm in depth, usually planted with naturalised grass, wild or meadow flower, and herbaceous species.

Figure 70: Medium depth green roof at Broughton Pavilion, Milton Keynes © The Green Project

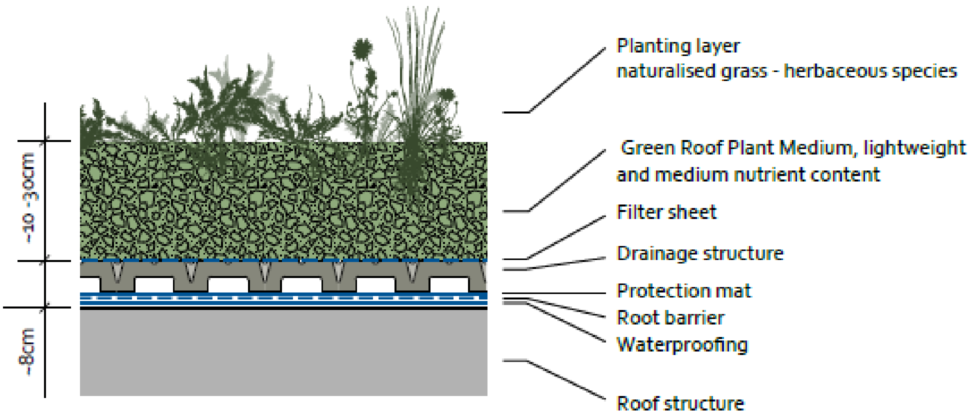

Figure 71: Medium depth green roof typical section

Table 34: Medium depth green roof evaluation

Benefits: **Public Health**	Flowering plants provides more visual interest over the years than low and slow growing sedum planting. Some roofs can provide people with access to nature and planted with amenity lawn.
Benefits: **Microclimate**	• Increased vegetation cover to absorb heat and air pollutants compared to thin substrate green roof.
Benefits: **Climate Resilience**	• Increased capacity to absorb, retain, and slowdown rainfall run-off through vegetation and substrate.
Benefits: **Biodiversity**	• Species-rich naturalised grasses and herbs, including wild and meadow flower species, attracting pollinator invertebrates. • Insects could find many suitable habitats within the taller, fast-growing plants.

Cost: Capital Investment	• Requires robust drainage system that has suitable capacity to hold and discharge water. • Plants are generally procured as seeds.
Cost: Installation	• Roof should provide water points for irrigation during establishment period and prolonged draught. • Some extent of structural strengthening required. • Seeds sowing is straightforward as does not require special skills.
Cost: Maintenance	• Min. 6-8 visual maintenance inspections per year. • Weeding, mowing may be required.

3.5.2.4 Deep Substrate Green Roof

With 300-800mm depth of substrate, the deep substrate green roof can support a variety of planting, along with hard landscaping to provide amenity spaces on the roof. This type is referred to as 'Intensive' green roofs, roof gardens, roof terraces or podium landscapes. Depending on the substrate depth, they can generally contain bulb, herbaceous and appropriate shrub and even small tree species.

Figure 72: Deep substrate green roof at Abbeygate Vizion, Milton Keynes © Frosts Landscapes

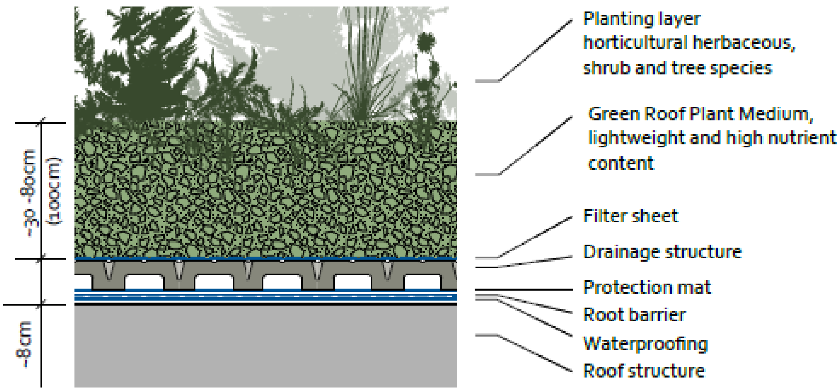

Figure 73: Deep substrate green roof typical section

Table 35: Medium depth green roof evaluation

Benefits: Public Health	Great for urban placemaking benefits due to versatile design opportunities and sophisticated plant selection. Access to the nature and with recreational open space on an elevated level. Quieter and potentially have better views than on street level. Potential to support urban agriculture.
Benefits: Microclimate	• For the vegetated areas: the plants shade and insulate the underlying roof. Increased capacity in evaporated cooling as more water is attenuated. • More foliage to absorb air pollutants.
Benefits: Climate Resilience	• Highly beneficial for stormwater management, due to additional water attenuation within the increased growing medium volume.
Benefits: Biodiversity	• High variety of plants to support pollinators while providing habitats for invertebrates and birds.
Cost: Capital Investment	• Require high-quality drainage components. • As amenity provision is expected, cost on plants, growing medium, plant supports (stakes and ties), as well as on hard landscape material and furniture will be highest.
Cost: Installation	• Both soft and hard landscape requires to be designed by qualified professionals, in collaboration with architect and engineers. • Water point must be provided. • Construction method must consider the requirement for heavy machinery lifting planting materials.
Cost: Maintenance	• Minimum 8-10 visual maintenance inspections per year should be carried out. • Higher water consumption may require regular irrigation in addition to pruning, fertilising, and replanting.

