OXFORD INDUSTRIAL DECARBONISATION PROJECT

Scenario Modelling

AN ERM REPORT FOR THE ZERO CARBON OXFORD PARTNERSHIP

FEBRUARY 2025

ZERO CARBON OXFORD

Introduction to this report, authors, and disclaimer

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About this document

This document reports the findings from WP4 of the ZCOP Local Industrial Decarbonisation Roadmap (LIDP) project, developing scenarios for industrial decarbonisation in Oxford and modelling their impacts.

Link to other work packages

The report builds upon the findings of the Oxford's Industrial Landscape & Baseline (WP1) report and the Technology Analysis and Prioritisation (WP3) report. The analysis was also informed through several stakeholder engagement activities (WP2).

This analysis identifies initiatives to accelerate decarbonisation, estimates demand for technology deployments, and calculates investment needs. These findings inform Oxford's Industrial Decarbonisation Roadmap and Action Plan (WP6).

Funded by DESNZ through the Local Industrial Decarbonisation Plans (LIDP) grant

Department for Energy Security & Net Zero

Contents

Executive Summary

Local initiatives can accelerate decarbonisation and reduce residual emissions, but an ambitious transformation is needed

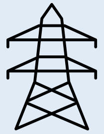
Many large industrials and business parks in Oxford have committed to decarbonisation, with ambitious plans for low-carbon technology deployments. However, several constraining factors might limit decarbonisation in a business-as-usual case, putting at risk the **Oxford City target for net zero emissions by 2040**.

Our **enabled & locally driven scenario** (consisting of initiatives to increase electricity capacity, expand Oxford's heat network, and engage SMEs) shows how emission reductions could be accelerated and overall residual emissions reduced – **achieving 66% reduction by 2035 and 90% reduction by 2040**. This, however, requires an ambitious transformation of Oxford's energy system and significant technology deployments – **45 MW of process electrification, 11 MW of heat pumps, 21 MW of heat network connections, and 31 MW of local renewables**.

Business-As-Usual Scenario

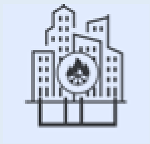
The business-as-usual case explores industrial decarbonisation in Oxford in a case without further intervention outlined by the actions of this roadmap. Technology uptake is driven by existing plans or national policies and is constrained by barriers such as limited grid capacity, lack of space for onsite renewables, and barriers to engagement for SME industrials.

Enabled & Locally Driven Scenario



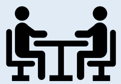
Increased Electricity Capacity

Accelerated upgrade of electricity network capacity and/or direct wire connections to local energy generation



Heat Network Expansion

Expanding existing city heat network plans to business parks and large industrials.

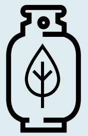


Accelerated SME engagement

Overcoming barriers for dispersed SME industrials to engage and invest in decarbonisation.

Speculative Scenario

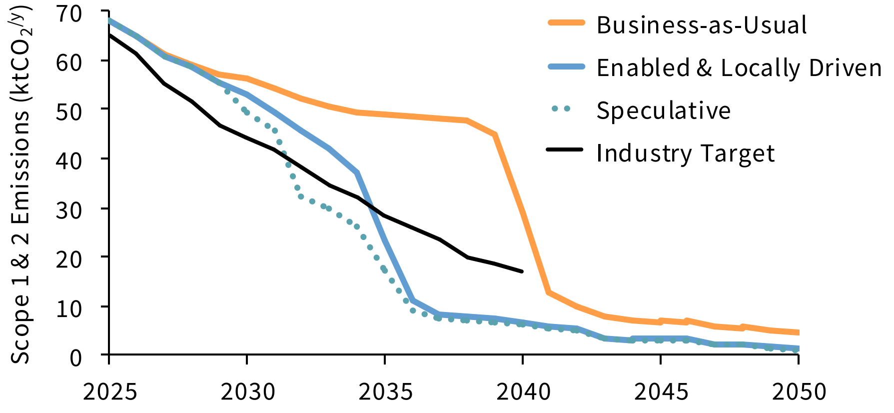
The enabled & locally driven scenario with an additional initiative:



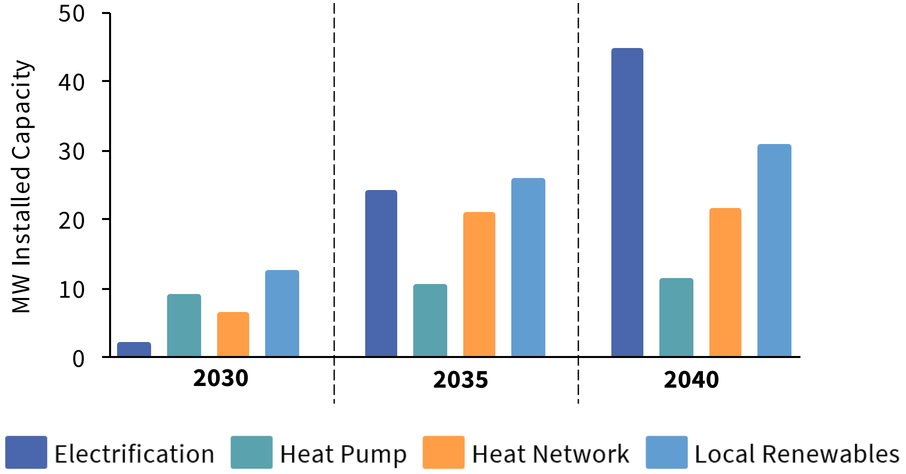
Alternative Gases

Exploring hydrogen and biomethane production for blending into the gas grid as an interim measure.

Oxford industrial cluster emissions across scenarios explored compared to Oxford City's target*



Technology uptake in the enabled & locally driven scenario



*Significant drops in emission trajectories of scenarios for business-as-usual (2040) and enabled & locally driven (2035) are a direct result of upgrades to electricity connections, allowing electrification of energy-intensive processes to occur at a large industrial. Industry target refers to the trajectory developed for industry within the ZCOP '2040 Net Zero Action Plan' for the city of Oxford published in 2021. Residual emissions result from hard-to-abate processes and grid-electricity emissions, with offsets of these residual emissions needed to achieve net zero.

Scenario Modelling & Outcomes

The impact of Oxford's industrial decarbonisation options has been assessed through energy, emissions and economic modelling

Feasible timelines and magnitudes for the uptake of the prioritised decarbonisation technologies across Oxford's industry were determined through a combination of stakeholder engagement, literature review and targeted analysis.

From this, two options for uptake were considered for each technology category:

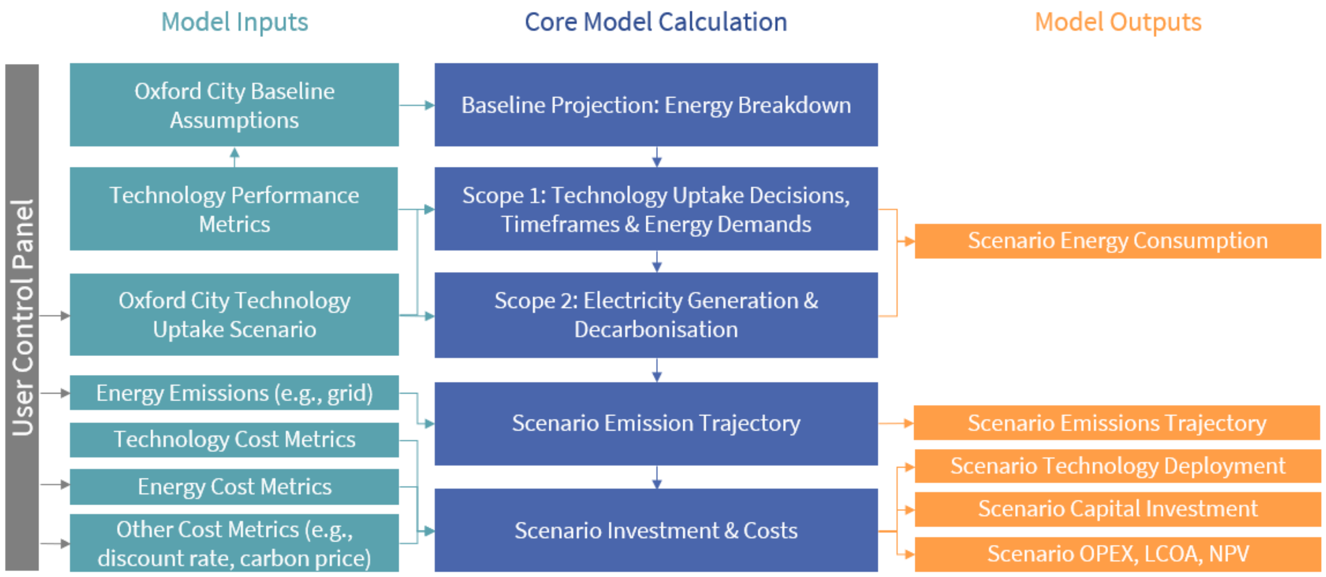
- **Business-as-usual uptake** – the expected timelines and magnitude of technology deployment without further intervention from Oxford City Council, ZCOP, or other local actors (i.e., timelines driven by existing plans or national policies)
- **Enabled & locally driven uptake** – more ambitious timelines and / or magnitudes for technology deployment that could be feasible with increased local interventions and enabling actions taken by Oxford City Council, ZCOP, or other local actors (i.e., timelines driven by increased ambition and local initiatives)

In the case of alternative gases, no current ambitions for increased uptake were identified, so instead a **highly speculative uptake** case was explored.

