centre for sustainable energy

Bristol net zero by 2030: The evidence base

Report to Bristol City Council of analysis of how the city can achieve net zero greenhouse gas emissions (scopes 1 and 2) by 2030

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RICARDO

eunomia

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Executive summary

This study shows that there is a route for Bristol to achieve net zero in its scopes 1 and 2 carbon emissions by 2030.

Securing this route needs a truly radical and transformative approach to how the city heats its buildings and uses energy, how people and goods get about, and how we reduce and treat our waste. It requires an unprecedented rate and scale of change, applying technologies and techniques and establishing and maintaining levels of public and business engagement which are currently the rare exception rather than the commonplace rule.

This includes achieving by 2030:

- much better insulated buildings heated by heat networks and individual electric heat pumps to enable the end of using gas for heating;
- far smarter use of electricity across the city and growth in roof-top solar PV to support the decarbonisation of electricity generation nationally;
- a significant shift to public transport and active travel (walking and cycling) and a switch to electric vehicles (EVs) for the remaining fleet to accelerate the phasing out of petrol and diesel vehicles in the city;
- a significant reduction in waste, greater re-use and recycling, and the removal of plastics from residual waste.

The co-benefits of action are significant, particularly in employment (some 75,000 – 100,000 person years of work ranging from semi-skilled to highly technical) and air quality, health, fuel poverty, and an improved public realm as a result of reduced traffic.

Creating the conditions for success will require concerted action for change, with aligned leadership and extensive effort right across the city's public, business and voluntary sectors, communities and individual households. This will need to start now and scale up rapidly, building on the city's current strengths and addressing its weaknesses in addressing the challenges of decarbonisation.

Over the next decade (and mainly the next few years), the city will need:

- sufficient funds for infrastructure investment and skills development (in the region of £5 – 7 billion between now and 2030 from private and public sources, about half of which would be reassigned from anticipated 'conventional' investment, such as in new gas boilers or petrol cars, and half is new and additional);
- new local powers to organise and require action;
- better national policies, regulations and market rules;
- a sustained culture change programme to establish new, shared expectations of how we will each live, work and travel in the city.

Ten key interventions have been identified to deliver the changes in Bristol which put the city on the path to net zero by 2030 for scopes 1 and 2 emissions.

A city for net zero: fostering shared purpose and enabling active participation

1 A sustained and extensive programme of public and business engagement to foster a strong sense of shared purpose and to support and enable the whole city to participate meaningfully in achieving Bristol's 'net zero' future.

A city empowered to achieve net zero: securing powers & capacity

2 The securing of new powers (to organise and require action and raise levies) and devolved (additional) funding, with national backing for '2030' pioneers to accelerate investment.

3 An extensive skills and capacity development programme to enable delivery at scale and capture the jobs created for the city.

4 Effective powers to set and enforce local planning policies and building standards to ensure all new build developments achieve meaningful net zero carbon standards and are aligned with the city's approach to decarbonisation.

A city with net zero infrastructure: installing the technology we need

5 Orchestrated city-wide programmes for insulation & heat pump retrofit and for district heating installation, on district-by-district basis (as 'net zero heat zones').

6 An accelerated electricity distribution network upgrade programme (incl. smarter operation) for a 'net zero' city.

7 A major investment in transport modal shift (public transport & active travel infrastructure) to secure a rapid reduction in vehicle miles, reclaiming road space from private vehicles, encouraging freight consolidation, and discouraging car journeys into and around the city.

8 A controlled but accelerated approach to EV charging infrastructure roll-out, aligned with a sustained push for EV car clubs and mobility as a service.

A city enabled for net zero: sector-specific initiatives to enable change

9 A significant drive to reduce, re-use and recycle, with particular focus on food waste, plastic use and recovering plastic from residual waste from both household and commercial sectors to avoid carbon emissions from its incineration.

10 A dedicated programme to involve businesses & households in developing and taking part in smart energy initiatives, signing up for genuine 100% renewable tariffs, and installing PV.

These interventions – and proposed first next steps to take to initiate them – are described in more detail in Section 9 of this report.

This study, commissioned by Bristol City Council, had three broad aims:

- To describe the changes which need to happen in Bristol to reach net zero greenhouse gases (scopes 1 & 2) by 2030.
- To identify the conditions for success which will need to be in place by (or before) 2030 for these changes to prove possible.
- To propose near-term actions and initiatives which will be needed to create these conditions.

The following pages summarise the analysis undertaken by the study team (the Centre for Sustainable Energy with Ricardo leading on transport and Eunomia leading on waste) for each aspect of decarbonisation relevant to scopes 1 and 2 carbon emissions: heat (**Section 4**), power (**Section 5**, transport (**Section 6**) and waste (**Section 7**). Each of these sections also includes an analysis of the strengths, weaknesses, opportunities and threats in relation to the current context for action at local and national level; this is the starting point for a strategy and action plan designed to achieve net zero by 2030 in Bristol. The potential co-benefits of successfully achieving that goal are described briefly in **Section 11.**

Decarbonising heat (phasing out the use of gas)

The analysis shows that there are technically feasible and potentially affordable pathways to decarbonising the space and hot water heating needs of Bristol's buildings by 2030. These require:

- The replacement of every gas boiler in the city by 2030 with either a connection to a suite of new heat networks (supplied by large heat pumps) (for c. 68,000 buildings in the selected scenario) or an individual building package, usually involving the installation of an air source heat pump and (in most cases) solid wall insulation (for 95,000 buildings in the selected scenario).
- Capital investment of £3 billion over the decade in a programme which establishes a 40 year zero carbon heat solution for the city (with avoided costs of £500 million on new gas boilers).
- A significant upgrade in the peak capacity and smarter operation of the electricity distribution network of the city (accelerating the anticipated upgrade by the 2040s), mainly focused on those areas where individual heat pumps are the optimal solution.
- An increase of 20 – 30% in typical heating bills (though with a far better chance of achieving healthy temperatures for the expenditure), with possible additional costs associated with the network upgrade of up to 10% (depending on how Ofgem determines these costs are to be recovered from network users). This increase would potentially be offset by avoiding the need to pay the gas standing charge.

This represents a very challenging break with the heating market and the dominant systems and patterns of consumer and supply chain behaviour which has been dedicated to gas central heating since the 1970s.

For this to prove achievable (and aside from the over-arching condition that grid electricity has been virtually decarbonised by 2030), the following enabling conditions will need to be put in place:

1. A comprehensive funding package which combines subsidies and grants, low cost capital and 'heat as a service' offerings to underpin the long-term investment required for heat networks and address the cost differential between heat pumps and gas boilers for individual buildings.
2. A programme of works that has been planned and orchestrated across the city, with major building owners engaged to establish and align their heat decarbonisation plans and a 'get something started' approach to build momentum and test capabilities and market appetite.
3. Skills upgrades for the city's heating engineers and building contractors to ensure quality installation of individual building packages.
4. Access to high quality heat network design engineers, installation contractors and system operators for the new heat networks required.
5. A series of new powers and regulation to drive out gas boiler replacements, require connection to new heat networks being installed where appropriate, effective consumer protections for heat network customers, and progressive carbon performance standards for all buildings.
6. A redesign of national fuel cost subsidy programmes (like Warm Homes Discount and Winter Fuel Payment) so that they are better targeted to avoid negative social impacts of higher heating costs resulting from heat decarbonisation (optimally by devolving funding to willing councils).
7. Public and business buy-in to this huge transformation, stimulated by public sector leadership, effective exemplars and evidence of the job creation opportunities of such a programme.

Generation, distribution & demand: powering Bristol's decarbonisation

Bristol's electricity demand is likely to increase by 50% by 2030 from current levels as a result of the electrification of heat and vehicles described in the adopted scenarios in this study. These new sources of demand out-run the continuing efficiency gains in other power uses which will more than compensate for the anticipated population growth. The evidence suggests that, with a significant new programme of solar PV installation on residential and non-residential buildings, Bristol could meet 20% of this increased demand from renewable electricity generation within its boundaries by 2030. Bristol will therefore need to undertake wider actions to support grid decarbonisation nationally to help meet this key dependency for Bristol's 2030 ambition. The analysis shows that:

- There is potential for 500 MW of new solar PV (at a cost of £600 million) across the city which generates a return of more than 5% (>300MW at >6% IRR) at current electricity prices (for export and avoided import) and latest 'post-subsidy' installation costs. Realising this (at 50MW of new installations a year) would result in nearly 1 in 2 (rather than the current 1 in 48) homes having some solar PV on their roofs by the end of 2030.
- The additional demand, and particularly the increased peak demand (even with smart, active management), will lead to a requirement to upgrade significantly the city's electricity distribution network and introduce more active management through the use of flexibility services and peak reduction initiatives.
- Beyond realising its own renewable energy potential within the city boundaries, Bristol can also help to accelerate grid decarbonisation nationally by businesses, public and voluntary sector organisations, and households (a) actively engaging in demand flexibility services and peak reduction initiatives and (b) contracting for genuine 100% renewable electricity tariffs to create new 'subsidy-free' market demand for more renewable generation.