3.5.2.5 Biodiverse Green Roof

When not purposefully planted, the biodiverse green roof is sometimes marketed as ‘brown roof’. This type of green roofs aims to maximise the diversity of ecological conditions on the roof to promote biodiversity objectives. This is achieved through variations in depth of growing medium; variation in surface and growing medium, materials; addition of habitat structures such as log piles and bird perches; and incorporation of bare unvegetated areas. In addition to deliberate plant introductions, natural plant colonisation and succession is encouraged. Biodiverse green roof can often be integrated into thin or medium depth substrate green roof to achieve multiple benefits.

Figure 74: Biodiverse green roof with dry meadow at 201 Bishopsgate, London © Living Roofs

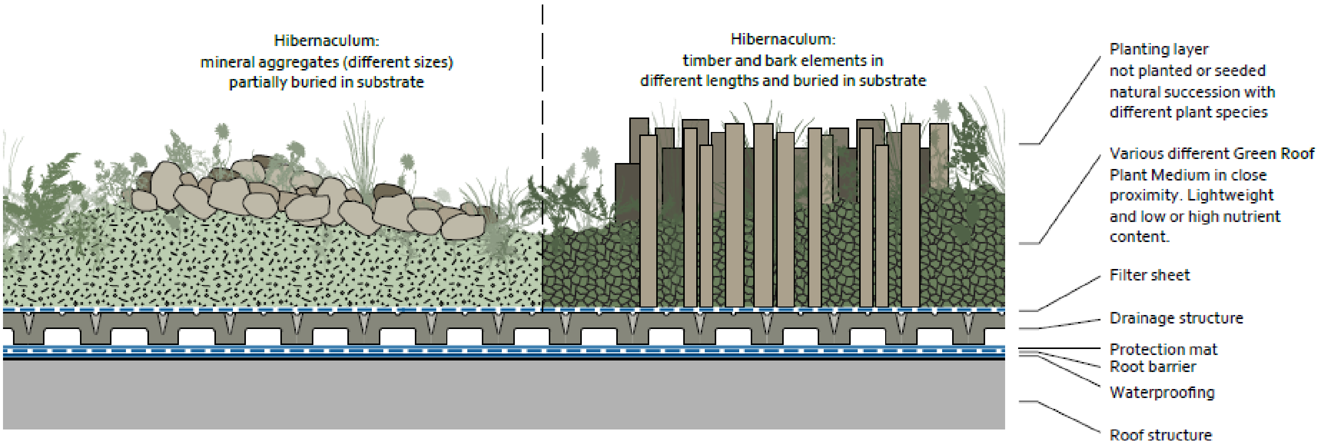

Figure 75: Biodiverse green roof typical section

Table 36: Biodiverse green roof evaluation

Benefits: Public Health	Dynamic appearance due to variable plant communities and natural succession. Access generally not encouraged.
Benefits: Microclimate	• Increased vegetation cover to absorb heat and pollutants.
Benefits: Climate Resilience	• Increased capacity to absorb, retain, and slowdown stormwater. •
Benefits: Biodiversity	• Instant positive ecological impact; extra flora / fauna habitat creation and mitigation including targeted Biodiversity Action Plan species throughout the year. • Varied substrate topography and materials creates a wide range of habitats for invertebrates.
Cost: Capital Investment	• Depends on design, cost will be similar to that of medium substrate green roof. • Opportunities to include locally sourced materials (recycled, if suitable).
Cost: Installation	• Design should involve qualified ecologists.

	• Could be relatively lightweight and require minimum structural strengthening.
Cost: Maintenance	• Min. 2-4 visual maintenance inspections per year. • No seedling/planting required. Remove undesired species. • Less management input required due to natural vegetation progression.

3.5.2.6 Ground-based Green Wall

This type of green wall incorporates climbing plants grown in the ground in front of desired wall or façade structure to be greened. The trellis system that typically supports climber plants can consist of vertical and horizontal wires or rods made from a large variety of materials including stainless steel.