The impact of technology uptake on Oxford's industry was then assessed through an **energy, emissions and economic model** to understand:

- Rate of technology deployment
- Impact on energy consumption
- Impact on scope 1 & 2 emissions
- Level of investment required
- Overall impact on costs for industrials

Overview of energy, emissions and economic model



Limitations:

- *Decarbonisation has been assessed considering high-level archetypes for demand at dispersed sites, business parks, and the South-East Sub-Cluster with only a limited amount of data on energy consumption and processes made available.*
- *The analysis has not considered the specifics of site-level processes both due to the lack of data and the confidentiality of data where available.*
- *Therefore, all results should be treated as indicative and with high levels of uncertainty. Their purpose is to serve as comparative estimates to evaluate the potential impacts of different decarbonisation initiatives.*
- *Investment and abatement costs are indicative based on information available for this. Further project specific detailed cost assessments should be done in future to evaluate these metrics with greater accuracy.*
- *Further details on modelling assumptions are available in the standalone report.*

Modelling of decarbonisation focused on the five technologies selected as the highest priorities for Oxford's industrials

Our analysis focuses on the five abatement technologies prioritised for Oxford's industrial emissions. The impact of deployin g these highest priority technologies has been assessed through stakeholder engagement and subsequent energy, emissions and economic modelling. In addition, the potential f or alternative gases (such as biomethane and hydrogen) was explored given its emerging nature and potential synergies with other sectors.

Energy Efficiency

Energy efficiency includes a wide range of measures to reduce energy consumption. It covers demand reduction (e.g., insulation), technology or process improvement, smart controls or digitalisation, and behaviour change.

Heat Pumps

Heat pumps are powered by electricity and act to transfer heat at very high efficiencies, providing space heating as replacements for gas boilers.

Heat Network

Heat networks, also known as district heating, are centralized heating systems that distribute heat from a central source to multiple buildings or facilities within a defined area through a network of insulated pipes.

Complex Electrification

This covers electrification of high temperature or direct heating applications (e.g., ovens, kilns) by replacing them with radiative or resistance heating technologies.

On-site Renewables

On-site renewables refers to the generation of electricity from renewable sources, typically solar photovoltaic (PV) panels, on an industrial site. Users generate a proportion of their electricity demand.

Alternative Gases

Alternative gases such as hydrogen or biomethane can be blended into the gas grid to reduce the overall emissions intensity of gas use in Oxford.

Many Oxford industrials have high ambitions, but these are currently constrained by barriers limiting deployment

Several barriers exist in a business-as-usual scenario

Many large industrials and business parks in Oxford have committed to decarbonisation, with ambitious plans for low-carbon technology deployments. Furthermore, the city council is driving for low-emission developments and entities such as Low Carbon Hub are supporting energy efficiency and solar projects.

This study has however identified several constraining factors that might limit decarbonisation. Among others, these include:

- **Electricity network capacity constraints**
- **Limited space availability for solar PV**
- **Barriers to SME engagement**

Business-As-Usual Scenario: The business-as-usual case explores industrial decarbonisation in Oxford in a case without further intervention outlined in the actions of this roadmap. Technology uptake is driven by existing plans or national policies and is constrained by these barriers.

Scenario analysis explores the impact of overcoming these barriers

Enabled & Locally Driven Scenario: Stakeholder engagement has identified distinct initiatives where ZCOP and local entities could collaborate to improve upon the business-as-usual case. Three of these are explored in our 'enabled & locally driven' scenario – combining increased electricity capacity, heat network expansion, and accelerated SME engagement.

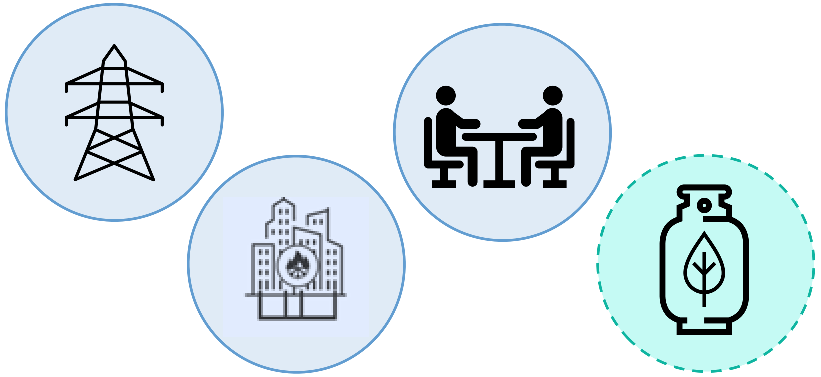
Speculative Scenario: A fourth initiative was explored in an addition to the above as part of a 'speculative' scenario – this investigated the impact of gas grid blending of hydrogen and biomethane as an interim measures.

Increased Electricity Capacity

Accelerated upgrade of electricity network capacity and/or direct wire connections to local energy generation

Accelerated SME engagement

Overcoming barriers for dispersed SME industrials to engage and invest in decarbonisation.



Heat Network Expansion

Expanding existing city heat network plans to business parks and large industrials.

Possible Low-Carbon Gases

Exploring hydrogen and biomethane production for blending into the gas grid as an interim measure.

An enabled & locally driven scenario acts to remove barriers and accelerate uptake of technologies

Assumptions used for modelling Oxford industrial decarbonisation scenarios:

Business-as-usual technology uptake for Oxford industrials:

Energy Efficiency

- Business parks gradually deploy energy efficiency measures as buildings are refurbished, with a 19% energy reduction by 2040.
- Over the next decade, small & dispersed sites slowly deploy ‘low-hanging fruit’ energy efficiency measures with low capital investment and quick payback periods, achieving 10% energy reduction by 2035.

Heat Pumps

- All new business park developments are built with heat-pumps or electrified HVAC systems. Business parks gradually replace existing gas boilers with heat-pumps as buildings are refurbished.
- Grid capacity challenges delay adoption of large-scale heat pumps in the Cowley area (assumed until 2038)
- Driven by national policies, small & dispersed sites gradually adopt heat pumps from 2035 as existing gas-boilers reach end of life.

Complex Electrification

- It is assumed that Mini Plant Oxford will eventually electrify its complex heating processes in alignment with wider BMW Group developments across Europe. The required additional grid capacity for this is estimated to be significant.

Electricity Supply

- It is conservatively assumed that electricity network upgrades (including possible substation development) in the Cowley area are not completed until 2040, limiting the deployment timelines of electrification for large industrials.
- Onsite renewables (such as solar PV) are deployed extensively at all new business park developments (generating 20% of demand)
- Existing business parks gradually deploying onsite renewables during renovation cycles (achieving 5% of demand).

Enabled & locally driven technology uptake for Oxford industrials:

Energy Efficiency

- Both business parks and SME industrials maximise energy efficiency opportunities, achieving a 19% energy reduction by 2035. This might involve additional retrofits at business parks and investments in measures with longer payback periods.

Heat Pumps & Heat Networks

- All new business park developments are built with heat-pumps or electrified HVAC systems.
- Business parks in proximity to the Oxford Energy Network (a heat network) connect into it by 2030, with other business parks gradually adopting heat-pumps as buildings are refurbished.
- This heat network is expanded to the Cowley area supporting decarbonisation of space heating (assumed by early 2030s)
- Driven by local support, SME industrials gradually adopt heat pumps from 2028 as existing gas-boilers reach end of life, with some SMEs being connected to the heat network instead.

Complex Electrification

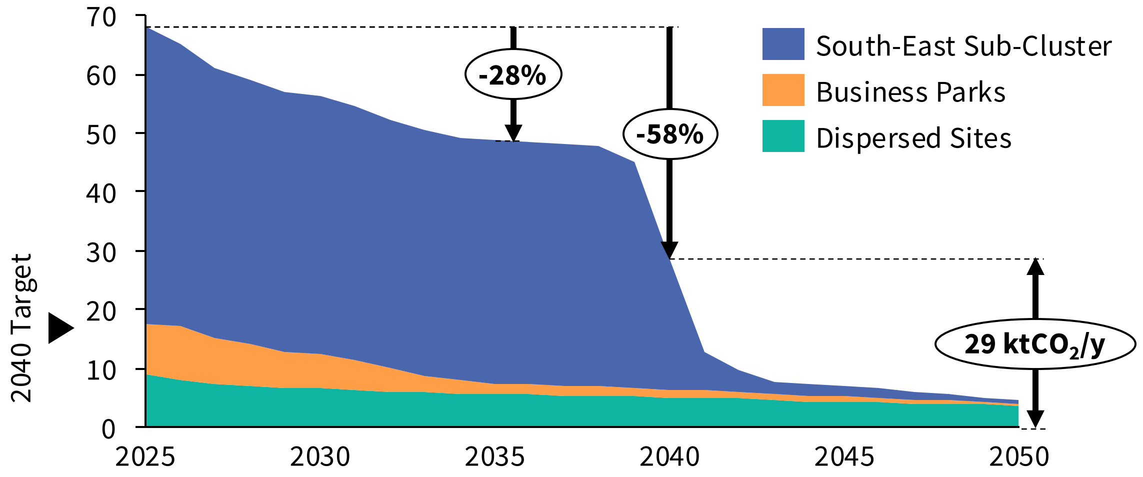
- It is assumed that Mini Plant Oxford will eventually electrify its complex heating processes in alignment with wider BMW Group developments across Europe. The required additional grid capacity for this is estimated to be significant.