These opportunities will be challenging to realise, given in particular (i) the collapse in recent years of the solar installation market following the end of the Feed in Tariff subsidies (though installation costs now appear to have adjusted to reinstate a reasonable investment case) and (ii) the tendency of the energy regulator Ofgem to limit the sort of anticipatory network investment that Bristol's net zero ambition would require from WPD. For these challenges to be overcome will require:

- The city's public, businesses and other organisations have been effectively supported to participate actively in value-adding demand flexibility services and demand reduction initiatives and to sign up for genuine 100% renewable electricity tariffs.
- WPD to have engaged with the city's net zero ambition and planned, costed and secured the regulatory approval for the accelerated upgrade of the electricity distribution network so that it enables 'net zero' by 2030, rather than current expectations of sometime in the 2040s.
- A major co-ordinated city-wide approach to promoting and realising the opportunities for solar PV across both the domestic and non-domestic markets with an associated rejuvenation and significant scaling up of Bristol's solar PV installation sector.

Decarbonising transport: phasing out the internal combustion engine

The analysis shows that decarbonising Bristol's transport use by 2030 is potentially achievable with:

- A nearly 50% reduction in car miles and 40% reduction in van and lorry miles travelled in the city (returning them to levels seen in the mid 1980s). This would be driven by a significant effort to shift travel to public transport, cycling, walking (to a modal split more like Amsterdam) and to reduce demand for vehicle use through behaviour and system change, including freight consolidation and use of cargo and e-bikes, car-clubs and 'mobility as a service' initiatives.
- Switching almost all remaining vehicles (125,000 cf 220,000 now) to ULEVs (mainly battery EVs), including an increased number of buses and reduced numbers of cars, lorries, and vans.
- Installation of an extensive private and public EV charging network with an appropriate mix of standard, fast and rapid chargers, a proportion of which are dedicated to car club and shared mobility services so that households do not need off-street parking to access a charged EV.

This will require every new vehicle bought in Bristol from c. 2023 onwards to be ultra low emission, with a more rapid-than-normal scrappage of petrol and diesel vehicles persisting throughout the decade as drivers switch to EVs and more and more people choose not to own cars and instead use a balance of public transport, mobility services like car-clubs, and cycling and walking to get around.

For this to prove achievable (and aside from the over-arching condition that grid electricity has been virtually decarbonised by 2030), the following enabling conditions will need to be put in place:

1. Transport planning, strategy, and budgets for the city and the West of England region and the associated political and business leadership is refocused to achieve net zero emissions as described here, with appropriate additional powers and funding devolved to enable rapid modal shift.
2. An effective public and business engagement programme has been developed and sustained to secure positive buy-in to this public transport, walking/cycling, mobility services and EV-oriented future for the city, highlighting the co-benefits for safety, air quality, health and the public realm.
3. Public transport is cheaper (free for many users), more reliable and more convenient with an integrated ticketing system. Procurement at volume has helped secure lower cost ULEV buses.
4. The city has an extensive EV car club/share scheme and a freight consolidation system.
5. Road space freed up by modal shift is rapidly re-claimed for public transport and non-vehicle travel. Other car-restricting measures (e.g. parking levies and access limits) are introduced.
6. The government continues to provide fiscal and regulatory support for EV take-up and the installation of charging infrastructure so that EVs are cost-competitive to the users and the installation of charging infrastructure keeps pace with and suits the pattern of rapid growth of EVs in the city. The city's public sector has led the way and Bristol has taken a national lead.
7. The job-creating installation of local EV charging infrastructure is subject to effective co-ordination of the relevant stakeholders, with appropriate powers to the local authority, so as to ensure there is an optimised balance of public and private chargers and that EV charging is smartly managed across the city to limit impacts on the electricity distribution network.

Decarbonising waste: avoiding waste and an end to burning plastic

This study only considers the disposal of waste generated by the homes and business premises located in the city. It does not address the emissions associated with the production of materials which subsequently become waste or with emissions avoided through reducing, reusing and recycling (thus not creating more primary material). Nor does it include waste imported to the city for disposal.

The analysis shows that significantly decarbonising Bristol's waste stream by 2030 is potentially attainable with:

- Reduction of all waste with particular effort to reduce plastic and textile use and food waste (all of which lead to reduced Scope 3 carbon emissions and wider environmental benefits).
- The achievement of at least the 65% recycling target set by the EU's Circular Economy package across domestic and commercial waste created by the city (cf c.45% now for household waste).
- Removal of plastic films and other unrecovered plastic (derived from fossil fuels) from the waste stream, to be recycled or treated in a way which does not release carbon emissions to the atmosphere.

Based on experience from cities in other countries which are securing much higher recycling rates than Bristol, for this to prove achievable the following enabling conditions will need to be put in place:

1. A comprehensive and sustained communications and engagement campaign to educate and enable behaviour change across both domestic and business sectors, with particular focus on areas with high levels of waste production and low levels of reuse and recycling.

For commercial waste:

2. Leadership from the public sector and businesses to reduce waste, increase recycling rates, and to publish and celebrate their performance to help create a zero-waste culture.
3. Public sector leadership to support re-use activities in the city, to drive demand for re-use items and to use procurement to build markets for goods made from recycled materials.
4. Legal requirements on businesses to sort waste for recycling is put in place (as is the case in Scotland and, shortly, Wales) together with effective enforcement of recycling and waste reduction requirements (with net cost reductions to businesses from lower disposal costs).
5. The awarding and use of greater powers for the city council to facilitate, license and enforce commercial waste collections, to reduce complexity, inefficiencies and enforcement challenges of multiple operators.

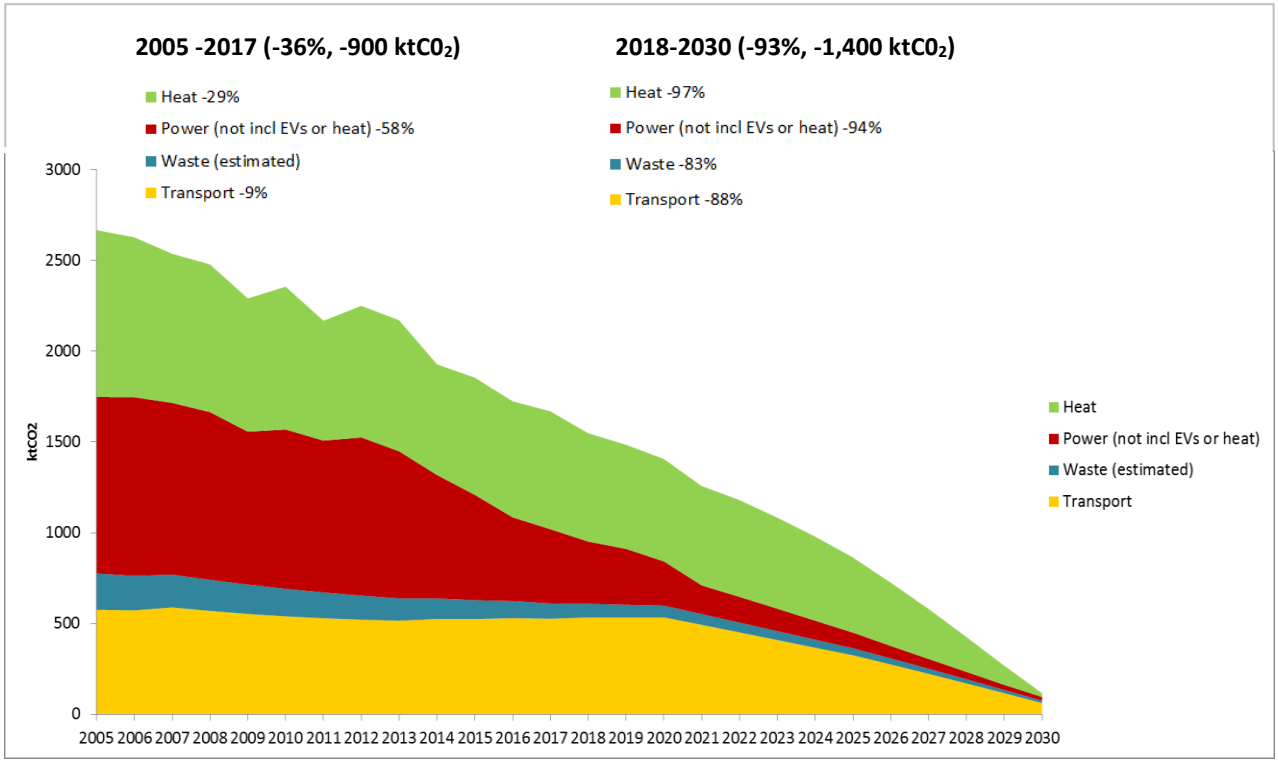
For domestic waste:

6. A Pay as You Throw (PAYT) scheme is put in place (with appropriate regulatory powers from national government) to drive rapid increases in household recycling by creating a cost associated with the amount of waste which households do not recycle, together with restrictions on the amount of residual waste per household.
7. Effective enforcement of recycling and residual waste reduction requirements (with net cost reductions to businesses from lower waste disposal costs).