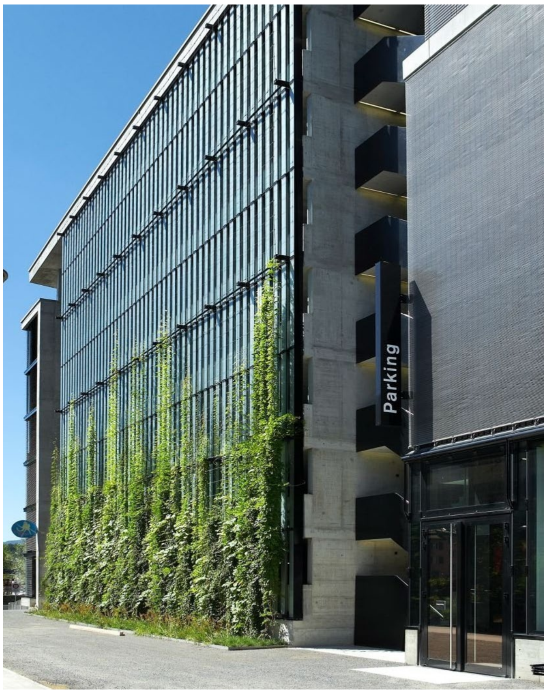

Figure 76: Ground-based green wall at Sihlcity, Zurich © Jakob

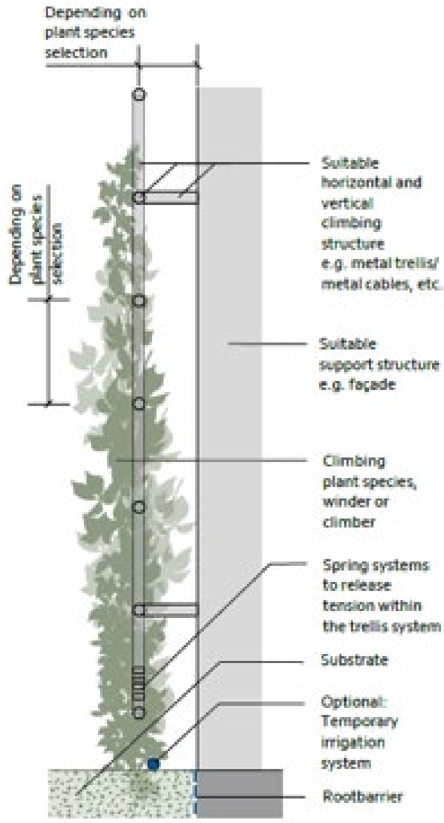

Figure 77: Ground-based green wall typical section

Table 37: Ground-based green wall evaluation

Benefits: Public Health	Planting will be mainly climber plants, limited variety. It takes time to achieve height of coverage on the façade.
Benefits: Microclimate	• Limited ability to provide shading from the sun and the evaporative cooling. • Air quality improvements and acoustic filtering are limited.
Benefits: Climate Resilience	• Less materials are required for the system. • In ground planting are likely to last longer than in containers. • Retention of water is only achieved on ground level.
Benefits: Biodiversity	• To achieve vertical coverage, planting species will need to have climbing/twining tendencies thus limited the variety and percentages of native species.
Cost:	• System relatively simple.

Capital Investment	
Cost: Installation	• Support system has minimum impact on façade structure.
Cost: Maintenance	• Minimum 2-4 visual maintenance inspections per year. Generally, it does not require trimming/pruning. • • Planting medium on the ground is easily accessible.

3.5.2.7 Green Wall System with Elevated Planters

Large or small planters can be incorporated into the vertical green wall to provide additional growing spaces. The elevated planters can be used in conjunction with ground-based planting, or independently.

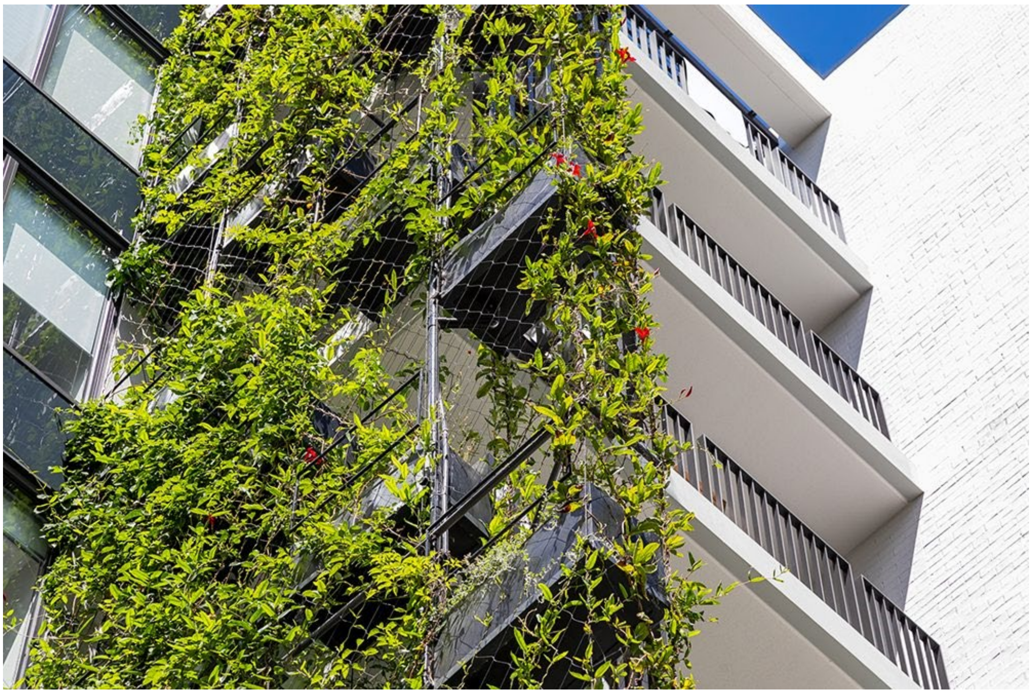

Figure 78: Green wall system with elevated planters at Harold Park, Sydney © Tensile