Electricity Supply

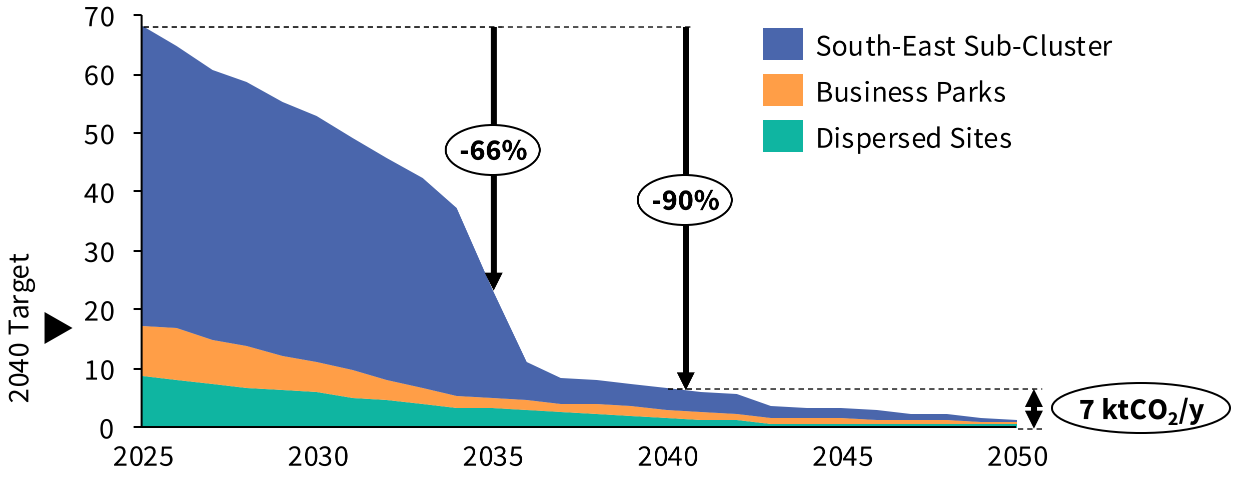
- Local actions result in accelerated electricity connections in the Cowley area (assumed by 2035) – either through quicker grid upgrades or local energy hub investments with direct wires.
- Onsite renewables (such as solar PV) are deployed extensively at all new business park developments (generating 20% of demand).
- Ambitious uptake of onsite renewables is achieved at existing business parks (10% of demand) by using a range of solutions, such as solar carport and microgrids.

Without local initiatives for industry there is a risk that Oxford City might miss its 2040 target for decarbonisation

Business-as-usual Scope 1 & 2 emissions* (ktCO_2/y)



Enabled & locally driven Scope 1 & 2 emissions* (ktCO_2/y)



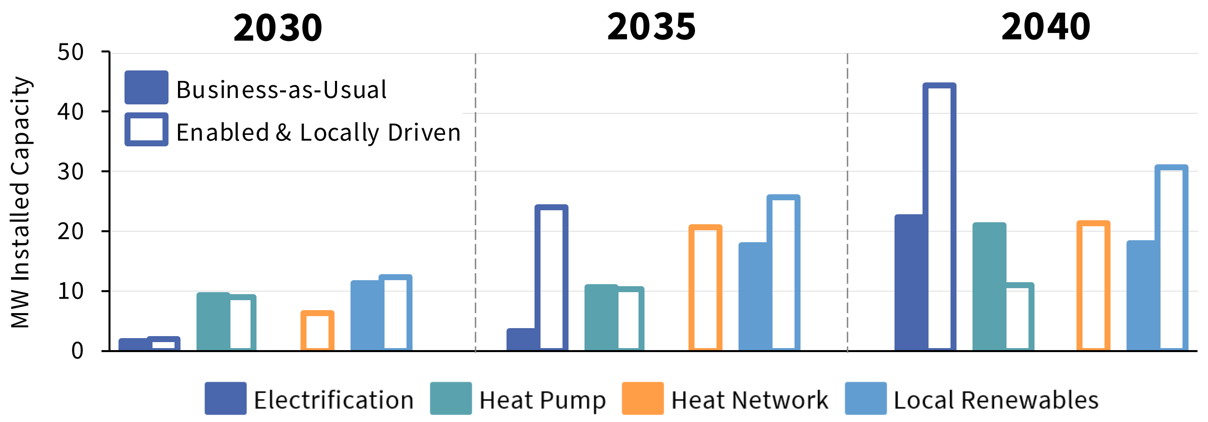
- In 2021, the Zero Carbon Oxford Partnership (ZCOP) **committed to collaborate on achieving net-zero carbon emissions for the city of Oxford by 2040** – 10 years ahead of the UK target. Oxford industrials were expected to reduce emissions by 82% from 2020 by 2040, with **offsets then needed to achieve net zero due to hard-to-abate processes**.
- More detailed modelling developed in this project reveals that in the **business-as-usual scenario this target is at risk** due to the grid-constraint challenges in the South-East Sub-Cluster and barriers to dispersed SME engagement. The scenario results in a remaining 29,000 tonnes of industrial CO_2 emissions in 2040 – with potential to be closer to 50,000 tonnes if grid connections are slower than assumed.
- Furthermore, there **remains 4,500 tonnes of industrial emissions in 2050** primarily from dispersed SME sites who have not been incentivised to decarbonise complex heating appliances (e.g., ovens, furnaces).

- Our enabled and locally driven scenario suggests that, **with the right enablers and initiatives**, Oxford's industrial sector could achieve a 66% reduction in emissions over the next decade. This path would leave only 7,000 tonnes of remaining industrial CO_2 emissions by 2040, equivalent to **90% reduction compared to current levels of emissions**. Therefore, this project's more detailed modelling shows how Oxford industry could exceed the targets originally set by ZCOP in 2021.
- The **most significant factor in reducing 2040 emissions is the early electrification** of complex heating at large industrials. This is enabled through accelerating grid upgrade timelines – reducing industrial connection times from an assumed 2040 business-as-usual case to an ambitious 2035 enabled case.
- The **expansion of the heat network acts to accelerate decarbonisation** in the early-2030s and thus reduce the cumulative emissions to 2040, although has limited impact on in-year emissions in 2040. **Engagement with dispersed SMEs reduces residual emissions in 2040.**

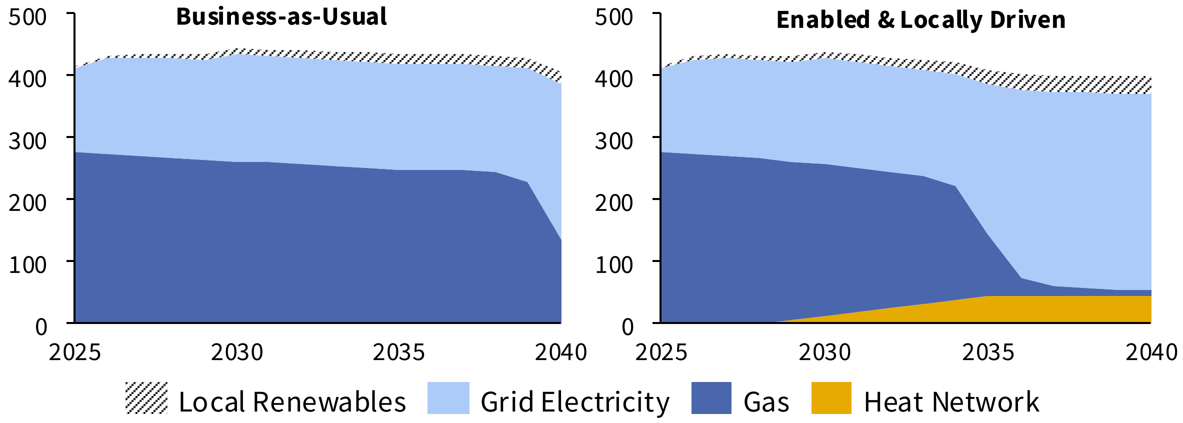
*Significant drops in emission trajectories of scenarios for business-as-usual (2040) and enabled & locally driven (2035) are a direct result of upgrades to electricity connections, allowing electrification of energy-intensive processes to occur at a large industrial. 2040 Target refers to the trajectory developed for industry within the ZCOP '2040 Net Zero Action Plan' for the city of Oxford published in 2021. Residual emissions result from hard-to-abate processes and grid-electricity emissions, with offsets of these residual emissions needed to achieve net zero.