For both waste streams:

8. Investment at regional level in additional food waste treatment capacity, textile reuse/recycling and in advanced pre-treatment plant to improve plastics recovery (particularly plastic film) from domestic and commercial residual waste, the incineration of which is the principal source of carbon emissions from the city's waste.

As shown in the graph below, Bristol's scopes 1 and 2 carbon emissions have been reducing steadily over the 12 years from 2005 – 2017, achieving a reduction of 36% or 900 $ktCO_2$. This has been largely down to what might be called the 'easy stuff' being done: low cost insulation improvements (reducing demand for heat), improved energy efficiency standards for appliances, equipment and boilers and the significant decarbonisation of the grid from the growth of renewable energy generation and phasing out of coal generation. However, from the analysis undertaken here, the scale of effort required between now and 2030 to achieve net zero is 1.6 times the rate of reduction achieved in the recent past. And the measures required to do this are more complicated and harder to achieve because they represent much more fundamental changes in the ways different systems (energy, buildings, transport, waste) currently work and how people currently expect to heat their homes or travel.



Section 8 explores these issues in more depth and draws out the gap between: (a) current activity on key measures required for net zero; (b) what is currently anticipated as a result of national policies and commitments; (c) what would need to have happened in Bristol by 2030 if the city was on course to meet the national target of net zero by 2050; (d) what Bristol needs to do to achieve net zero by 2050. This is shown in Figure 22, which also shows how these different trajectories for carbon emissions relate to the Tyndall Centre's recently published 'science based' carbon budget for Bristol, based on the city doing its 'fair share' of emission reductions to achieve the goal of the 2015 Paris Agreement. The table

below reveals the rate of change required in the context of current activity, Bristol being on course by 2030 to achieve net zero by 2050, and Bristol achieving net zero by 2030.

Measure	Estimated current situation	'Target 2050' (by 2030)	'Bristol 2030' (by 2030)	Scale up necessary for net zero by 2030 (cf 2050)
Individual heat pumps	<200	27,000	**96,000**	3.5
District heating connections	< 1,000	21,000	**68,000**	3.2
Insulation upgrades (complex: solid wall etc)	<5,000	73,000	**73,000**	Same (but still at least >20 times higher than current rate)
Electric vehicles	<1,000	57,000	**124,000**	2.2
Vehicle mileage reduction	0% (recent years)	-5%	**-40%**	8
Solar PV installations	28MW	c.200MW	**>350MW**	>1.5

The estimated funding requirement to achieve net zero by 2030 – and potential approaches to securing that funding – are explored in **Section 10,** with a summary outlined in the Table below.

Measure	Capex (£m) (incl c.10% opex)	Opex (annual costs) (£m)
Heating networks	£1,950m	Covered by heat sales
Individual building heat pumps	£580m	Covered by electricity bills
Insulation retrofit	£650m	N/A
Roof-top solar PV	up to £625m	Covered by electricity sales
Transport modal shift	£1,000-2,100m	Operations (incl. subsidised travel) covered by ticketing & road-user/parking levies
EV charging infrastructure	£175m	Covered by EV charging costs
Electricity network upgrade	up to £1,000m?	Covered by electricity bills
Waste decarbonisation	Depends on approach	Covered by levies?
Smart energy engagement initiative		Up to £1m a year to facilitate
Culture change programme		up to £2m a year
TOTAL	**£5 – 7 billion** + any major new public transport infrastructure	**£2-3 million a year 'new'**

While this total funding requirement is significant, it is important to recognise that some of this investment and expenditure – perhaps as much as half – should not be considered 'new' or 'additional'. Instead it can be viewed as a reassignment of investment which could have anyway been expected in the course of the next decade in 'conventional' (but carbon intensive) approaches. Many of the key interventions described above are designed to help achieve this reassignment. The required balance – or additional investment – covers the higher costs of decarbonisation solutions over conventional solutions (in current market conditions and current costs of technology and energy). Overcoming these higher costs will be necessary to meet the legally binding national target

of net zero by 2050. Bristol's ambition to achieve this target by 2030 suggests that this should be considered as 'accelerated additional investment'. **Section 10** explores this in more detail.

1 Introduction: objectives of the study

In November 2018, Bristol's Full Council unanimously passed a motion calling for the Mayor to set a new goal of achieving a carbon neutral city by 2030, for both production (Scopes 1 and 2) and consumption (Scope 3) greenhouse emissions. The Mayor adopted that goal in July 2019 with a commitment to develop a Climate Strategy for Bristol, guided by the new One City Environmental Sustainability Board.

This study has been commissioned to help Bristol City Council and other stakeholders understand what needs to happen in Bristol (and specifically the city council administrative area) for the city to achieve that goal in relation to the Scope 1 and 2 emissions.[1] These scopes encompass direct fossil-fuel energy use within the city (principally in vehicle engines, heating boilers and cookers, and industrial processes including waste disposal, and the emissions associated with electricity used in the city (most of which has been generated elsewhere). The study does not address the emissions associated with the production of materials which subsequently become waste or with emissions avoided through reducing, reusing and recycling (thus not creating more primary material).

The study is building on work undertaken by Regen for the City Council earlier in 2019 to establish a Bristol Carbon Neutrality Baseline.[2] That analysis also detailed emissions reduction scenarios for the city associated with: (a) already committed local and national actions (the 'Committed' scenario), and; (b) an assumption that actions are accelerated and scaled up nationally and locally by the adoption by the UK of the 'net zero by 2050 target under the Climate Change Act 2008 (the 'Target 2050' scenario). Neither of these scenarios achieved a net zero outcome; even the more ambitious 'Target 2050' scenario only reduced emissions by 46% from 2016 levels by 2030. There is therefore a significant gap between the level of emission reductions anticipated in these scenarios and the intentions of the city of Bristol to cut emissions more quickly.

This study is therefore seeking to understand what more – or else – would need to happen compared with these scenarios to close that gap and achieve the city's adopted goal of net zero emissions by 2030**. In effect, to achieve in the next 10 years for Bristol what the UK Government has now committed to achieve for the whole country in the next 30 years**. The study is also designed to describe the nature of the challenges – and opportunities and dependencies – this accelerated progress creates for the city and explore how it might rise to them.

Specifically, the objectives for the study set by Bristol City Council can be described as follows:

1 Achieving net zero for Scope 3 emissions associated with consumption in the city (i.e. those caused by the manufacture and supply of the goods consumed – but not produced – in the city by its residents, businesses and organisations) is being addressed in a separately commissioned study.

2 https://www.bristol.gov.uk/documents/20182/33395/Bristol+Baseline+Report+April+2019.pdf/76006e21-ab62-fa44-235a-2c5285f1dc2e

Objective 1: Describe, in the form of a high-level roadmap, the changes which need to happen in Bristol to reach net zero greenhouse gases (scopes 1 & 2)

Objective 2: Identify specific interventions for the periods 2020-25 & 2026-30 to rapidly accelerate progress

Objective 3: Undertake a cost and impact assessment of interventions to inform prioritisation

Objective 4: Set out key barriers and potential solutions to overcome them (incl. action needed from national government)

Bristol City Council awarded the study commission to the Centre for Sustainable Energy, supported by Ricardo Energy & Environment (exploring transport aspects of the study) and Eunomia (exploring waste management aspects of the study).

2 What 'net zero by 2030' means: the challenge of decarbonisation

This study starts from the position that achieving net zero emissions for Bristol will require the city's scopes 1 and 2 emissions to be reduced to virtually zero by 2030, all but ending the use of fossil fuels in and for the city. This is because there are not appropriate opportunities to sequester or offset the city's carbon emissions to any significant degree.

This section briefly explains the reasons for this starting point and describes the high-level implications of Bristol achieving net zero greenhouse gas emissions.

An end to fossil fuel use in and for the city

With these considerations and while also accommodating the energy-using needs of an anticipated 13% increase in the city's population by 2030[3], achieving virtually net zero scopes 1 and 2 carbon emissions from the city of Bristol will require the following conditions to be met:[4]

- Electricity supply for the city is decarbonised.
- No fossil fuels are being used for heating, cooking or industrial processes.
- No fossil fuels are being used for transport.
- No net emissions are produced as a result of new build developments.
- Maximising waste reduction, re-use & recycling and avoiding carbon emissions from city's residual waste by not burning any residual plastic waste.

