Appendix 2

Broxtowe Housing Decarbonisation Roadmap

Executive Summary

In early 2024 Nottingham University Consultants and Develeco Projects Ltd were commissioned to identify cost-effective retrofit opportunities to help decarbonise Broxtowe's housing stock, as part as Broxtowe County Council's commitment to meet 2050 net-zero carbon emission targets.

The team built upon the work developed for Nottingham City Council through the £220 million UK Community Renewal Fund between 2021 and 2022. A significant part of this work was focused on developing a method to look at carbon-cost effectiveness of housing retrofit strategies. This method was further developed, updated and applied to examine Broxtowe's housing stock.

In this report, we present the findings in detail. The report is divided into the following sections:

Section 1. Establishing the status quo: in addition to establishing targets, benchmarks and approaches, this also contain a housing stock characterisation and a fuel poverty analysis.

Section 2. Generic housing performance assessment: this section uses generic dynamic building simulation models representing the main housing typologies as identified in Section 1 to quantify the implications (in terms of energy/carbon reduction and running costs) of fabric retrofit alongside low carbon heating and renewable energy integration.

Section 3. Generic housing embodied carbon calculations: the generic models representing the main housing typologies used in Section 2 were used to calculate the embodied carbon emissions of each retrofit strategy (Life Cycle Stages A1-A5, B1-B5, and C1-C43).

Section 4. Specific housing performance assessment: the method used for the generic models in Section 2 were applied to selected properties to quantify the implications (in terms of energy/carbon reduction and running costs) of fabric retrofit alongside low carbon heating and renewable energy integration.

Section 5. Specific housing embodied carbon calculations: the method used for the generic models in Section 3 were applied to the selected properties in Section 4 to calculate the embodied carbon emissions of each retrofit strategy (Life Cycle Stages A1-A5, B1-B5, and C1-C43.

Section 6. Lifetime capital cost of retrofit: the lifetime capital cost for each typology was calculated using the materials, specifications, and quantities as set out within Section **Error! Reference source not found.**, 3, 4 and 5.

Section 7. Net lifetime cost of retrofit: the net lifetime cost for each typology was calculated considering the lifetime capital cost of the works minus the lifetime cost savings, using the annual energy costs taken from Sections 2 and 4 and the lifetime capital cost data from Section 6.

Section 8. Carbon-cost effectiveness: the cost of the retrofit investment per tonne of carbon dioxide equivalent saved from the atmosphere over the lifetime of the retrofitted property was calculated for each of the properties studied.

Section 9. Broxtowe housing decarbonisation roadmap: in this section, the key data outputs for each typology are summarised and recommendations are suggested alongside estimated projections.

Section 10 is comprised of appendices and Section 11 is a list of references.

Why retrofit?

Retrofitting UK homes is essential for several reasons. First, it enhances environmental sustainability by reducing carbon emissions and improving the longevity of the housing stock. This is crucial for tackling climate change and preserving the environment for future generations. Second, retrofitting improves household energy efficiency, leading to lower energy bills. By upgrading insulation and installing energy-efficient systems, homes will require less energy to maintain comfortable temperatures, resulting in significant cost savings for homeowners and tenants. Third, retrofitting generates local and domestic economic opportunities. As the demand for retrofitting increases, so does the need for skilled labour and the production of energy-efficient materials. This can stimulate local economies and create new job opportunities within the construction industry. Lastly, retrofitting significantly improves the quality of life for occupants. Energy-efficient homes provide consistent temperatures and better air quality, enhancing health and comfort. This is particularly beneficial for vulnerable groups such as the elderly and disabled. Importantly, lower energy costs can help alleviate fuel poverty, making it easier for households to afford other essentials. *Overall, retrofitting homes in the UK is essential for fighting climate change, cutting energy bills, boosting the economy, and improving living conditions. By investing in retrofitting, the UK can create a more sustainable and comfortable future for everyone.*

What is the quality of the homes in Broxtowe?

An overview of the current condition of Broxtowe’s complete housing stock (including owner-occupied, privately rented and socially rented) was established utilising data from the Energy Performance Certificate (EPC) database as of April 2024. The EPC database provides details on a building's energy use, typical energy costs, and recommendations for improving energy efficiency. As is typical to the UK, the most common dwelling types in Broxtowe are detached, semi-detached, mid- and end-terrace houses, flats, and detached bungalows, collectively accounting for approximately 95% of the area's properties. Further analysis of the archetypes showed that houses constructed from 1900–1966, flats constructed from 1900–1929 and 1950–1975, as well as detached bungalows constructed from 1950–1975 are less energy efficient (i.e., have EPC ratings D–G) than homes built during other periods. These homes with lower EPC ratings, which make up approximately 66% of Broxtowe's housing stock, have several key characteristics that need improvement. Characteristically, they often feature no or older insulation, outdated heating systems, and single-glazed windows, all which result in higher energy consumption and costs. These homes typically require substantial retrofit upgrades, including better insulation, more efficient heating systems, and possibly the addition of renewable energy sources, to improve their overall energy efficiency. *As these homes tend to have the highest energy costs and the poorest indoor conditions, and given the estimated number found in Broxtowe, they are a priority for retrofitting.*

Why do we need to consider fuel poverty?