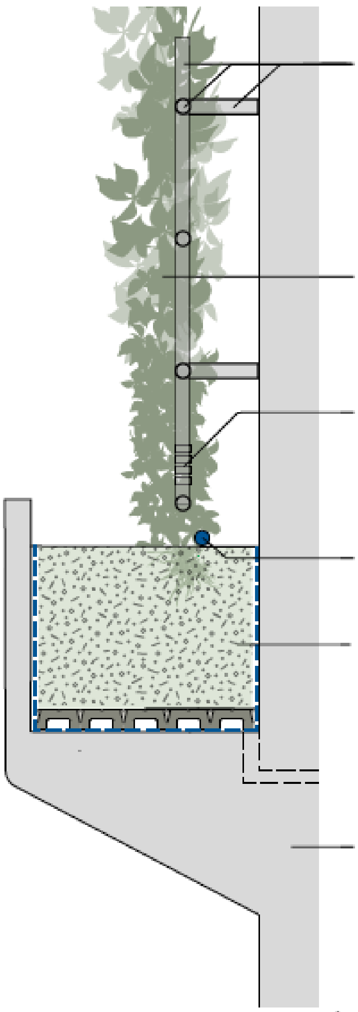

Figure 79: Green wall system with elevated planters typical section

Table 38: Green wall system with elevated planters evaluation

Benefits: Public Health	Quicker vertical coverage as plants will grow on different levels. Visual amenity can be appreciated from both inside and outside of building.
Benefits: Microclimate	• Increased ability to provide shading from the sun and the evaporative cooling. • Air quality improvements and acoustic filtering are increased with higher foliage covering.
Benefits: Climate Resilience	• Multiple planters can retain the rainfall and slow down run-off.
Benefits: Biodiversity	• In addition to climbing plants, elevated planters provide opportunities for shrubs, grasses, or hanging plants. • Integration of bird/bat boxes are more achievable.
Cost: Capital Investment	• In addition to trellis system, additional cost will be required for planters, and its associated irrigation and drainage components. • The cost is subject to significant variation depending on the complexity, project scale, and planting design.
Cost: Installation	• Structure required to be strengthened to support elevated planters and the planting materials they contain.
Cost: Maintenance	• Minimum 6-8 visual maintenance inspections per year. Drainage function of each planter should be checked. • Irrigation required at the establishment period.

	• If the planters are not accessible from the interior, access of moving platforms will be required.

3.5.2.8 Modular Living Wall Systems

This type of green walls consists of modules either pre-grown or unplanted in which plants can be inserted in situ following installation. These modules are installed on a sub-frame with an integrated hydroponic drip irrigation system and attached to the back of a primary structure.

Figure 80: Modular living wall system at Glasshouse Car Park, Cheshire © ANS Global