Each of these conditions is considered briefly below, before the means to achieve them are explored in subsequent chapters.

2.1 Electricity supply for the city is decarbonised

Achieving net zero emissions in Bristol by 2030 requires that all of the electricity used in the city has been decarbonised. This is both because electricity-related emissions currently constitute 30% of Bristol's total carbon emissions and because, as explained in Sections 2.2 to 2.4 below, other current uses of fossil-fuels will need to be eliminated and those uses met instead by electricity.

3 From 2016 according to ONS (2019): https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/localauthoritiesinenglandtable2

4 It should be noted that these conditions will need to be met for the city to achieve net zero carbon emissions, whatever the target date.

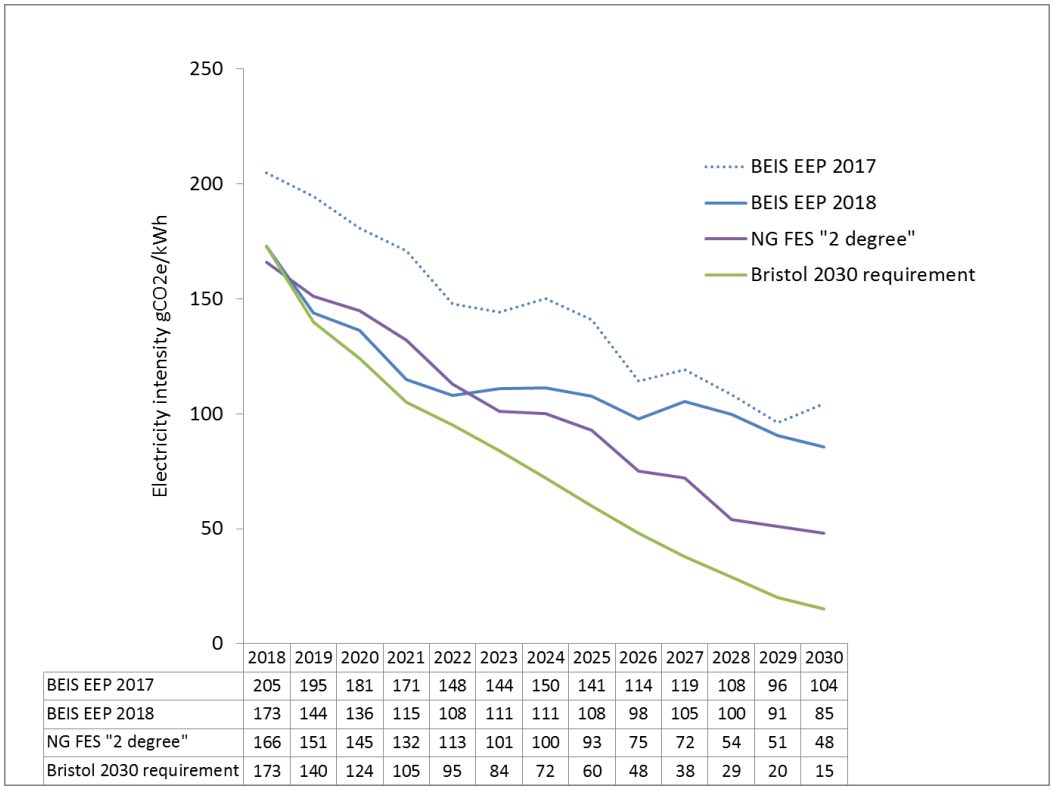
This therefore represents a huge dependency for the achievement of net zero emissions in Bristol by 2030.

Bristol currently produces about 8% of its electricity consumption from renewables situated in the city (cf 35% for GB as a whole). The analysis undertaken for this study demonstrates that there is significant additional potential for zero carbon electricity generation in the city (principally roof-top solar PV). But even with this fully realised as part of Bristol's contribution to national efforts to decarbonise electricity, Bristol will still need to rely on zero carbon generation elsewhere to meet its electricity demand in full, particularly given increase in demand required to displace fossil fuels currently used for heating and transport.

Whatever the city manages to achieve in realising its own potential for zero carbon electricity generation, the city's achievement of its 'net zero by 2030' goal will therefore be reliant to a significant extent on deployment of zero carbon electricity generation elsewhere in the UK, supplied to Bristol via the national grid.

Latest official projections and industry scenarios for the rate of decarbonisation for electricity nationally are not on track for a 2030 decarbonised grid. That said, expectations are shifting quite quickly, particularly in the light of the significant cost reductions for off-shore wind deployment. Figure 1 below shows the comparison between: the government's two most recent projections for grid carbon intensity based on current policies and commitments (showing how much its expectations have changed within one year); the National Grid Future Energy Scenarios' '2 degree' scenario (the most ambitious of their scenarios, also applied in the 'Target 2050' scenario), and; an indicative trajectory that would represent the level of decarbonisation needed to support Bristol's net zero by 2030 goal.

Figure 1: UK electricity carbon intensity projections to 2030



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BEIS EEP 2017	205	195	181	171	148	144	150	141	114	119	108	96	104
BEIS EEP 2018	173	144	136	115	108	111	111	108	98	105	100	91	85
NG FES "2 degree"	166	151	145	132	113	101	100	93	75	72	54	51	48
Bristol 2030 requirement	173	140	124	105	95	84	72	60	48	38	29	20	15

This dependency creates a significant risk that, however successful Bristol is in replacing infrastructure and equipment to cut fossil fuel use for heating and transport and improving the efficiency of electricity usage, the 2030 net zero target is still not met because the carbon intensity of 'grid electricity' has not reduced sufficiently by then.

There are four responses which can reduce the risk to Bristol's 2030 target created by this dependency and the size of any 'overspill' beyond 2030 of Bristol's continuing carbon emissions:

i. Ensure Bristol contributes as effectively as it can to grid decarbonisation by engaging strongly with demand flexibility services (to enable the variability of weather-dependent renewables to be managed more easily and cheaply at a local and national level) and by realising as much of the potential for zero carbon electricity generation in the city as possible by 2030 (rather than simply hope deployment elsewhere will be enough).

ii. Shrink the demand for electricity in existing uses and the size of the increase in demand associated for new uses of electricity associated with displacing fossil fuels for heat and transport.

iii. Encourage organisations, businesses and households in the city to sign up for genuine zero carbon electricity tariffs from their energy suppliers to stimulate the market for renewable electricity.

iv. Make political representations (ideally in tandem with others) to secure policies and interventions nationally to drive faster decarbonisation of the electricity system than is currently anticipated.

These issues are addressed further in the more detailed sector chapters below, including exploring the implications for Bristol's carbon emissions by 2030 of a slower decarbonisation pathway for electricity.

2.2 No fossil fuels are being used for heating, cooking or industrial processes

Reducing the city's carbon emissions to virtually zero will require the phasing out of the use of fossil fuel gas ('natural gas'), oil, and coal for heating, cooking or industrial processes across the city. It is not possible to burn these fuels for these purposes without releasing carbon dioxide so their use must be stopped.

This is a significant task. Government statistics indicate that more than 85% of heat used in the city's buildings is currently supplied by fossil gas with a small proportion (less than 3%) of oil and coal and the rest heated electrically.

Because of the scale of this dependency (which is typical of a UK city), heat decarbonisation is widely recognised as a significant challenge.[5] Part of this challenge is the reality that peak heat demand on the coldest days of winter is typically 5 times greater than current peak electricity demand, so electrification of heat risks creating a shortfall in electricity supply for a few days a year and peak loads which electricity networks would need to be significantly upgraded to handle. It will also require peak demand flexibility for all types of electricity demands, improved energy performance of buildings through improved insulation, thermal storage and improved heating controls, and use of high co-efficient of performance heat pumps (which can generate three times more kWh heat output than their kWh electricity input) rather than direct resistive heating (which generate on a one-to-one basis and thus contribute significantly more to peak and average demand).

2.3 No fossil fuels are being used for transport

The city must also stop using fossil fuels – petrol, diesel and LPG – for transport, including both personal/business travel and freight uses. As much as 99% of all vehicle-based transport in the city is currently fuelled by petrol or diesel. There are currently 800 electric vehicles registered in the city out of a total of 220,000 vehicles. Recent increases in bus use (up by c. 50%) and cycling (doubled) in the last 5 years have not translated into significant reductions in vehicle miles

Chapter 6 outlines what meeting this condition requires for Bristol.

5 For example, the Committee on Climate Change (2019) states: "In this report, we highlight particular priorities where progress has been too slow: low-carbon heating…" (p15) and emphasises that "Switching homes to low-carbon heating remains a major challenge." (p29)

2.4 No net emissions are produced as a result of new build developments

There is significant new building development underway and planned for the city (some 20-25,000 new homes by 2030 and c. 50,000 m^2 of new commercial building each year), both as additional capacity for a growing population and, to a lesser extent, to replace existing 'outmoded' mainly commercial buildings. The city's goal of net zero carbon emissions will only be achieved if there are no net carbon emissions from these new developments or from the additional transport demand they stimulate.