Ambitious deployments of heat pumps, local renewables, process electrification and energy infrastructure upgrades are needed

Total installed capacity of abatement technologies by 2030, 2035, and 2040 (MW output)



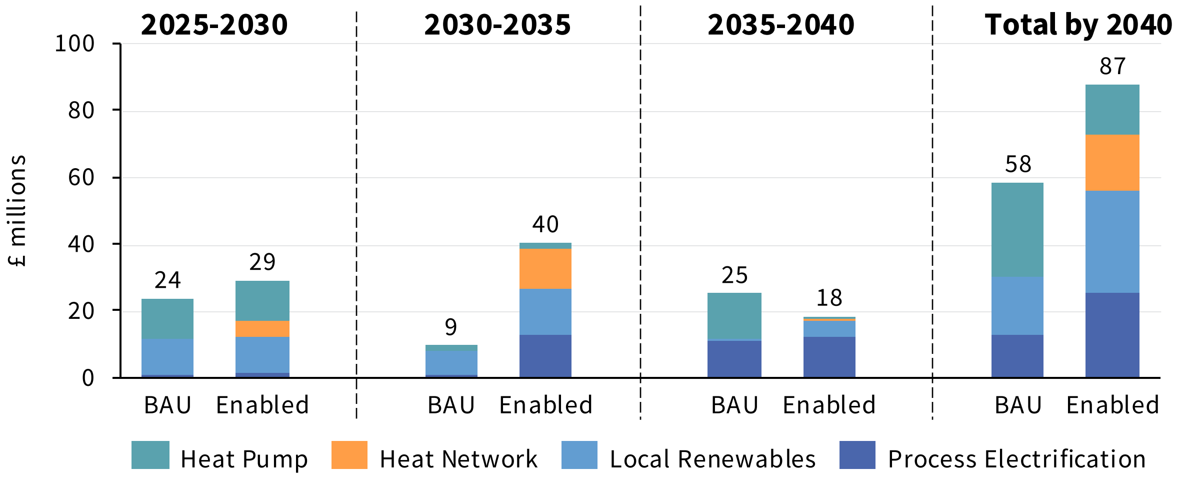
Impact on total energy supply demanded by Oxford industrials (GWh/y)



- The 'enabled & locally driven' scenario requires uptake of 45 MW of process electrification, 11 MW of heat pumps, 21 MW of heat network connections, and 31 MW of local renewables. Without heat network connections, an additional 10 MW of heat pumps would be needed.
- **Most heat pump deployments are achieved by 2030**, driven by uptake from business parks as they renovate buildings or build new developments. In addition, 1-2 MW of heat pumps are deployed gradually at dispersed sites through to 2040. In the case where a heat network is not expanded to Cowley, an additional 19 MW of heat pumps are needed to decarbonise the South-East Sub-Cluster by 2040.
- In the 'enabled & locally driven' scenario, **connections to an expanded heat network are expected to be achieved by 2035**, accelerating decarbonisation of space heating for the South-East Sub-Cluster and some business parks on the proposed route (as an alternative to heat pump deployment).
- **Local renewable deployments (with energy storage as needed) occur gradually from 2025-2035** as a complementary technology for electrifying heating. Business parks deploy rooftop solar during regular building refurbishments, with additional solar carport deployments also considered in the 'enabled & locally driven' case. Local **microgrids may be adopted to balance supply-and-demand** for these local renewables.
- In the 'enabled & locally driven' scenario, the **electrification of complex heating at large industrials commences between 2033-2037.** This is expected to place significant extra demand on the electricity network (an estimated 135 GWh per year) and therefore does not occur until Cowley grid upgrades are completed and/or local renewables with direct wire connections become available.
- The combined impact of these deployments is a **phase out of industrial gas usage and a 150% increase in electricity demand**. In the 'enabled & locally driven' scenario this occurs before 2040, whereas for business-as-usual it is delayed to the early 2040s. Up to 9% of electricity could be generated locally and heat networks could supply 11% of total energy demand.

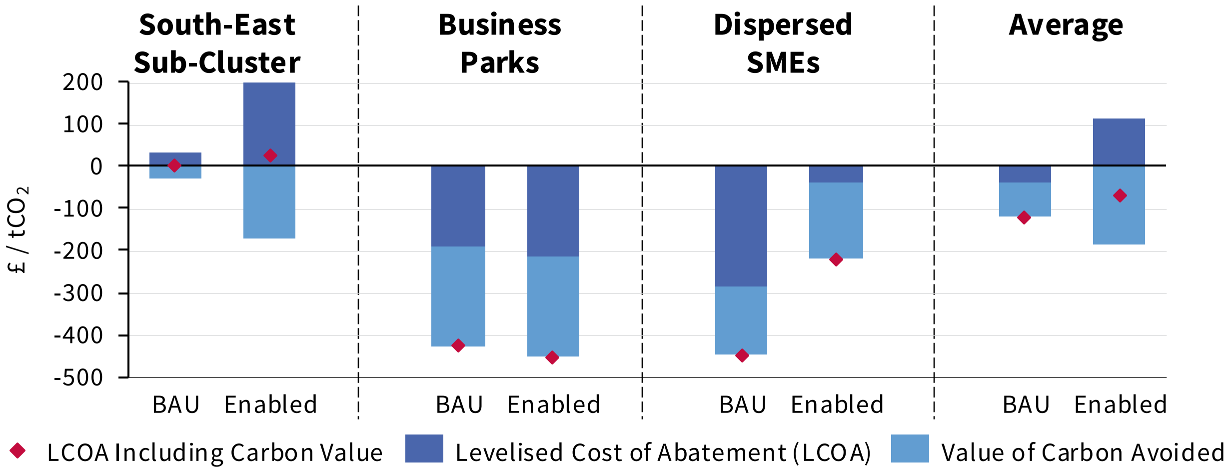
A total investment of £87 million is estimated by 2040, with business parks and SMEs able to recoup costs through energy savings

Capital investment required over period to install abatement technologies



- The 'enabled & locally driven' scenario requires **capital investments of between £20-40 million within each 5-year period from 2025-2040**, totalling £87 million. This is 50% more than the business-as-usual case by 2040.
- **30% of this investment is for process electrification** – electrifying complex heating at large industrials – and includes an indicative cost for grid connections. In contrast, in the business-as-usual case, this investment may be delayed until beyond 2040.
- To decarbonise space heating, capital investments totalling **£15-28 million for onsite heat pumps** are required, with a potential additional **£17 million for connections to a shared heat** network in the 'enabled & locally driven' scenario.
- Lastly, to support decarbonisation, **between £18-31 million could be invested into local renewable generation** projects, such as rooftop solar, solar carports, or energy hubs.

Levelised cost of abatement for different types of industrials



Carbon value refers to an assigned monetary value on CO_2 emissions which is used for decision making. In this analysis, we have aligned with central values used by UK government. These do not typically reflect actual monetary benefits for individual industrials but instead consider system wide benefits and objectives. Individual industrials may develop their own internal carbon value assumptions that differ from those used by policy makers.

- **For business parks and dispersed sites, the upfront costs of abatement measures could be recouped** through energy savings*, with a total reduction in costs seen compared to a 'no abatement' baseline. For dispersed sites, the extent of these savings 'per tonne CO_2 abated' are reduced in the 'enabled & locally driven' scenario as more ambitious uptake occurs.
- **In the South-East Sub-Cluster, it is expected that deploying abatement measures would increase costs overall** compared to a 'no abatement' baseline. The levelised cost of abatement was estimated at £199 per tonne CO_2 (although this is highly uncertain). However, if a monetary value for CO_2 emissions is included the result is approximate cost neutrality, highlighting the importance of internal carbon pricing for large industrials and/or policy incentives to drive decarbonisation.

*While overall a cost saving is estimated by the modelling, the ability to recoup costs will depend upon the commercial arrangement and may be complicated by landlord-tenant dynamics.

Analysis of individual initiatives provides insights on the measures with greatest impacts and investment needs

Impact of individual initiatives when compared to the business-as-usual scenario:

Increased Electricity Capacity

- This initiative has the **greatest emissions impact** of all those investigated, resulting in an additional 26% emissions reduction by 2040 compared to the BAU.
- It impacts the emission trajectory of the **South-East Sub-Cluster**, enabling faster uptake of technologies as grid constraints are overcome sooner.
- The initiative **increases the total capital investment by £34 million** compared to the BAU by 2040, with additional deployments of process electrification, heat pumps, and local renewables (e.g., solar carports and energy hubs).
- The initiative **increases the levelised cost of abatement**, resulting in an average cost of £111 per tonne CO_2 (excl. carbon value).

Accelerated SME Engagement

- The small contribution of SME emissions to overall cluster emissions means that this initiative has **limited impact on emissions** both by 2040 (additional 5% reduction) and cumulatively from 2025-2040 emissions (27,000 tonnes of CO_2 avoided).
- However, this is the **only initiative with a significant impact on dispersed sites** – reducing their emissions by two thirds in 2040 compared to the BAU (from 5,000 to 1,600 tonnes of CO_2 remaining).
- The initiative **increases the total capital investment by £12 million**, with greater uptake of heat pumps, local renewables, and electric appliances.
- The cost of the initiative can be recouped with **cost savings achieved of £24 per tonne of CO_2 abated** (slightly less than the BAU case).

Expansion of Heat Network to Industrials

- This initiative acts to **reduce the cumulative emissions** of the cluster, resulting in an additional 76 thousand tonnes of CO_2 avoided from 2025-2040 compared to the BAU case. It has a relatively **limited impact on emission reductions by 2040** (extra 7% reduction compared to BAU).
- A heat network could be **beneficial to all site types** investigated as an alternative to heat pumps and could also **help overcome local grid connection challenges** for decarbonising heating.
- This initiative **increases capital investment by £7 million** by 2040 compared to the BAU but could halve the demand for heat pumps.
- The **levelised cost of abatement is increased** with an average cost of £21 per tonne CO_2 (excl. carbon value).