Fuel poverty occurs when a household cannot afford to heat their home to an adequate temperature due to a combination of low-income, high-energy costs, and poor energy efficiency of the property. In the UK, a household is considered to be in fuel poverty if it needs to spend a high proportion of its income on energy to maintain a satisfactory heating regime. The government uses the Low Income Low Energy Efficiency (LILEE) definition for fuel poverty in England. Under this definition, a household is considered fuel poor if it lives in a property with an energy efficiency rating of band D or below and, after spending the required amount on energy, its residual income falls below the official poverty line. Fuel poverty can have serious implications for health and well-being, as cold homes can exacerbate conditions such as respiratory and cardiovascular diseases. It can also lead to higher energy bills, forcing households to make difficult choices between heating their homes and other essential expenses. *The rate of LILEE fuel poverty in Broxtowe is 13.5%, which is slightly higher than the English average of 13.1%, but lower than the typical rate across the East Midlands (15.1%).* To get a better understanding of these fuel poverty statistics, a mapping assessment was undertaken to analyse the spatial distribution of LILEE fuel poverty versus deprivation. The findings indicate that the LILEE definition likely underestimates the true extent of fuel poverty in Broxtowe (and across England), justifying further exploration of subjective fuel poverty rates. Additionally, a rough estimation was done to identify the financially vulnerable households that are omitted by default from LILEE statistics, i.e., those where the main earner is economically inactive and living in a property with an EPC rating of A–C. It was estimated that 1,251 homes fit this description and would likely be categorised as fuel poor according to other fuel poverty definitions. *Knowing the true* *extent of fuel poverty can drive retrofit initiatives to improve the energy efficiency of homes in Broxtowe, including identifying how to target assistance more effectively.*

What immediate needs does the analysis reveal?

Using data from the EPC database, a housing characterisation review for Broxtowe was conducted to identify key factors to guide the retrofit approach. From this, it was found that 66% of Broxtowe's housing is rated D-G and therefore can be considered energy inefficient and likely need retrofitting to improve performance. Additionally, 88% of Broxtowe's housing stock has gas boilers as the source of heating. The most common wall construction in detached (27.7%), semi-detached (47.5%) and terraced homes (41.9-51.3%) is solid brick with no insulation, and partially/fully insulated cavity walls for flats (30.1%) and filled cavity walls for bungalows (53.5%). Altogether, the proportion of uninsulated and partially insulated cavity walls present a great opportunity for less disruptive fabric improvements across all homes.

EPC data also showed that Broxtowe's housing stock has a large proportion of homes with non-insulated floors – between 44-60% across all typologies. Retrofitting these uninsulated solid ground floors is relatively uncommon because it often requires completely rebuilding the floor, resulting in higher costs and significant disruption for the occupants. Roof insulation is common, but the thickness varies greatly. More than 80% of properties already have double glazing.

We classified retrofit measures as ‘typical’ and ‘deep’. Typical retrofit measures (e.g. adding roof or wall insulation) are those which are generally easier and less expensive to implement, causing minimal disruption to occupants. They typically result in moderate energy savings and performance improvements. Deep retrofit measures, on the other hand, involve comprehensive upgrades across multiple systems, such as the building envelope (e.g., floor insulation), electrical, structural, and mechanical components. These extensive upgrades lead to higher upfront costs and greater disruption for occupants compared to typical retrofits. However, deep retrofit measures can achieve significant performance enhancements and long-term energy savings. *On the whole, the extent to which energy consumption and carbon emissions are reduced depends on the type of retrofit approach implemented and the type of property.*

So, what should be addressed first and why?

Upgrading the building fabric is recommended as the first measure in the retrofit process to improve the energy efficiency of homes. Key measures should include insulating the houses to minimise heat loss through the fabric and improving the airtightness barrier to reduce uncontrolled ventilation between the interior and exterior which is often seen in 'leaky' and draughty homes.

Roof insulation is the easiest retrofit measure and can be one of the first steps in a fabric upgrade. Wall insulation, however, was identified as the most significant fabric *measure, proving more effective than other retrofit strategies across all house types.* This effectiveness is due to the larger exposed envelope area of the walls compared to other fabric elements. Therefore, retrofitting walls should be prioritised whenever possible.