In line with the discussion above about 'offsets', in the context of a target of net zero by 2030, there are no 'additional' carbon emission reductions elsewhere which could be funded by the new development to legitimately offset on-site emissions. The net zero condition will therefore need to be met within the development site. If this is not done, these new developments will need to be retrofitted by 2030 to improve their performance to the point where they do meet the condition and are no longer undermining the 2030 target.

2.5 Maximising waste reduction, re-use & recycling and avoiding carbon emissions by not burning any residual plastic waste

Waste is estimated to contribute about 5% of Bristol's scope 1 and 2 emissions, principally from the burning of plastic waste – which is derived from fossil fuels - as part of the city's treatment of its residual domestic and commercial waste streams.[6] In the future this will be incompatible with achieving net zero emissions. Removal of plastic films and other unrecovered plastic (derived from fossil fuels) from the waste stream, to be either recycled or landfilled so that it is not incinerated and its carbon released to contribute to climate change.

However, waste is also the end result of consumption which causes carbon emissions (reported under Scope 3) and wider environmental impacts. Achieving net zero across all emission scopes will therefore require reductions in all waste with particular effort to reduce plastic and textile use and food waste (all of which lead to reduced Scope 3 carbon emissions and wider environmental benefits). This includes an increase in re-use of goods (e.g. repair and thriving second hand markets) to avoid new consumption and the achievement of at least the 65% recycling target set by the EU's Circular Economy package across domestic and commercial waste created by the city (cf c.45% now for household waste).

What this condition means in practice and what will be involved in its achievement is described in more detail in Chapter 7.

6 The waste left-over after all reduction, re-use and recycling has occurred.

2.6 No significant sequestration or offsetting

There is undoubtedly some potential for Bristol to increase tree cover within the city; that would sequester carbon emissions and also contribute valuably to reducing urban heat island effects in summer and improving air quality. However, the carbon sequestration achieved by realising this potential will be extremely modest (and slow to be achieved) in the context of Bristol's overall emissions.[7] It cannot therefore be relied on to offset significant 'residual' emissions from energy, transport or waste management. Hence the focus on reducing the city's scopes 1 and 2 emissions to virtually zero.

Similarly, for the purposes of the study, the option to offset Bristol's emissions by undertaking carbon reduction and/or sequestration activities elsewhere (either nationally or internationally) has been set to one side. Given the objective of the UN Paris Agreement to reduce emissions globally to avoid dangerous anthropogenic climate change, it is not obvious that there are 'spare' emission reduction or sequestration opportunities that are not already needed to meet the Paris Agreement objective. In a world seeking to meet that objective, offsetting Bristol's emissions through funding actions to cut or sequester carbon somewhere else (or by buying carbon credits from someone who claims to have done so) would create very limited additionality. At most it might make those reductions happen slightly earlier than would have otherwise been the case, so does not relieve the city of the need to cut emissions permanently.

This perspective is explored in the Tyndall Centre's recent study on what would constitute a fair carbon budget for Bristol (and every other UK local authority) in the context of the Paris Agreement[8]. They propose a total carbon budget for Bristol from 2018 – 2100 of 13.3 MtCO2. Under both the 'Committed' and 'Target 2050' scenarios, this total budget is used up by 2026 and 2027 respectively (see Section 8 for further exploration of this issue).

2.7 No unproven technologies allowed

The 2030 target date for achieving net zero is sufficiently close in time to require that a strategy and action plan to deliver the target has to rely on technologies that are understood, proven and at or near market. That includes heat networks, heat pumps, building insulation, solar PV, wind, battery and thermal storage, electricity demand flexibility, electric vehicle (EVs), and effective waste stream sorting.

It can be tempting to build in to the analysis a reliance on technologies such as carbon capture and storage (CCS – which extracts and stores indefinitely the carbon emissions from fossil fuel, steam-reforming of methane for hydrogen production, or biomass combustion) or the mass production and

7 In the recent iTree study for Bristol, the 600,000 trees currently growing in the city sequester less than 1% of the city's annual emissions (or about 7 hours' worth of Bristol's annual scope 1 and 2 emissions). See https://bristoltreeforum.org/2019/04/09/bristols-i-tree-eco-survey-is-published/

8 https://carbonbudget.manchester.ac.uk/reports/E06000023/

distribution of hydrogen without emitting carbon. These frequently feature in long-term decarbonisation strategies, including those from the Committee on Climate Change.

However, they tend not to feature before 2030. And they are recognised as 'unproven', given they have yet to be subject to detailed technological and commercial viability assessments (or, in some cases, basic pilot and safety testing in some cases). Their inclusion as decarbonisation solutions, even beyond 2030, represents what some would describe as highly optimistic and others would dismiss as wishful thinking.

For example, there is a well-understood and proven technique to produce hydrogen by steam reforming natural (fossil fuel) gas. However, aside from the energy losses associated with the process, it produces carbon dioxide as a by-product which would need to be captured and stored indefinitely for the hydrogen to count as 'zero carbon'. Thus such production relies on CCS being available, reliable in the long-term and cost-effective, a very significant and 'at risk' dependency.

Similarly, hydrogen can be produced by electrolysis of water, which, if zero carbon electricity is used for the process, would count as zero carbon. However, the conversion losses associated with the process are significant. That suggests that electrolysis-derived hydrogen will be far more expensive than the electricity being used to produce it (and which could instead be used more cost-effectively directly for most of the purposes to which the hydrogen would be put).

In both production systems, the widespread availability of hydrogen as a fuel would also require the gas transmission and distribution network to be safe for hydrogen and all boilers and other gas-burning equipment to be replaced or upgraded to be suitable and safe to be fuelled by hydrogen. While there are plans to start testing some of these issues in an area of Leeds and associated test facilities (the Leeds H21 project), the expectation of that project is that, even if all of the dependencies are met promptly, any conversion of the gas network to hydrogen would not take place until the 2030s.

This is not to say hydrogen will not play some role in a net zero future, but, given these significant technological and commercial limitations, its most likely role is to be produced and used more-or-less 'on site' in relatively modest quantities for high value energy applications such as zero-carbon industrial processes and use in electricity peaking plant instead of diesel or fossil gas.

Given this analysis and the study requirement to describe a decarbonisation strategy which achieves net zero for Bristol by 2030, these yet-to-be-proven technologies have not been included here.

That is not to say, as we shall see, that we do not need to anticipate some changes in attitudes, practices, skills and regulatory arrangements over the next 10 years to meet the net zero by 2030 goal which have yet to be proven achievable in those sorts of timescales.

3 Our approach: 'walking right round the issue' to reveal conditions for success and routes to change

The analysis for this study was designed to understand what is required in Bristol and elsewhere to achieve the net zero target by 2030 and an end to fossil fuel use by and for the city, as described in Section 0 above.

That boils down to a series of questions:

- What is technically needed– from how we are heating our buildings, generating and using electricity, travelling and moving goods around, and managing our waste – to achieve net zero emissions in Bristol by 2030?
- What are the conditions which need to exist in the city and more widely for this to be delivered successfully by 2030 – and how to do these compare with national scenarios of change anticipated by others such as the Committee on Climate Change and National Grid's Future Energy Scenarios?
- How do current conditions compare with these future conditions for success and what needs to be done to shift current conditions towards those future conditions at the required pace?
- How do the anticipated nature and rates of change compare with experience in the past or elsewhere – are there precedents or proxies which could be used to guide Bristol's action planning to achieve change?

The risk in undertaking such an analysis is that the 'conditions for success' are considered through a principally technocratic lens; we need this many heat pumps or that many EVs or this level of improvement in building energy performance or waste recycling. It could tell you what needs to be done in terms of measures installed or technical advances needed, but it will not tell you what needs to change so as to ensure those installations actually happen at the scale and rate required.