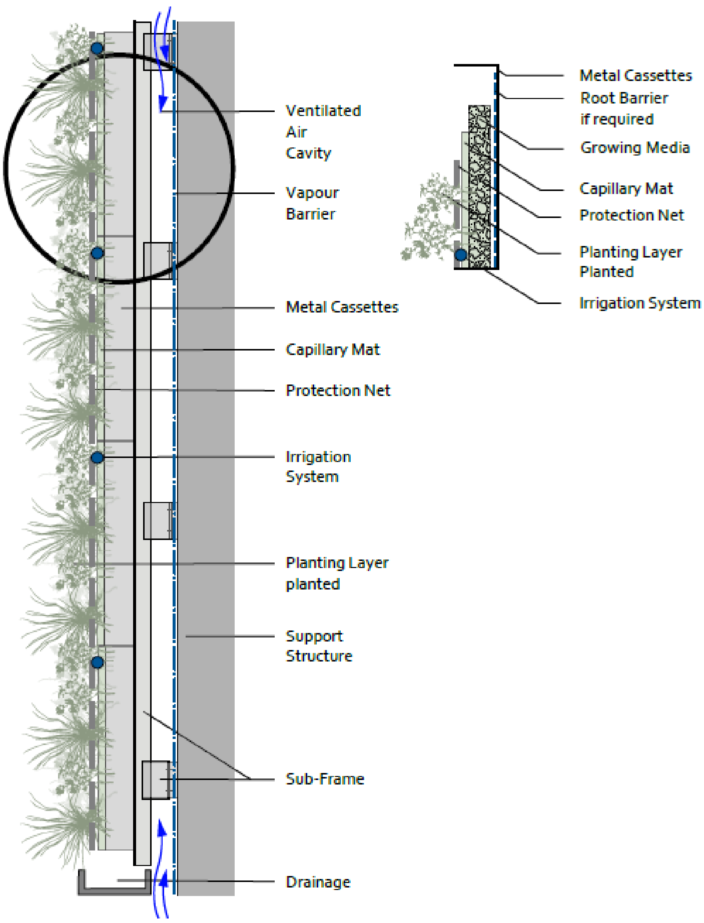

Figure 81: Modular living wall system typical section

Table 39: Modular living wall system evaluation

Benefits: Public Health	They provide high aesthetic value, helping with placemaking. Year-round interest due to broad plants species variety.
Benefits: Microclimate	• Higher vegetation coverage to reflect sun and heat. • Denser foliage to absorb air pollutants. • Some winter insulation benefits.
Benefits: Climate Resilience	• Forms additional stormwater attenuation on site. Collected water can be used for irrigation. However the demand for water will be quite high in summer due to the exposure of most plants.
Benefits: Biodiversity	• Potential to plant very diverse flora among the modules to provide source of nectar for pollinators. • Large vertical area of sheltered habitats for insects. • Bird and bat boxes can also be incorporated.
Cost: Capital Investment	• System more complex and the planting require design appropriate to location.
Cost: Installation	• Structure strengthening required to support subframes and the modules. • Specialist required for installation
Cost: Maintenance	• Minimum. 8-10 visual maintenance inspections per year. Maintenance to drainage, irrigation, plants required. • Plants replacement due to size too large for containers. • Access by moving platforms or abseiling will be required.

3.5.2.9 Suitability Considerations

The four Spatial Options have varying levels of relevance according to density of development.

In higher density settings, where space is often limited, all types of green roofs and green walls play a key role in urban sustainability and ecological resilience. **Deep substrate green roofs**, with their capacity to support a diverse range of plantings, including trees and shrubs, provides people with access to nature while supporting local ecology, and retaining run-off in areas with a large amount of sealed surface.

Incorporating **medium depth green roofs** or applying them along with **biodiverse green roofs** in high-density areas provides an opportunity to create microhabitats, supporting a variety of plant, birds, and invertebrate species. The vertical space in high-density settings makes **green walls with elevated planters** or **modular living wall systems** a preferred choice, offering a sense of nature and dynamic visual amenity without occupying valuable ground space.

Conversely, in low density scenarios with more ground-based habitats and available space, the simple, low maintenance systems will be more appropriate. **Thin or medium substrate green roofs and biodiverse green roofs,** being lighter and requiring less maintenance, can be implemented on a larger scale, contributing to environmental benefits without the need for intensive upkeep.

As the ground space is more abundant, **ground-based green walls** can be an excellent choice to provide a touch of greenery without the need for sophisticated systems. As there are more opportunities to plant directly into ground in low density scenarios, the ground level green infrastructure should be prioritised where possible overall.

For individual projects, the optimal choice of the type of green roofs and/or green walls will rely heavily on a thorough assessment of benefits and costs appropriate to the project. At the stakeholder engagement workshop on 23 November 2023, participants highlighted climate resilience and biodiversity are two key benefits that the polices need to take into account for both high density and low density scenarios.

Best practice considerations are provided below to inform and guide policy-setting. Regardless of the types of green roofs or the green walls to be applied, a balance across these considerations helps to achieve the most appropriate design response in accordance with individual project priorities and constraints.

Maximising benefits:

Create diverse habitats and shelters for wildlife.
Planting should incorporate more native species and maximise food sources for pollinators.
Using natural materials where possible.
Encourage usage of recycled materials.
Integrate bird/bat boxes, insect hotels, hibernacula, bee hives etc.
Ecologist's input in design and monitoring to ensure success.
Incorporate water storage as part of drainage system, slowing down run-off.
Reusing site-collected water for irrigation.
Solar panels should be incorporated where possible.
Holistic building design approach to ensure people can benefit from direct access to nature (structure, location/orientation).
Variety in plant species to create year-round interest.
Provide opportunity to access, in addition to visual access: participating in planting activity, food growing.

Achieving cost effectiveness:

Select drought resistant, hardy, low maintenance plants.
Select simple, robust systems that are easy to install and to maintain.
Ensure irrigation source and mechanism are considered at the outset. In times of hosepipe ban, tanks that store water will be beneficial. Automated systems could reduce labour for watering.
Instant effect is expensive, allow time for plants to mature.
Involving building occupiers in maintaining roof garden/allotments may be cost-saving.

3.5.3 Cost analysis of Green Roofs and Walls

Costings have been calculated for the seven different variations of green roofs and walls. These costs have not been separated by building typology, but instead by the specification of green roof or wall. The base of these costings has been built up with the assistance of industry suppliers to ensure the costs are as accurate as possible from the design information available. The same allowances and considerations should be made for these costs as the building costs set out in the preceding section (e.g., estimate sensitivity tolerance, influencing factors etc.).