Alternative Gases

- This initiative has a **strong contribution to emission reductions** when deployed in addition to BAU efforts – an additional 11% reduction by 2040 and cumulative emission avoidance of 135,000 tonnes of CO_2. However, it has a more **limited impact when adopted in addition to all other initiatives combined.**
- Blending of alternative gases into the gas grid affects the cumulative emissions of the **South-East Sub-Cluster and dispersed sites** as these continue to use gas into the mid-2030s.
- The initiative **increases the levelised cost of abatement for the cluster**, resulting in an average cost of £114 per tonne CO_2 (excl. carbon value).

Impact of individual initiatives on Oxford's emissions, investment needs, and installations

		BAU	Capacity	Heat Network	Engage	Enabled	Alt. Gases	Speculative
Remaining emissions in 2040 - Total	$ktCO_2/y$	**28.9**	**10.2**	**24.0**	**25.5**	**6.5**	**20.7**	**6.1**
- South-East Sub-Cluster	$ktCO_2/y$	22.5	3.8	17.9	22.4	3.6	15.9	3.6
- Business Parks	$ktCO_2/y$	1.4	1.4	1.4	1.4	1.4	1.3	1.3
- Dispersed Sites	$ktCO_2/y$	5.0	5.0	4.7	1.6	1.6	3.5	1.2
Emission reduction in 2040 compared to 2024	%	**59%**	**85%**	**66%**	**64%**	**91%**	**70%**	**91%**
Cumulative emissions - Total	$ktCO_2$	**840**	**658**	**764**	**813**	**599**	**705**	**545**
- South-East Sub-Cluster	$ktCO_2$	672	491	599	672	460	555	416
- Business Parks	$ktCO_2$	68	67	67	67	65	65	63
- Dispersed Sites	$ktCO_2$	101	101	98	74	74	84	66
Capital Investment - Total	£ million	**58**	**92**	**65**	**70**	**87**	**58***	**87***
Levelised Cost of Abatement (excl. carbon value) - All	£ / tCO_2	**-37**	**111**	**21**	**-24**	**113**	**114**	**154**
- South-East Sub-Cluster	£ / tCO_2	32	193	90	45	199	187	238
- Business Parks	£ / tCO_2	-193	-198	-180	-222	-214	-170	-194
- Dispersed Sites	£ / tCO_2	-286	-286	-218	-39	-38	67	27
Levelised Cost of Abatement (incl. carbon value) - All	£ / tCO_2	**-120**	**-62**	**-107**	**-120**	**-72**	**-39**	**-44**
- South-East Sub-Cluster	£ / tCO_2	3	32	-8	16	25	58	47
- Business Parks	£ / tCO_2	-428	-434	-416	-459	-452	-407	-434
- Dispersed Sites	£ / tCO_2	-448	-448	-392	-222	-221	-135	-173
Capacity Installed by 2040 - Process Electrification	MW (output)	**22**	**42**	**22**	**25**	**45**	**22**	**45**
Capacity Installed by 2040 - Heat Pumps	MW (output)	**21**	**31**	**10**	**23**	**11**	**21**	**11**
Capacity Installed by 2040 - Heat Networks	MW (output)	**0**	**0**	**21**	**0**	**21**	**0**	**21**
Capacity Installed by 2040 - Local Renewables	MW (output)	**18**	**28**	**22**	**25**	**31**	**18**	**31**

*Does not include investment in hydrogen and biomethane production

Appendix

ANALYSIS OF INDIVIDUAL INITIATIVES

The impact of individual initiatives has been assessed in comparison to the business-as-usual case

This study has identified several areas where ZCOP and local entities could collaborate to improve upon the business-as-usual case. These are explored in our 'enabled & locally driven' scenario through a combination of the four distinct initiatives highlighted below. Over the next few slides, we further describe the context of these initiatives and investigate the potential impact that they might have on Oxford industrial decarbonisation individually.

Increased Electricity Capacity
Accelerated upgrade of electricity network capacity and/or direct wire connections to local energy generation

Heat Network Expansion
Expanding existing city heat network plans to business parks and large industrials.

Accelerated SME engagement
Overcoming barriers for dispersed SME industrials to engage and invest in decarbonisation.

Possible Low-Carbon Gases
Exploring hydrogen and biomethane production for blending into the gas grid as an interim measure.

Approach to assessing the impact of initiatives:

- The possible impact on energy, emissions and economics of each of these local initiatives has been assessed using the model developed for this ZCOP ID roadmap.
- In this appendix, the impact of each initiative has been assessed relative to the business-as-usual scenario in isolation of the other initiatives.
- This individual assessment is used to evaluate the priority areas for enabling and driving decarbonisation locally.
- It should be noted that the impact of some initiatives may overlap, resulting in reduced total impacts once combined in the 'Enabled & Locally Driven' scenario.
- All assumptions on timelines and magnitudes are indicative and included only for the purposes of scenario analysis. They do not necessarily reflect specific plans of industrials or energy providers, whose information is commercially sensitive and not available for this study.
- Actual timelines and magnitudes will depend on the enabling actions identified in this study, as detailed in the action plan.

Spotlight: Challenges with electricity grid connections in Oxford

Capacity constraints in Oxford's electricity network are expected to delay electrification of large industrial processes.

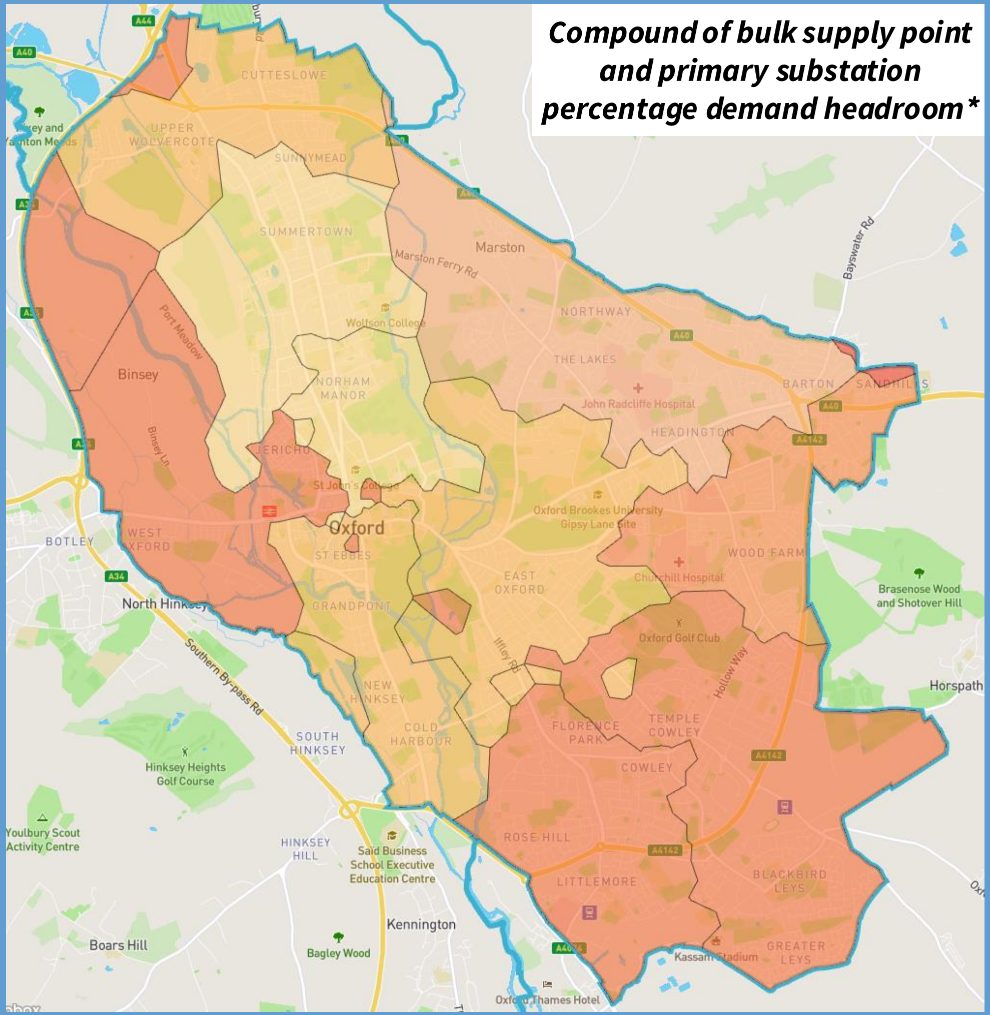
Oxford's persistent grid constraints have been recognised through prioritisation in SSEN's Strategic Development Plan process and in planned upgrades to the infrastructure in Cowley around 2030. Nevertheless, this is not expected to realise sufficient grid capacity to electrify industry.

Work is ongoing to assess the future needs for grid upgrades. There are two primary routes to evaluate future demand; through the LAEP/DFES planning and via direct applications to SSEN to join the queue.

Alternative solutions will play an important role in releasing constraints on the grid:

- Firstly, the uptake of flexible capacity connections can significantly decrease the connection timelines
- On-site solutions such as renewables, storage, and micro/smart grids can be operated to reduce demands on the grid
- Industrials can also directly fund capacity upgrades and private wires

Industry is just one sector of Oxford's economy expected to rapidly electrify in the coming decades. Both the transport and built environment sectors are expected to undergo rapid increases in electricity demand driven by electric vehicle uptake and heat pump and e-boiler installation in domestic, commercial, and institutional buildings.