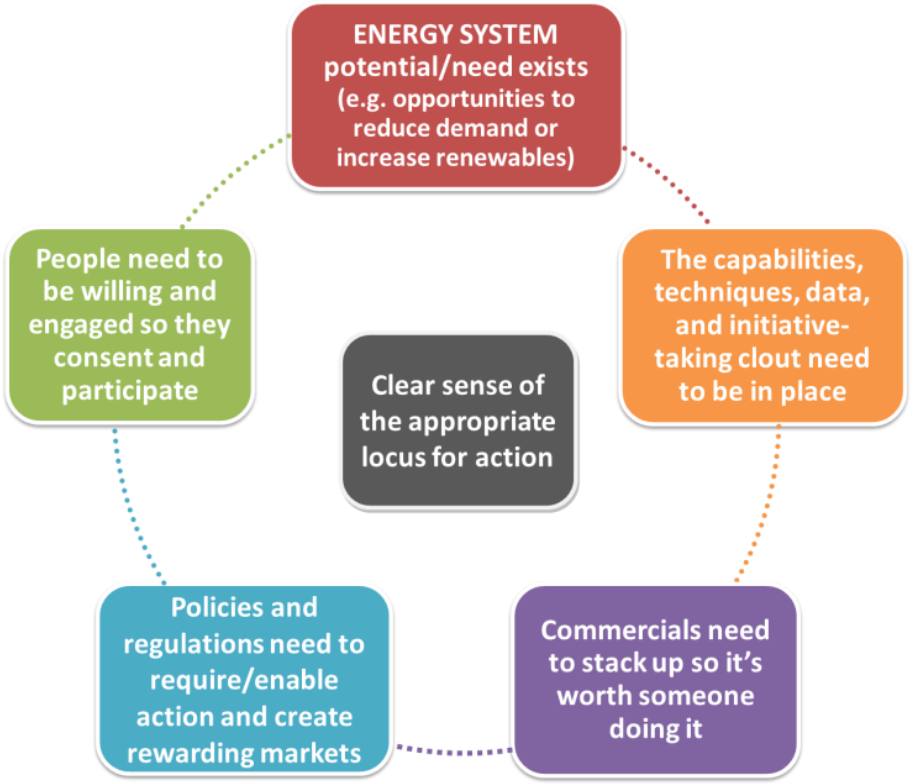
To treat this as a largely technical exercise would be to overlook the range of non-technical factors which strongly influence and, in some cases, ultimately determine whether the scale and nature of technical change required will be realised in practice.

For example, the transformation of how we heat buildings and travel around require a different pattern of capabilities and supply chains, many of which are relatively rare, still emerging, or focused on serving other interests (which may currently appear more rewarding). And they require a level of public involvement in, and consent for, change which, to date, has often not featured in nationally driven programmes. In many cases it will require a different regulatory approach and the balance of costs and incentives will need to have changed.

To avoid missing these sorts of issues, the study has sought to 'walk right round' the issues and consider not only the technical, but also the 'capability', commercial, policy and regulatory, and

socio-cultural dimensions involved. It has therefore used the 'walking right round the issues' model (see Figure 2 below) developed by CSE which it has applied in previous studies.[9]

Figure 2: CSE's 'walking right round the issue' systems model



By assessing each of these dimensions, this approach should result in a more comprehensive understanding of what is involved in delivering change and the conditions required for success. The five dimensions have therefore been used both to consider the conditions for success in 2030 to achieve the required technical changes and to inform a SWOT (Strengths Weaknesses, Opportunities, Threats) analysis of current conditions.

By doing so, the study can establish a clearer picture of (a) the current state of play in relation to each required change and (b) the full range of factors influencing the opportunities and challenges involved in achieving change. This will ensure the city's strategy to achieve net zero by 2030 – to be informed by this study – can draw on the fullest possible understanding of what needs to happen and the current state of play, the starting point for any successful strategy.

In addition, the study team has drawn on its detailed sector knowledge (i) to characterise the scale of the challenge relative to current rates of change or improvement in each sector and (ii) to

9 For example , https://www.cse.org.uk/downloads/file/west-of-england-energy-study-report-and-recommendations.pdf & https://www.cse.org.uk/downloads/reports-and-publications/policy/community-energy/insulation-and-heating/planning/renewables/towards-a-smart-energy-city-maping-path-for-bristol.pdf. These references also include more detailed description of how this 'systems' model is applied.

consider the likely impact of different types of intervention based on examples or proxies from both the UK and other countries for achieving decarbonisation or other related ambitions (e.g. increased recycling rates, modal shift from cars to cycling, walking or public transport, rates of building retrofit, insulation and heating system replacement).[10]

It should be noted that, given the time and resources available for this study and the quality of data available, the sector-specific technical analyses inevitably represent significant simplifications of the real conditions in the city which need to be addressed.

For example:

- There is inadequate data available on the detailed energy performance characteristics and building fabric of each property that ultimately determines their suitability for different types of zero carbon heating and the type and cost of energy saving retrofit. The analysis therefore relies on modelled building-by-building heat demand and a set of assumptions which result in inevitable simplifications; as a result **the analytical outputs should be treated as indicative of the scale and rate of change required to meet the net zero target rather than a precise plan for what needs to happen to each building in the city.**

- Given the limited time and data available, the transport analysis focuses on overall vehicle mileage and vehicle types operating in the city rather than specific traffic flows across and into and out of the city.

- Similarly, there is limited understanding to date of how the pattern of EV charging infrastructure will develop (between private and public chargers, home and office, and on-street charging with car-clubs etc) or what factors will ultimately determine this mix. The same EV-to-charger ratio and public to private mix of ownership has therefore been assumed in both scenarios explored in the transport analysis.

- There is only limited data available on the composition and waste treatment of commercial waste streams, requiring a number of assumptions to be made to reach conclusions about what will be needed to decarbonise these.

- There is limited evidence on the relationship between different types of intervention and changes in practice and behaviour by households, businesses and other organisations, particularly for the scale and speed of change outlined here as required to meet the net zero target.

The specific analytical approaches adopted for each sector analysis are introduced in the sections below and described in more detail in separate technical annexes (in press).

10 It should be noted that in many cases, the required rates of change to achieve net zero by 2030 in Bristol are unprecedented, leaving little evidence to draw on to prove that a certain type of intervention will reliably achieve a certain impact.

4 Decarbonising heat (phasing out the use of gas)

Summary

The analysis shows that there are technically feasible and potentially affordable pathways to decarbonising the space and hot water heating needs of Bristol's buildings by 2030. These require:

- The replacement of every gas boiler in the city by 2030 with either a connection to a suite of new heat networks (supplied by large heat pumps) (for c. 68,000 buildings in the selected scenario) or an individual building package, usually involving the installation of an air source heat pump and (in most cases) solid wall insulation (for 95,000 buildings in the selected scenario).
- Capital investment of £3 billion over the decade in a programme which establishes a 40 year zero carbon heat solution for the city (with avoided costs of £500 million on new gas boilers).
- A significant upgrade in the peak capacity and smarter operation of the electricity distribution network of the city (accelerating the anticipated upgrade by the 2040s), mainly focused on those areas where individual heat pumps are the optimal solution.
- An increase of 20 – 30% in typical heating bills (though with a far better chance of achieving healthy temperatures for the expenditure), with possible additional costs associated with the network upgrade of up to 10% (depending on how Ofgem determines these costs are to be recovered from network users). This increase would potentially be offset by avoiding the need to pay the gas standing charge.

This represents a very challenging break with the heating market and the dominant systems and patterns of consumer and supply chain behaviour which has been dedicated to gas central heating since the 1970s.

For this to prove achievable (and aside from the over-arching condition that grid electricity has been virtually decarbonised by 2030), the following enabling conditions will need to be put in place:

1. A comprehensive funding package which combines subsidies and grants, low cost capital and 'heat as a service' offerings to underpin the long-term investment required for heat networks and address the cost differential between heat pumps and gas boilers for individual buildings.
2. A programme of works that has been planned and orchestrated across the city, with major building owners engaged to establish and align their heat decarbonisation plans and a 'get something started' approach to build momentum and test capabilities and market appetite.
3. Skills upgrades for the city's heating engineers and building contractors to ensure quality installation of individual building packages.
4. Access to high quality heat network design engineers, installation contractors and system operators for the new heat networks required.
5. A series of new powers and regulation to drive out gas boiler replacements, require connection to new heat networks being installed where appropriate, effective consumer protections for heat network customers, and progressive carbon performance standards for all buildings.
6. A redesign of national fuel cost subsidy programmes (like Warm Homes Discount and Winter Fuel Payment) so that they are better targeted to avoid negative social impacts of higher heating costs resulting from heat decarbonisation (optimally by devolving funding to willing councils).

7. Public and business buy-in to this huge transformation, stimulated by public sector leadership, effective exemplars and evidence of the job creation opportunities of such a programme.

Heating buildings and hot water in the city currently accounts for about 45% of the city's carbon emissions. About 90% of current heat is supplied by gas or oil and there are some 160,000 fossil-fuel fired boilers in the city.

To decarbonise heat used in the city by 2030 therefore requires the replacement in 11 years (2020-30 inclusive) of all of these fossil-fuelled heating systems across the city with efficient electric heating of one kind or another, either as individual systems serving properties or as part of district heating networks using large electric heat pumps as their heat supply. Heat demand can also be reduced by insulating buildings to reduce their need for heat input to achieve an adequate standard of warmth.