All costs have been calculated on a cost per unit and therefore their output will vary depending on development design and site orientation, which will impact both CAPEX and £/unit. All of the rates are exclusive of additional drainage or irrigation allowances, but are inclusive of main contractor, and sub-contractor, preliminaries and OH&P.

In contrast to the previous cost assessments, a "lower range" and "upper range" have been calculated for these interventions due to the variance that can occur from economies of scale with these products.

The comparison findings indicate that there is a significant variance in the costs associated with different types of green walls, depending on the desired specification.

Table 40: Green roof and wall costings

Ref	Description	Unit	Lower Range [£ GBP]	Upper Range [£ GBP]
Green Roofs				
1.	Thin Substrate Green Roof	m^2	120	250
2.	Medium Depth Green Roof	m^2	200	320
3.	Deep Substrate Green Roof	m^2	370	800
4.	Biodiverse Green Roof	m^2	120	290
Green Walls				
5.	Ground-based Green Wall	m^2	400	490
6.	Green Wall system with elevated planters	lm[47]	930	1,160
7.	Modular Living Wall System (Office)	m^2	1,740	2,180
8.	Modular Living Wall System (Warehouse)	m^2	1,510	1,780

[47] lm refers to linear metre as unit of measurement

A.1 Consultation summary

A.1.1 Overview

As part of the preparation of the Milton Keynes Carbon and Climate study public consultation was held using the CommonPlace platform. Consultation took place for a period of six week from 17 October 2023 to 28 November 2023. The consultation was informal and the aim was to inform the preparation of the Study. Consultation was separate to the statutory consultation that MKCC will undertake to include the preparation of the Local Plan.

The consultation was open to all and responses were received from members of the public, community organisations and four statutory consultees (Historic England, Natural England, Anglian Water and the Canals and Rivers Trust). In total 83 comments and 49 reactions were received in response to the question: *What do you think the priorities should be for reducing emissions in Milton Kenyes?* There were 144 comments made and 159 reactions in response to the question: *What do you think a sustainable Milton Keynes looks like?* A further 14 responses were submitted via email covering thoughts in response to both questions.

Respondents were asked what their priorities are for reducing emissions in Milton Keynes and what does a sustainable Milton Keynes look like? Respondents were invited to drop a pin onto a map of Milton Keynes and share thoughts about which areas are vulnerable to climate change, why this was and what could be done to address this.

All responses have been carefully considered and incorporated into the study as appropriate. This Appendix sets out a summary of the comments of written comment. Comments placed on the map have been considered in the Climate Vulnerability Section 2.6.

A.1.2 Key themes

The word cloud below illustrates the most common words used in response to the question: what are the priorities for reducing emissions in Milton Keynes?

The word cloud below illustrates the most common words used in responses to the question: what does a sustainable Milton Keynes look like?

Comments made have been summarised and categorised into topics below.

Consultation comment	Response
Net Zero Buildings	
The city's population is growing rapidly, new homes need to be planned for in a sustainable and environmentally sensitive way.	The purpose of this study is to provide evidence to support MKCC in planning for sustainable growth in the New City Plan.
New buildings should be built to a high environmental standard, be fit for future climate needs and be adaptable as the needs of the user change over time.	This has been considered in the Recommendations report for this study.
All new buildings should achieve the lowest possible embedded CO_2 considering both the materials and construction methods used.	Energy efficient new buildings have been included in the Recommendations report for this study.
New buildings should be designed to achieve recognised and certified standards including PassivHouse and BREEAM 'Outstanding' so that energy consumed for heat and light is exceedingly low.	
New homes should not use fossil fuels, including gas.	Modelling assumed the phasing out of gas in line with Government projections.
The orientation and roof design of all buildings should be designed to optimise the scope for solar PV.	This has been considered in the Recommendations report for this study.
Suggestion that all new homes should have solar panels and rain water storage.	This study recommends that MKCC progress roof mounted solar PV policies and policies that require the efficient use of water.
There should be a study of the thermal efficiency of tall buildings compared with low- and medium-rise developments.	This is outside the scope of this study.
Secure the improved energy performance of existing homes, for example by developing programmes such as those being pursued by Wolverton Community Energy.	Wolverton Community Energy has been consulted as part of the preparation of this study. This study has considered the energy performance of future homes and it will be for MKCC to consider specific programmes that could help achieve the policy requirements. It is outside the scope of this study to consider the energy performance of existing homes.
Grants should be considered for improved insulation, heat pumps and double glazing for existing property.	This is outside the scope of this study.
Buildings should be constructed to encourage wildlife, with the inclusion of features, such as swift boxes.	This is outside the scope of this study, however MKCC is undertaking separate work to inform the New City Plan in respect of biodiversity, see for example the Milton Keynes Nature, Green and Blue Infrastructure Strategy (August 2023)
Transport ***General***	
New developments should not cater to private car usage and should encourage sustainable modes of transport, including public transport.	Recommendations to encourage the use of public transport have been included. The transport modelling includes assumptions on future car use, recognising that some car use will continue into the future. The Central Milton Keynes recommendations in the Recommendations report recognise the potential for using land associated with the grid network for other uses where there is a decline in car use.
Milton Keynes was originally design for the car, the roads should be reprioritised to cater for more sustainable modes of travel. The car focused design may hinder the change to sustainable travel.	
New developments should be mix-used to allow easy access to key amenities for day-to-day like.	