Installing an air source heat pump (ASHP) proved to be a cost-effective measure for most of the house types tested. Its cost-effectiveness was further enhanced when combined with external wall insulation and draught-proofing.

How much energy could be saved because of implementing the recommended measures?

Overall, the performance analysis indicated that upgrading the fabric and draught-proofing layer could reduce heating demand by up to 86% with extensive fabric measures (deep retrofit). *When fewer, less disruptive, and less expensive fabric measures were considered (typical retrofit), heating demand could be reduced by up to 70% compared to a leaky and non-insulated scenario, depending on the housing archetype.* A breakdown of this is shown for each archetype in Table 0.1.

Table 1: Percentage reduction in heating demand achieved with deep and typical retrofit measures across different heating systems in comparison to a leaky and non-insulated building

Archetype	Deep retrofit measures	Typical retrofit measures
Detached house	81%	61%
Semi-detached	83%	58%
Mid-terrace	86%	70%
End-terrace	86%	70%
Mid-terrace flat	80%	61%
End-terrace flat	81%	52%
Bungalow*	84%	54%

**Bungalow analysis considered a specific housing model, not a generic archetype*.

Greater reductions in total annual energy demand were observed when the traditional gas heating system was replaced with a low-carbon heating system, due to its high efficiency. We assumed a typical efficiency of 0.89 and a seasonal coefficient of performance of 0.8 for a gas boiler and took a realistic approach to the ASHP performance by varying the SCOP from 1.8 to 2.8 for space heating across different retrofit scenarios. Replacing a gas boiler with an ASHP reduced annual energy demand by up to 78% with deep retrofit measures, while maintaining a gas boiler reduced it by up to 61% compared to a leaky and non-insulated building with gas heating. *With typical retrofit measures, total annual energy demand was reduced by up to 73% with an ASHP and up to 49% with a gas boiler, compared to a leaky and non-insulated gas-heated building.* However, it should be noted that the cost-effectiveness of the ASHP compared to the gas boiler will depend on the energy costs of electricity and gas. This breakdown is shown in Table 0.2.

Table 2: Percentage reduction in total energy achieved with deep and typical retrofit measures across different heating systems in comparison to a leaky and non-insulated gas-supplied building

		Deep retrofit measures	Typical retrofit measures
Detached house	Gas boiler	28%	21%
	ASHP	38%	28%
Semi-detached	Gas boiler	22%	15%
	ASHP	42%	32%
Mid-terrace	Gas boiler	33%	27%
	ASHP	33%	20%
End-terrace	Gas boiler	36%	29%
	ASHP	36%	25%
Mid-terrace flat	Gas boiler	27%	20%
	ASHP	38%	31%
End-terrace flat	Gas boiler	30%	19%
	ASHP	41%	29%
Bungalow*	Gas boiler	19%	12%
	ASHP	28%	20%

*Bungalow analysis considered a specific housing model, not a generic archetype.

Considering the energy price cap that was in place from October to December 2024 (the most recent price cap at the time of the analysis), replacing a gas boiler with an ASHP can reduce annual energy costs by up to 42% when deep retrofit measures are implemented. In comparison, maintaining a gas boiler can lower costs by up to 36% compared to a leaky, non-insulated building. When typical retrofit measures are considered, annual energy costs can be reduced by up to 32% with an ASHP and by up to 29% with a gas boiler, compared to a leaky, non-insulated gas-supplied building. This energy cost analyses suggested that switching to ASHP resulted in marginally lower annual costs compared to a traditional heating system. It is noted that the adoption of ASHP can help transition to net zero greenhouse gases, and energy costs can be further reduced depending on the electricity cost incentives.

What is the impact of implementing retrofit measures on embodied carbon?

Embodied carbon calculations involve assessing the total greenhouse gas emissions associated with the production, transportation, installation, maintenance, and disposal of building materials, measured in carbon dioxide equivalent (CO_2e). In this project, embodied carbon was considered for the key archetypes and for typical versus deep retrofit measures – this is one of a few instances when the embodied carbon of retrofit was considered in the UK. From this, it was determined that - across all property types - implementing a typical retrofit, as opposed to a deep retrofit, results in a saving of roughly 30-40% in embodied carbon. For example, in the case of a detached house, a deep retrofit results in 12.4 tonnes of CO_2e, whereas a typical retrofit generates 8.7 tonnes of CO_2e. This additional 3.7 tonnes of CO2 must be saved in operational carbon emissions over the lifetime of the property to make the deep retrofit scenario worthwhile. This is not unexpected since the deep retrofit utilises more materials and requires more work.