Finding the least cost path to heat decarbonisation in Bristol: our analytical approach

The analysis undertaken for this study sought to identify the least-cost approach to decarbonising space and water heating demand for all of the buildings in Bristol. It was informed by the study undertaken by Element Energy for the city council (in 2018) which focused on decarbonising heat by 2050. The study team here has taken a different approach from that study, in particular by using a more sophisticated modelling tool (THERMOS)[11] which has been specifically developed to assess the viability of heat networks. The details of this tool and the development of the 3D building-by-building energy demand model, including their limitations, are provided in a separate technical annex (in press).

To simplify the heat decarbonisation cost-optimisation analysis, the modelling assessed three different options for each building in the city:

- Heat networks in which the supply plant is a large air-source (ASHP) or water-source (WSHP) heat pump.
- ASHPs on individual buildings
- External wall insulation where the building is suitable.[12]

The heating options were mutually exclusive but the modelling applied insulation to each building to the extent that, on a cost optimisation basis, doing so reduced the overall cost of the zero carbon

11 See THERMOS at https://www.thermos-project.eu/home/

12 It should be noted that the building-by-building dataset did not separately identify heritage buildings or stone-construction buildings, where internal solid wall insulation would be more appropriate. Such decisions would of course be made on a case-by-case basis in the context of an actual delivery programme.

heat solution for that building.

This simplified list of options in based on the following assumptions:

- Grid electricity will be zero-carbon by 2030 (the dependency discussed in Section 2.1)
- The limited available or realisable bio-methane (equivalent, with the potential doubling of current production in the city, of only about 2% of the city's current gas demand) and any future zero-carbon hydrogen resources will not be distributed directly to buildings but used to fuel buses or heavy goods vehicles, industrial processes, peaking electricity plant or the heat sources for heat networks.
- Fewer than 10% of the solid-walls in the city have been insulated
- Solid wall insulation provides a decent proxy for an energy saving retrofit of a property from both a complexity and cost perspective.
- Most cavity walls and lofts have already been insulated (and they are very low cost to undertake compared with solid wall insulation).

The analysis focused on existing buildings. For the purposes of this study, we have assumed that all new buildings in the city will have a district heating connection or a heat pump to achieve zero carbon and be sufficiently well insulated to not require significant heat apart from for hot water.

The analysis used industry-sourced costs for district heating components (pipe costs etc), AHSP and WSHP of different sizes and coefficients of performance and external wall insulation. A wide range of scenarios (26 in total) was explored for every building in the city using different types of heat pump for heat networks, three different price curves for pipes (taking account of ground conditions), and discount rates. [13] It sought the least cost combination of the three options over a 40 year period (the

13 We applied two discount rates in the set of scenarios examined – 2.5% and 0% - but have selected here a scenario using a 0% discount rate. This is because, as Krogstrup and Oman (2019) have recently explored for the International Monetary Fund (Working Paper 1WP/19/185), to do otherwise would suggest that (a) the interests of future generations are worth less than those of current generations and (b) the future value of carbon reductions is lower (even though a tonne saved today is patently more valuable in terms of reduced risk of climate-related damage than a tonne saved in 10 years). As the authors explain: "*Weighing the future benefits of climate action against the present costs requires valuing time and hence the present value of the welfare of future generations, but there are no objective criteria for making such an evaluation, which is inherently subjective and political (Grubb et al. 2014, Stern 2006,Weitzman 1998, 2010, 2011, Dasgupta 2008)…. Cline (1992) has argued that the pure rate of time preference should be zero, since it is not ethical to weight future generations less than current generations*."

In the context of the scenarios explored here, using a higher discount rate would favour technologies with shorter lives (individual building heat pumps) and thus reduce the apparent value of installing heat networks. In the directly comparable scenario (with only the discount rate changed from 0% to 2.5%), this switches 40,000 buildings from heat networks to individual heat pumps. To demonstrate the sensitivities involved, these would be 'restored' to heat networks even under a 2.5% discount rate if it is assumed that electricity prices are 50% higher by 2030. Given the 'option' value of heat networks (because that the heat source could be an electric heat pump or hydrogen or green gas and so can flex to reflect wider

assumed life-time of district heating pipes and heat exchangers and insulation), taking account of the assumed need to replace the heat pumps for both district heating and individual homes every 20 years.

The scenario selected to represent the study team's view of 'best fit' for the decarbonisation of the city's heat used the lower range of heat pipe costs (on the basis of industry advice regarding current heat pipe pricing strategies by suppliers in the UK) and applied WSHP for heat network supply (with the understanding that the docks and other larger waterways in the city are suitable).

The number of buildings being attached to heat networks, receiving individual heat pumps and receiving insulation in this scenario is shown in Table 1 below:

Table 1: Heating and insulation solutions for least cost heat decarbonisation (count by 2030)

Type of property	District heating	EWI added	% no EWI but suitable*	ASHP (individual building)	EWI added	% no EWI but suitable*
Residential	61,873			93,465		
Non-residential	5,816			963		
Total	**67,689**	4,525 (7%)	18%	**94,428**	68,260 (72%)	0.1%
* remainder not suitable for EWI						

The total upfront capital investment of £3,175 million required for these installations is shown in Table 2. Note that, in the scenario, individual and system heat pumps are replaced after 20 years, while heat network pipes and heat exchangers are assumed to last for 40 years.

Table 2: Total upfront capital investment required for heat decarbonisation scenario

	District heating	ASHPs	Insulation
Total cost of installation (£m)	£1,950m	£584m	£650m
Average cost per property (£)	£28,810	£6,200	£8,930
Average heat demand per property (kWh) (after insulation, if applied)	25,660 kWh	7,660kWh	-5,500 kWh

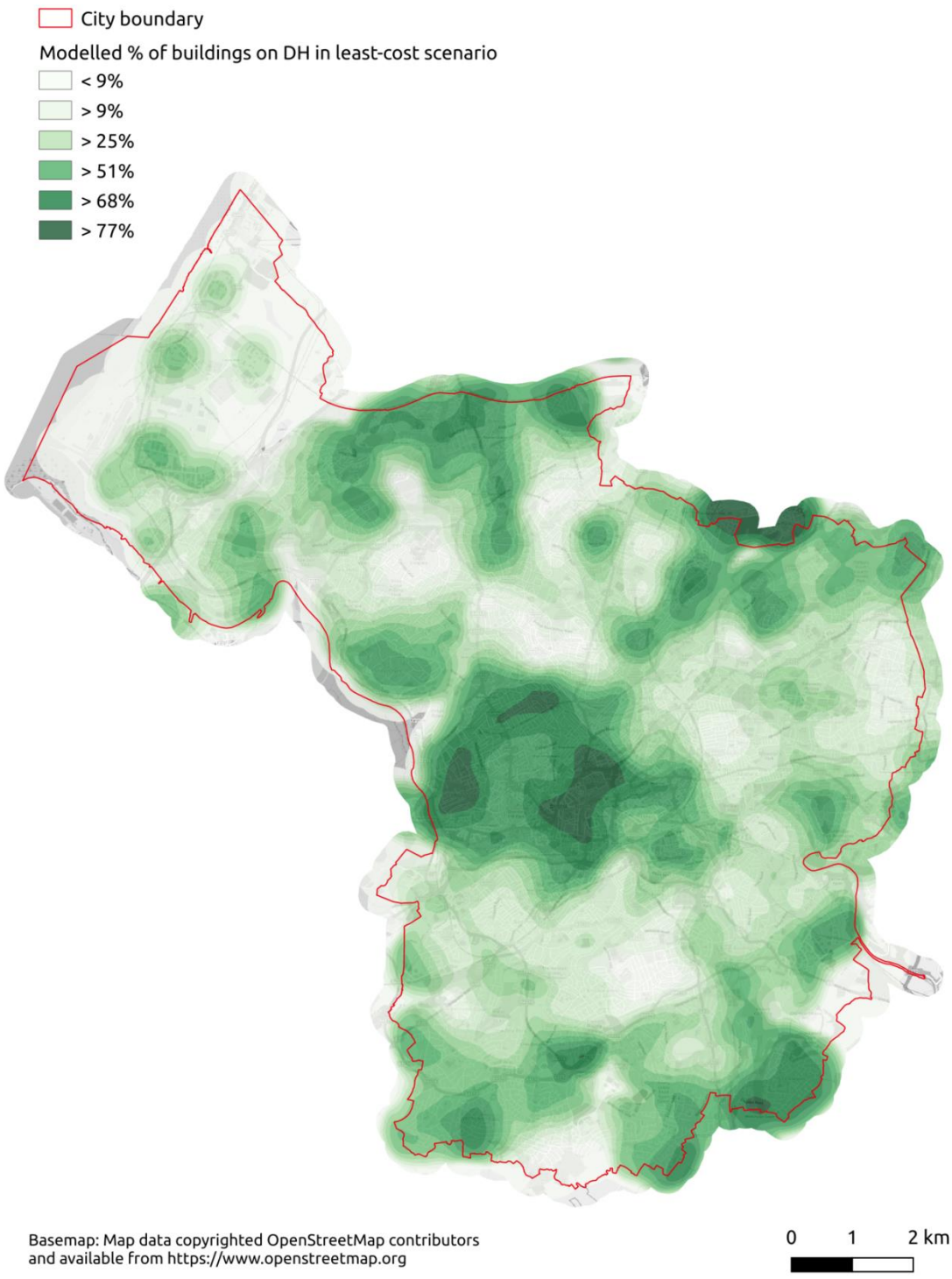
Set against this, it should be noted that there will also be avoided capital expenditure in the city amounting to at least £500 million for gas boiler replacements which will no longer be required by 2030.

technological and system developments), this seems inappropriate (quite apart from the ethical question about treating future generations' interests as less important).