* Data visualisation produced from SSEN's LENZA tool and datasets. Darker reds indicate less headroom available on the network and therefore an increased potential for grid constraints to delay electrification projects.

Accelerated upgrade of electricity network capacity and/or direct wire connections to local energy generation

The **Increased Electricity Capacity (‘Capacity’)** initiative explores the impact of accelerating the timelines for increased grid connections for large industrials and expanding the deployment of renewables at business parks to include solar carports. Actions to overcome grid-capacity challenges include pro-active engagement with energy networks and local investment in renewable energy projects (e.g., direct wire deployments).

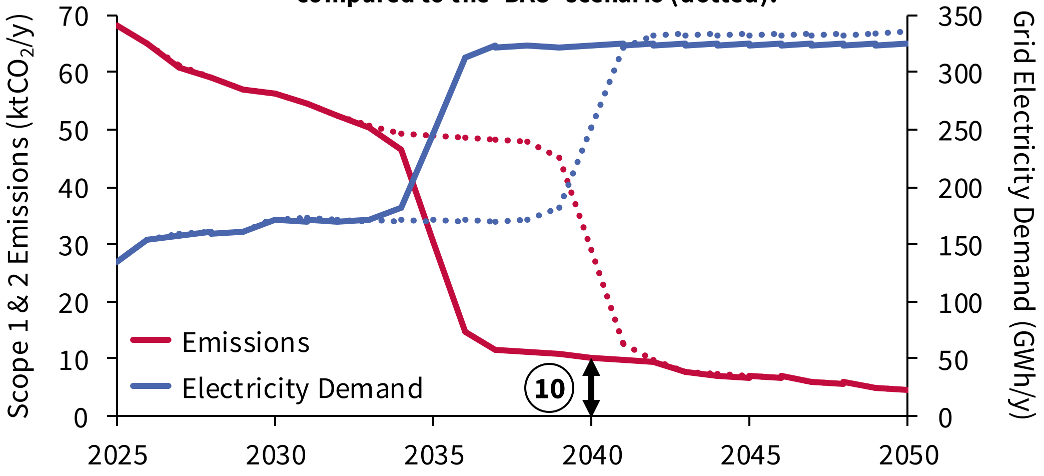
Business-as-usual technology uptake assumption:

- It is conservatively assumed that electricity network upgrades (including possible substation development) in the Cowley area are **not completed until 2040**, limiting the deployment timelines of electrification for large industrials.
- Renewables are deployed across business parks to meet **5%** of their electricity demand by 2035.

Enabled & locally driven technology uptake assumption:

- The future electricity demands of both Oxford’s industrials and the proposed heat network are identified rapidly and communicated to both local area energy planning (LAEP) teams, the local electricity distribution network operator (SSEN) and transmission network operators (**assumed by 2028**).
- Timelines for distribution and transmission network upgrades remain uncertain, however early communication and local acceleration of permitting could act as an enabler. It is assumed that **most upgrades occur at the latest by 2035**.
- There may be some upgrades, however, where timelines are much longer due to the scale of increase. In these cases, the option for deployment of local renewable energy generation (e.g., **solar carports** / farms, wind turbines, SMRs) with direct wire connections is explored. It is assumed that by 2035, **10%** of electricity demand in existing business parks is met by local renewables.
- Either way, whether through grid upgrades or direct wires to local renewables, it is assumed that **all required electricity capacity is available by 2035 at the latest**.

Emissions and grid electricity demand for the ‘Capacity’ scenario (line) compared to the ‘BAU’ scenario (dotted).



Impact of initiative:

- This initiative has the **greatest emissions impact** of all those investigated, resulting in an additional 26% emissions reduction by 2040 compared to the BAU.
- It impacts the emission trajectory of the **South-East Sub-Cluster**, enabling faster uptake of electric technologies as grid constraints are overcome sooner, resulting in a 5-year shift in the decarbonisation profile.
- The initiative **increases the total capital investment by £34 million** compared to the BAU by 2040, with additional deployments of process electrification, heat pumps, and local renewables (e.g., solar carports and energy hubs).
- The initiative **increases the levelised cost of abatement for the cluster**, resulting in an average cost of £111 per tonne CO_2 (excl. carbon value).

Spotlight: Existing proposals for a multi-sectoral heat network across the City of Oxford

There has been longstanding interest in developing a comprehensive heat network for Oxford which was highlighted in the previous ZCOP Decarbonisation Roadmap. This sits alongside a growing drive at the national level to identify and deliver heat network opportunities.[1,2]

UK Government has provided substantial funding for new networks[3] and is in the process of delivering heat network zoning[4]; that will mandate heat consumers to connect to a heat network, once available, in defined geographies ("zones").

Several smaller heat network systems have been investigated and, in some cases, implemented across the educational/institutional sectors in Oxford[5], but there remains in aggregate a sizeable demand available from educational, health, and residential buildings.

Industry can also benefit from connecting to the heat network, especially to decarbonise the notable low temperature process heat and space heating demands across the city's industrial landscape.

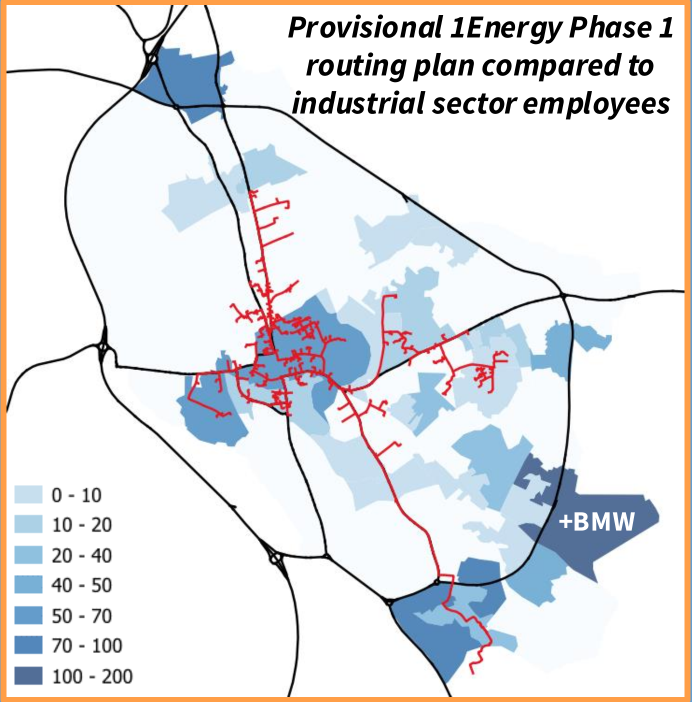
1Energy Oxford Heat Network

1Energy have applied for Green Heat Network Funding from UK Government[3] to support development of the project. Oxford City Council have publicly supported the project ambition.[6]

The map on the right shows the provisional plans for heat network routing. At the time of writing, the project is still identifying a suitable location, heat source, and grid capacity for the energy centre; which could alter the prioritised routings.

Engagement with 1Energy throughout the project has identified the potential to expand to Cowley; this could be enabled by further funding applications or a change in use of current funding.

Provisional 1Energy Phase 1 routing plan compared to industrial sector employees



1 - Heat networks - GOV.UK. 2 - UK heat networks: market overview - GOV.UK. 3 - Green Heat Network Fund (GHNF): guidance. 4 - Heat network zoning. 5 - Heat network feasibility – Carbon Alternatives. 6 - Decision - Letter of Intent to support 1Energy application to the Green Heat Network Fund | Oxford City Council.

Expansion of the Oxford City heat network to industrial sites

The **Heat Network Expansion ('Heat Network')** initiative explores the impact of connecting several business parks (Osney Mead, Oxford Science Park, and ARC Oxford) and the South-East Sub-Cluster to an expanded heat network by 2029. Actions to achieve this include building awareness of the heat network with industrials, development of the business case for connections, and expansion of the current Oxford Heat Network plans to include the Cowley area.

Business-as-usual technology uptake assumption:

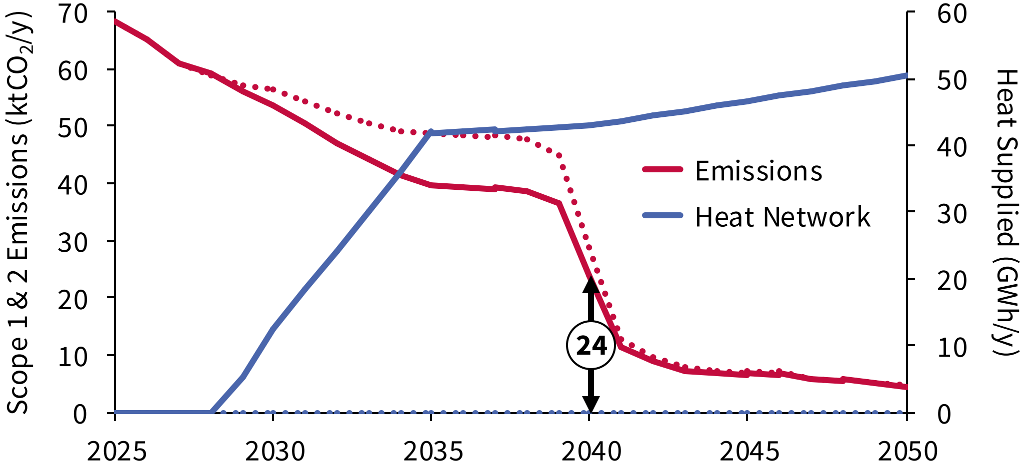
- The proposed heat network for Oxford City focuses on public and large commercial buildings and does not develop connections for business parks or other industrial sites.