Consultation comment	Response
Look to promote local shops, allowing people to walk and shop locally, with shops encouraged to come back to the high street.	The Framework for Sustainable Places (Baseline report) recognises that sustainable places meet the community's needs locally where possible.
Look to split the pavements which are currently being shared by pedestrians, cyclists and people on e-scooters, which makes them unsafe.	This is outside the scope of this study.
Walking and cycling	
Improved redway network. Walking and cycling routes should be direct and convenient to get from point A to point B, as the current redways are often circuitous and difficult to follow.	Recommendations include the promotion of walking and cycling.
Increase and improve the provision of secure cycle parking at key locations in Milton Keynes, such as entertainment hubs and rail stations.	Recommendations include the promotion of walking and cycling, although detailed matters such as the provision of secure cycle parking is outside the scope of this study.
Cycle and walking routes should be provided within the green infrastructure to allow more attractive routes, which are well lit for safety.	Recommendations include the promotion of walking and cycling, and encouraging multifunctional green spaces.
Look to embed active travel principles.	Recommendations include the promotion of walking and cycling.
Public transport	
More consideration is needed on how people commute, particularly in terms of their ability to use public transport.	The principle of efficient and reliable public transport is supported through the recommendations. The availability of public transport has been considered in the spatial options analysis, which recognises for example that there will be less opportunity to use public transport if Spatial Option 4 rural approach is progressed.
Concern over the new road (linking the H1 grid road to the A422) that facilitates the rapid transit network, due to the ability for this to be used by other forms of vehicles.	This is outside the scope of this study
Integrate and promote the use of buses, trams and trains to reduce car use, making it easier for people to travel using sustainable modes of travel.	The principle of efficient and reliable public transport is supported through the recommendations.
Ensure the provision of safe and accessible public transport, so everyone can benefit from sustainable travel.	
More investment into the efficient and reliable public transport, that is ideally net-zero.	
Explore the provision of a park and ride at J13 of the M1.	This is outside the scope of this study.
Car use and parking	
Any plans to introduce an Ultra Low Emissions Zone should be phased, to give motorists time to prepare.	This is outside the scope of this study.
Concerns over the feasibility of sustainable modes of travel, such as walking and cycling; some journeys will always require a car, for example to visit out-of-town supermarkets.	The potential for different forms of transport has been considered in the spatial options analysis.
It will be difficult to get some communities to change their behaviour, for example walk/cycle instead of using the car.	This is noted and inherently considered in the transport modelling.

Consultation comment	Response
Consider it unrealistic to deliver new communities without motorised transport. Raises whether it is more beneficial to promote sustainable connectivity between communities.	The potential for different forms of transport has been considered in the spatial options analysis. The transport recommendations support the principle of sustainable connections between communities.
Review parking standards, which are too onerous and result in streets dominated by parking.	This is outside the scope of this study.
Look at alternative traffic control, rather than the over use of traffic lights.	This is outside the scope of this study.
Potential to introduce 20mph zones.	This is outside the scope of this study.
Waste	
Improve the waste management of public areas. The example of Bury Common in Newport Pagnell, where the bins are not emptied regularly enough.	This is outside the scope of this study.
Look to provide more bins in public spaces to reduce litter.	This is outside the scope of this study.
Agriculture	
Protect farmland from more house building	This study has not identified land for development.
There are concerns about putting solar panels on agricultural land- the land should be kept for agricultural land in order to provide cheaper and locally sourced food.	This study recommends allocating sites for ground mounted solar PV, in identifying allocations MKCC will need to balance many considerations including existing land use.
Retaining green field land for food production, and to tackle biodiversity loss and support habitat creation.	This study recommends identifying opportunities for food growing.
Green Infrastructure	
Plant more trees, including street trees. It is suggested that trees are regularly planted in the gardens of private properties, not verges, and are then removed by homeowners. The planting of trees should be prioritised to provide shade and natural cooling.	Recommendations include incorporating Green Infrastructure principles, such as street trees, accessible green spaces, good maintenance and green roof/walls.
Provide well-designed green spaces that are safe and accessible to everyone. This could include turning the area that is currently designated at SEMK into woodland.	
Ensure green spaces are enhanced and maintained well.	
New buildings should look to incorporate green walls and roofs, with the suggestion that these are often argued against by developers.	
Look to develop a Local Nature Recovery Plan which should include the protection of ancient and established hedgerows, and consider how people can have wilder gardens to encourage birds and hedgehogs.	This is outside the scope of this study, however MKCC are separately preparing a Local Nature Recovery Plan.
Green spaces should include areas to allow residents to grow their own food, such as allotments.	Recommendations encourage food growing areas.
People would like to see biodiversity given a higher priority.	This is outside the scope of this study, however MKCC is undertaking separate work to inform the New City Plan in respect of biodiversity, see for example the Milton Keynes Nature, Green and Blue Infrastructure Strategy (August 2023)