In the specific embodied carbon calculations undertaken for the specific house type, i.e. the bungalow typology, this trend is replicated. The calculations estimated that typical retrofit results in approximately 28% less embodied carbon compared to a deep retrofit. Specifically, a deep retrofit generates 12.9 tonnes of CO_2e, while a typical retrofit produces 9.3 tonnes of CO_2e. Therefore, the additional 3.6 tonnes of CO_2e from a deep retrofit must be offset by savings in operational carbon emissions over the property's lifetime to justify the deep retrofit. *This concludes that while retrofitting aims to reduce operational carbon emissions by improving energy efficiency, it can also introduce embodied carbon due to the materials and processes involved. To some extent, careful selection of materials and a focus on long-term operational savings can help mitigate its impact.*

What are the cost implications of retrofit measures?

The cost implications of retrofit measures can vary significantly based on their *type and extent*. Key factors to review include *initial cost, payback period, operational savings, embodied carbon, and cost effectiveness.* Typical retrofits, which include roof insulation, draught-proofing, and window upgrades, are generally less expensive and less disruptive, offering moderate energy savings. In contrast, deep retrofits involve comprehensive upgrades such as floor insulation and the installation of advanced heating systems like ASHPs. Although these deep retrofits have higher initial costs due to the extensive work required, they provide substantial long-term energy savings – and significantly improved comfort (which was outside the scope of this work). The payback period for retrofit measures depends on the energy savings achieved and the initial investment, with typical retrofits having a shorter payback period due to lower upfront costs, while deep retrofits take longer to pay off but offer greater savings over time. Despite having higher embodied carbon due to the extensive materials and work involved, deep retrofits can offset this through operational carbon savings over the building's lifetime, making them more environmentally beneficial in the long run. Additionally, it is important to note that the cost-effectiveness of retrofit measures can be influenced by factors such as energy prices, government incentives, and the specific characteristics of the building, with the relative costs of electricity and gas playing a role in the cost-effectiveness of ASHPs compared to gas boilers.

What next for Broxtowe?

Based on the findings of this project, that are discussed in detail across this report, the following recommendations can be made:

Recommendation 1 – Take a fabric-first approach. By prioritising improvements to the building's envelope, such as insulation and airtightness improvements, this method can lead to substantial energy savings by reducing the need for supplementary heating and improving overall energy efficiency. Other benefits include healthier and more comfortable indoor conditions for occupants and reduced operational costs and carbon emissions. As a starting point, the implementation of roof and external wall insulation would be the most impactful in any retrofit strategy.

Recommendation 2 – Integrate a comprehensive framework for managing and delivering retrofit projects and initiatives. The quality assurance process in retrofitting, particularly under the PAS 2035 framework, involves several key steps to ensure that retrofit projects are carried out effectively and meet high standards. By following a framework such as PAS 2035, Broxtowe Borough Council can ensure that their retrofit projects and initiatives deliver the desired energy savings and improvements in building performance without compromising on quality or safety.

Recommendation 3 – Consider the distinct characteristics and benefits of typical versus deep retrofit. Overall, while typical retrofits are suitable for achieving moderate improvements with lower upfront costs, deep retrofits are ideal for those seeking significant energy efficiency gains and long-term benefits. However, the comprehensive upgrades required for deep retrofit, such as floor insulation and advanced heating systems, require substantial investment and extensive work. Consequently, the payback period for deep retrofits can be quite long, making them less financially viable. Additionally, the financial benefits of deep retrofits can be influenced by fluctuating energy prices and the availability of government incentives. Without substantial financial support, the high costs and long payback periods make deep retrofits challenging to justify financially.

Recommendation 4 – Review the cost-carbon effectiveness as part of the decision making. From a whole life carbon reduction perspective, typical retrofits are more effective than deep retrofits when assessed over a 20-year period. They consistently cost less and result in greater whole life carbon savings, making them more carbon cost-effective overall.

Recommendation 5 – When planning a retrofit, consider that costs can vary significantly depending on the type and extent of the measures implemented. The retrofit process in this report is divided into three key stages. Stage 1 focuses on fabric improvements to reduce operational energy consumption and carbon emissions. Stage 2 builds on Stage 1 by integrating low-carbon heating systems. Stage 3 further enhances Stage 2 by incorporating renewable energy generation. For example, based on the assumptions outlined in this report, the cost for Typical Retrofit Stage 1 is estimated to be between £11,590 and £35,633, depending on the property type and as relates mainly to estimated capital cost for roof and external wall insulation and other factors detailed in the report. Building up on this, for Typical Retrofit Stage 2 (add low carbon heating), will result in energy bills being 8% to 22% lower than the pre-retrofit scenario, at an estimated cost of between £12,200 and £14,118 per property. Regarding Typical Retrofit Stage 3 (renewable energy generation), it was observed that while solar installations offer the most attractive financial payback compared to fabric and low carbon heating improvements, they are not as effective in reducing whole life carbon over a 20-year period.