Enabled & locally driven technology uptake assumption:

- Increased engagement between heat network developers and industrials results in increased awareness of the potential opportunities to supply heat to industrial consumers.
- The heat network is adapted to allow connections to business parks near the existing boundaries of development (Osney Mead and Oxford Science Park) (**assumed by 2029**).
- In addition, broad interest in the heat network from the South-East Sub-Cluster and ARC Oxford business park leads to further expansion of the proposed heat-network to the South-East area of Oxford (**assumed from 2029**).
- A limited proportion (**assumed 30%)** of dispersed sites also connect to the heat network as it develops (e.g., due to proximity to larger connection points).

- To cater for increased demand, the expanded heat network requires an additional energy centre to be established, with renewable electricity provided either via a new grid connection or private wire connection to dedicated local renewable generation (**assumed by 2029**).

Emissions and heat supplied via a heat network for the 'Heat Network' scenario (line) compared to the 'BAU' scenario (dotted)



Impact of initiative:

- This initiative acts to **reduce the cumulative emissions** of the cluster, resulting in an additional 76 thousand tonnes of CO_2 avoided from 2025-2040 compared to the BAU case. It has a relatively **limited impact on emission reductions by 2040** (extra 7% reduction compared to BAU).
- A heat network could be **beneficial to all site types** investigated as an alternative to heat pumps and could also **help overcome local grid connection challenges** for decarbonising heating.
- This initiative **increases capital investment by £7 million** by 2040 compared to the BAU but could halve the demand for heat pumps.
- The **levelised cost of abatement is increased** with an average cost of £21 per tonne CO_2 (excl. carbon value).

Spotlight: Level of engagement of SMEs with decarbonisation

Survey of industrials on decarbonisation activities

Analysis was conducted on industrial businesses in Oxford City Council region to understand the level of engagement with decarbonisation and to identify barriers to engage.

Data was collected through surveys, with questions exploring the interest of businesses to work towards decarbonisation and the progress they have made to date.

Excluding project partners, who are advanced in decarbonisation planning, the survey returned an additional 13 further entries from industrial businesses in Oxford. These responses suggest that:

- Financial barriers were ranked by over 90% of industrials as the main constraint or in the top three constraints to decarbonisation.
- Infrastructure and technological constraints were also ranked highly by most industrials as barriers to decarbonisation.
- Social and environmental constraints were consistently ranked the lowest barriers.

Approximately 30% of the surveyed (non-project partner) industrials have begun implementing decarbonisation targets, and of the remaining approximately 90% are actively interested and learning about setting these targets.

It is important to recognise the sample size is small, and covers a wide range of industrials, therefore is not necessarily representative of all industrials in the region. This small sample size is however indicative of the limited engagement by industrials with decarbonisation.

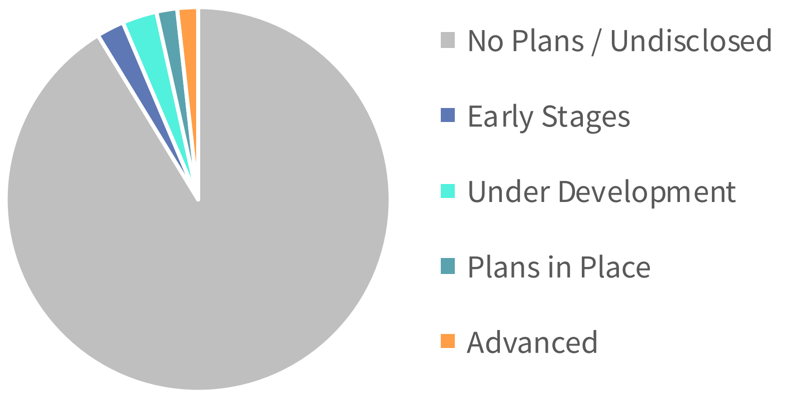
Desk-based website review

In addition to surveys, this project reviewed 172 websites of industrial businesses in Oxford to gather evidence of decarbonisation ambitions.

The chart below shows most businesses reviewed have not published decarbonisation plans – only 9% have disclosed plans on their websites.

Overall, the engagement of SMEs with decarbonisation appears limited, but there is a willingness to learn more if barriers can be overcome.

Proportion of industrial websites reviewed with disclosed decarbonisation plans



Accelerated uptake of energy efficiency, electrification, and onsite renewables for dispersed sites

The **Accelerated SME Engagement ('Engage')** initiative explores the impact of overcoming barriers for dispersed SME industrials (and their landlords) to engage and invest in decarbonisation through a variety of local measures such as capacity building, incentives, and novel financing solutions.

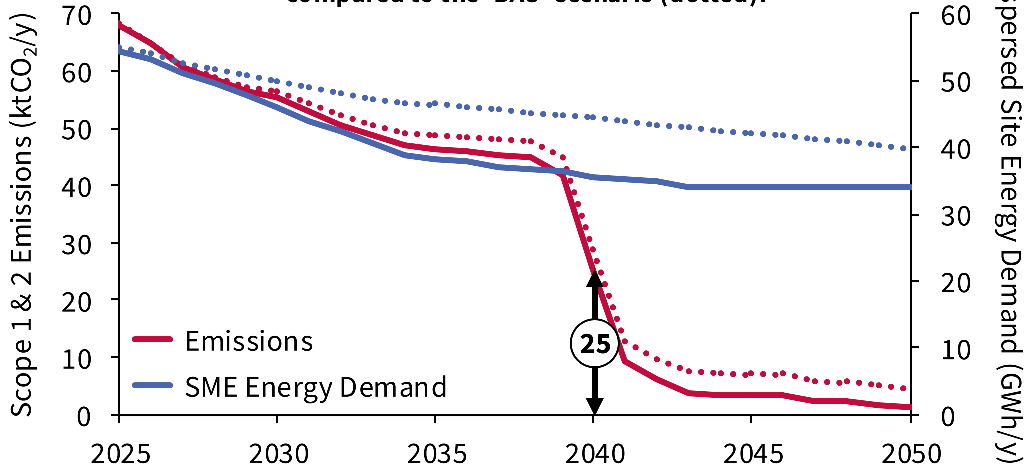
Business-as-usual technology uptake assumption:

- Over the next decade, small & dispersed sites slowly deploy 'low-hanging fruit' energy efficiency measures with low capital investment and quick payback periods, achieving 10% energy reduction by 2035.
- Uptake of heat pumps for small & dispersed sites is driven only by national policy. It is assumed that new installations of gas-boilers are banned from 2035, resulting in a gradual uptake of heat pumps as existing gas-boilers reach end-of-life.
- It is conservatively assumed that there are insufficient incentives to electrify complex heating at small & dispersed sites (with barriers including high-electricity prices, increased capital and lack of awareness).
- It is assumed that there are insufficient incentives to deploy onsite renewables at small & dispersed sites.

Enabled & locally driven technology uptake assumption:

- Small & dispersed sites maximise energy efficiency achieving 19% energy reduction by 2035, enabled through increased awareness, robust supply chains, and financial support.
- Local initiatives drive faster uptake of heat pumps for small & dispersed sites. It is assumed that from 2028 most sites would choose a heat-pump when replacing a gas-boiler.
- From 2028, incentives and information exist to encourage small & dispersed sites to opt for electric technologies as replacements for existing gas-fired complex heating equipment.
- It is assumed that, on average, at least 10% of electricity demand from small & dispersed sites is met by onsite renewables (e.g., encouraged by financial support).

Emissions and dispersed site energy demand for the 'Engage' scenario (line) compared to the 'BAU' scenario (dotted).



Impact of initiative:

- The small contribution of SME emissions to overall cluster emissions means that this initiative has **limited impact on emissions** both by 2040 (additional 5% reduction) and cumulatively from 2025-2040 emissions (27,000 tonnes of CO_2 avoided).
- However, this is the **only initiative with a significant impact on dispersed sites** – reducing their emissions by two thirds in 2040 compared to the BAU (from 5,000 to 1,600 tonnes of CO_2 remaining).
- The initiative **increases the total capital investment by £12 million**, with greater uptake of heat pumps, local renewables, and electric appliances.
- The cost of the initiative can be recouped with **cost savings achieved of £24 per tonne of CO_2 abated** (slightly less than the BAU case).

Spotlight: Oxfordshire hydrogen and biomethane potential

The ZCOP Roadmap [1] identified hydrogen as an "emerging technology without a clear potential or route forward in Oxford". It was considered only for applications in heavy-duty transport and for partial gas-grid blending. The ZCOP Roadmap noted that "the role for hydrogen blending into the gas grid is uncertain, and whilst it may achieve short-term reductions, should not lock in suboptimal solutions".

Hydrogen is expected to be relatively expensive compared to other decarbonisation options, especially in dispersed locations such as Oxford, which is generally considered to confine its use cases to the hardest-to-abate, high temperature direct heating processes – of which there is very little across Oxford.