Consultation comment	Response
MKCC should be looking to encourage a higher coverage of green infrastructure, as is seen in the older / original parts of Milton Keynes. Milton Keynes should return to the original concept with houses being separated from the roads by bushes and trees.	The recommendations encourage the promotion of Green Infrastructure across the MKCC administrative area.
Residents note that MKCC seem to be discouraging landscaping within the public realm, due to the cost of maintenance, residents feel this should not be the case.	This is outside the scope of this study.
All apartments should be provided with a balcony.	This is outside the scope of this study.
Developments should look to reduce hardstanding and promote soft landscaping, which will help reduce temperatures and result in less water run-off.	The benefits of soft landscaping are recognised in the climate risk analysis and this is reflected in the recommendations.
Carbon Sequestration	
Carbon should be sequestered by the green environment.	Carbon sequestration has been considered in this study and it is recommended that land use which has the most potential to sequester carbon is protected.
Riverside meadows have the potential to sequester carbon as part of multi-functional spaces which also manage flood risk and provide open space.	Land with most potential to sequester carbon is considered in Section 2.3.3.
New plantations will only be effective for carbon sequestration where they have long-term woodland management.	This is noted and should be considered as part of MKCC's long term management approach.
Renewable energy	
There was support for hydropower, particularly on the River Great Ouse. Specifically there is potential for electricity generation as part of existing weirs, such as in the River Great Ouse at Stony Stratford and Haversham weirs.	This is outside the scope of this study.
There may also be scope for local heat generation from heat-pumps drawing heat from main sewers.	The preferred spatial option (1 Densification) creates opportunities for low carbon heat networks. Further consideration of the heat source for these is outside the scope of this study.
Support for micro generation on new build and retrofit.	This has been considered and renewable energy generation is recommended.
There is scope for more wind-farms within the wider MK area.	This study considered the potential for wind generation and found that it is only possible in a less conservative scenario, where river and surface water flood zones and Agricultural Land Category 3 are included in the suitable land search area. In this less conservative scenario, wind generation is estimated at 190 GWh per year.
Support for more renewable energy generation including wind and solar.	The study recommends progressing ground mounted Solar PV allocations in the Local Plan and policies relating to roof mounted solar PV. See above in respect of wind.
Opposition to more wind farms and ground mounter solar PV.	Renewables will play an important part in MKCC addressing climate change.
New developments should be required to produce a minimum level of power from solar energy.	This study recommends that MKCC progress roof mounted solar PV policies.
Look at using solar energy for streetlights.	This is outside the scope of this study.

Consultation comment	Response
Suggestion to look at a Gen 5 nuclear fusion module reactor is used to enable Milton Keynes to achieve net zero goal.	This is outside the scope of this study.
The heating of new homes should be done via ground source heating networks.	The preferred spatial option (1 Densification) creates opportunities for low carbon heat networks and it is recommended that these are progressed.
Consideration should be given to installation of vertical ground-source heat-pumps linked to local district heating systems as part of area-wide thermal retrofitting of energy inefficient housing.	See above in respect of heating networks. In line with good practice when drafting policy, specific technologies are not recommended, nevertheless it is expected that ground-source heat-pumps will be an important part of addressing climate change in Milton Keynes.
Suggestion to look at subsidised the installation of air source heat pumps and solar panels.	This is outside the scope of this study.
Concerns over how MKCC will fund initiatives.	This is outside the scope of this study.
Other	
Look at increasing the density of existing parts of Milton Keynes and reuse of brownfield land to reduce the development on greenfield land.	The preferred spatial option (1 Densification) creates opportunities promoted densification and the carbon sequestration findings support the reuse of brownfield land.
MKCC should take an all-encompassing approach to sustainable development, reflecting the three sustainability pillars at the heart of national planning policy: economic, social and environmental.	The Framework for Sustainable places (Baseline report) describes a all-encompassing approach to sustainability which has been considered throughout this study.
A sustainable city should work for women and girls.	The Framework for Sustainable places (Baseline report) recognises that places should be for everyone regardless of gender, age or race.
Education campaigns should be used to change behaviour.	This is outside the scope of this study.
Concerns raised about how MKCC plan to tackle social inequalities. There is a noticeable division in Milton Keynes where accessibility to open spaces, public transport, jobs, amenities and better-quality housing are provided in the more affluent areas of the city.	This is outside the scope of this study.
Concerns Milton Keynes has already seen too much development and would now not be able to become sustainable and achieve the net zero goal.	This study has not set the quantum of development expected to be brought forward in the New City Plan, rather it has assessed the options for growth with view to ensuring it is as sustainable as possible.
People should retain their right to move freely around Milton Keynes.	This study does not include any suggestion that this should not be the case.