Biomethane was also included in the ZCOP Roadmap [1] for gas-grid blending. It noted that the "Didcot biomethane injection point currently contributes ~1% to the gas mix in Oxfordshire" with an increase expected as food waste collections expand. Overall, uptake of biomethane is generally considered to be limited by availability of sustainable, waste feedstock. As part of this project, a high-level review was conducted to explore potential for additional biomethane supply in Oxfordshire:

Didcot Green Hydrogen[2,3,4]

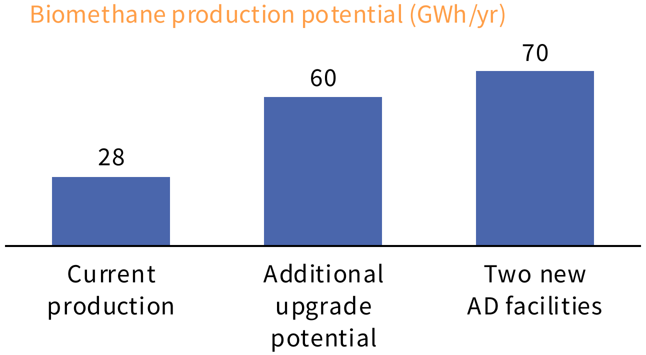
RWE are developing a proposed green hydrogen production facility in Didcot.

In 2022, the project secured Government support to deliver a FEED study.

The project is expected to "support the decarbonisation of the region with a mix of viable offtake routes" and come online around 2030 with a 10 MW capacity.

Initial indicative view on biomethane availability in Oxfordshire

Oxfordshire currently has 10 operational biogas plants, of which only one upgrades the biogas to biomethane, producing 28 GWh/yr of biomethane. If the other existing biogas plants were retrofitted with upgrading facilities, this could provide an additional 60 GWh/yr of biomethane.



Alternatively, deployment of two new anaerobic digestor (AD) facilities to treat wastewater, manure, food waste or agricultural waste could generate an additional 60-80 GWh/yr of biomethane.

Potential biomethane source	Average capacity of single biomethane production facility (GWh/yr)
ADs at wastewater treatment plants	~ 30
ADs to treat animal manure	~ 30
ADs to treat food and agriculture waste	~ 40
Landfills	~ 250

ERM high-level estimates considering sources of: ADBA Report - Biomethane: The Pathway to 2030, Biogas Map | Anaerobic Digestion, Database of active and planned AD plants in the UK | ADBA. New – IEA Bioenergy Task 37 updated list of biogas upgrading plants – Bioenergy.

1 - 2040 Net-Zero Action Plan. 2 - RWE hydrogen activities in UK. 3 - Didcot Green Hydrogen | Hydrogen UK Project Map. 4 - Net Zero Hydrogen Fund strands 1 and 2: summaries of successful applicants 2022.

Procurement of low-carbon gases (speculative consideration)

The **Procurement of Alternative Gases** ('Alt. Gases') initiative explores the possible impact of procurement and **blending of low-carbon gases**, such as biomethane or hydrogen, into the gas grid as an interim solution until industrials can electrify. The potential for low-carbon gases to support industrial decarbonisation in Oxford is **highly speculative with no current plans** to scale up their procurement. This analysis is therefore only exploratory with further work needed to assess feasibility.

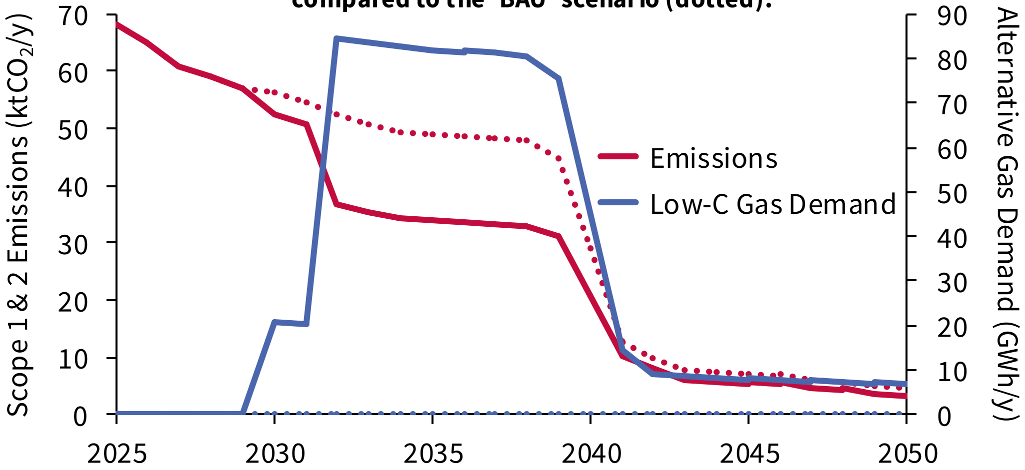
Business-as-usual technology uptake assumption:

- A limited amount of 'green gas' is already procured by Oxford industrials. No additional direct procurement is considered.

Highly speculative uptake assumption:

- 8% (energy basis) of natural gas demand from 2030-2040 is replaced by hydrogen as a result of hydrogen blending into the natural gas grid. This doesn't require upgrades to pipework or existing gas-combustion equipment.
- From 2028 to 2032 there is increased injection of biomethane (produced sustainably and locally from anaerobic digestion of waste) into the Oxfordshire gas network.
- By 2035, a quarter of the remaining gas demand is replaced by industrial procurement of biomethane via 'renewable guarantees of origin'. This could be achieved through the deployment of two new anaerobic digestion facilities in Oxfordshire.
- Note that the decline in industrial business-as-usual gas demand over time means that any low-carbon gas project would need to identify alternative offtakers as industrial demand declines. Alternative offtakers could come from the transport (e.g., e-fuels) or domestic / commercial buildings sectors.

Emissions and alternative gas demand for the 'Alt. Gases' scenario (line) compared to the 'BAU' scenario (dotted).



Impact of initiative:

- This initiative has a **strong contribution to emission reductions** when deployed in addition to BAU efforts – an additional 11% reduction by 2040 and cumulative emission avoidance of 135,000 tonnes of CO_2. However, it has a more **limited impact when adopted in addition to all other initiatives combined***.
- Blending of alternative gases into the gas grid affects the cumulative emissions of the **South-East Sub-Cluster and dispersed sites** as these continue to use gas into the mid-2030s.
- The initiative **increases the levelised cost of abatement for the cluster**, resulting in an average cost of £114 per tonne CO_2 (excl. carbon value).

*as other initiatives accelerate reduction in gas demand by promoting electrification or heat networks, and therefore reduce the impact of decarbonising the gas-grid on industrial emissions.

Appendix

TECHNICAL ASSUMPTIONS

Technical assumptions for modelling purposes

Energy and carbon value projections

	Unit	2025	2030	2035	2040	Reference
Energy Costs	**£ / MWh**					
Grid Electricity		188	139	128	125	2023 Green Book – Central – Commercial/Public Sector
Natural Gas		48	37	37	38	2023 Green Book – Central – Commercial/Public Sector
Hydrogen		241	241	241	241	HAR1 Strike Price
Biomethane		79	79	79	79	2024 Ecotricity – South West
Heat Network		84	84	84	84	Stakeholder engagement.
Emission Intensity	**tCO2/MWh**					
Electricity (Scope 2)		0.13	0.05	0.02	0.02	2023 Green Book - Grid Average - Commercial projection
Natural Gas (Scope 1)		0.18	0.18	0.18	0.18	DESNZ 2023, GHG reporting conversion factors
Carbon Value	**£ / tCO2**	273	294	318	343	2023 Green Book – Central

Additional assumptions:

- Discount rate: 3.5%
- Cost of Energy Efficiency: £22/tCO2
- Results calculated over analysis period of 2025-2040 inclusive.
- It is assumed that replacement of equipment occurs at end-of-life with 'cost of abatement' considering cost premium compared to counterfactual.

Note that all results should be treated as indicative and with high levels of uncertainty. Their purpose is to serve as comparative estimates to evaluate the potential impacts of different decarbonisation initiatives. Investment and abatement costs are indicative based high-level assumptions. Further project specific detailed cost assessments should be done in future to evaluate these metrics with greater accuracy.

Technology performance and investment

	Efficiency (%)	Load Factor (%)	Lifetime (yrs)	CAPEX (£m/MW)	Fixed OPEX (£m / MW / yr)	Reference
Commercial Gas Boiler	80%	5%	20	0.16	0.008	Eunomia 2024, Cost of Domestic and Commercial Heating ERM estimates of efficiencies, lifetimes, and load factors.
Commercial Gas Oven	80%	40%	20	0.72	0.036	
Commercial Electric Boiler	95%	5%	20	0.19	0.008	
Commercial Electric Oven	90%	40%	20	0.57	0.028	
Heat Pump	300%	23%	20	1.33	0.067	
Heat Network Connection	95%	23%	N/A	0.80	0.075	Stakeholder engagement
Electricity Connection Upgrade	N/A	N/A	N/A	0.20	N/A	OFGEM data - median connection offer issued by DNOs
Local Renewables	N/A	10%	25	1.10	0.006	DESNZ 2024, Solar PV Cost Data DESNZ 2021, Feed-In-Tariff Load Factor Analysis IRENA Renewable Power Generation Costs in 2023

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