The distribution of modelled solutions across the city

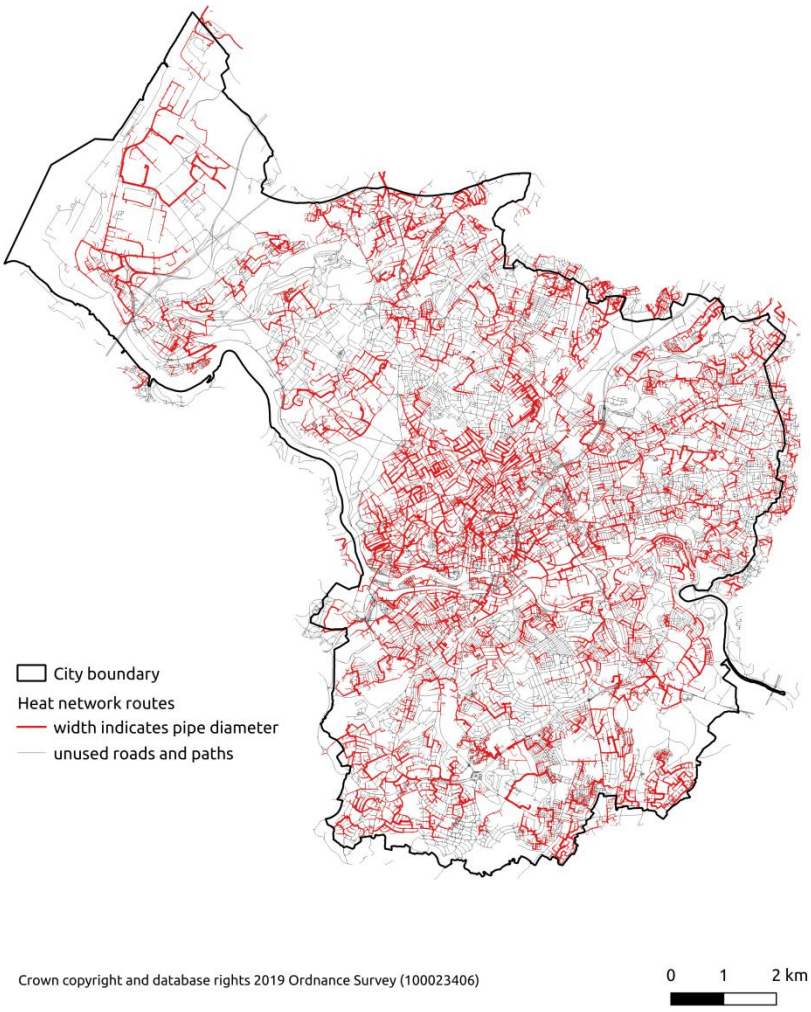
These distribution of these modelled solutions across the city are shown in Figure 3.

Figure 3: Map of Bristol showing % of buildings connected to a heat network as the least-lifetime-cost heat decarbonisation solution in selected scenario



The darker the green in Figure 3, the higher the proportion of heat network connections selected as the least-lifetime-cost heat decarbonisation solution in the modelled scenario. There are clearly areas where the analysis connects most buildings to new district heating networks. In these areas, it may well make sense for a higher proportion of properties to be connected if, when planning the practical application of an installation programme driven by the heat decarbonisation goal, the network is being installed anyway.[14] As Figure 4 shows, there are some areas where there are no buildings in which the least-lifetime-cost heat decarbonisation involves installing a heat network.

Figure 4: Roads and paths with (in red) and without (in grey) heat networks in selected least-lifetime-cost heat decarbonisation scenario



14 That said, the THERMOS heat network modelling tool has been designed to take this choice into account: it will tend to select only those buildings for which the additional costs of connecting in to a heat network meet the criteria set for the task – in this case, decarbonise heat at least-lifetime-cost.

This scenario modelling can therefore be used to identify areas 'designated' for heat networks which should then be subject to more detailed scrutiny (including for locations and types of heat pump supply), and areas designated for individual building solutions (typically involving a package of heat pump and solid wall insulation). In practice, the ideal combinations of insulation-driven energy performance improvement and electric heating choice would be done on a property-by-property basis in these areas.

Establishing rates of installation

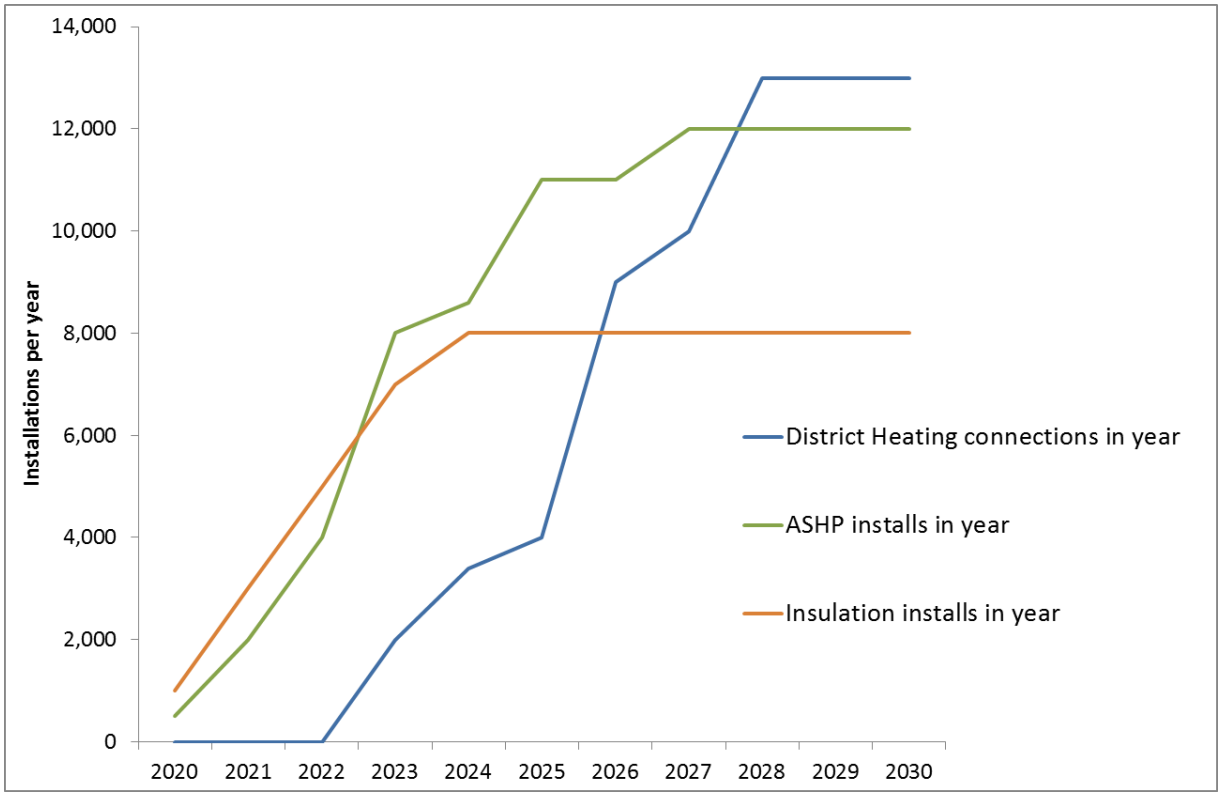
To establish installation rates for the solution selected for each building, the study team considered the typical rate of replacement for gas boilers (c. every 14 years) and assumed, in the context of a net zero by 2030 ambition, that the goal would be to replace all of them by 2030 (i.e. every 12 years).

However, it would inevitably take time to re-skill the heating engineering workforce in the city to switch from gas boilers to heat pump or district heating heat exchanger installations and to establish the necessary quality standards and skills in the city's building trade to deliver solid wall installation. We have also considered the planning time for district heating networks which would mean that the installation of heat exchangers in connected buildings would happen later in the decade.

In addition, and perhaps more significantly, it would take time to establish the public expectation that these were the solutions they needed to adopt (rather than replacing their gas boiler like-for-like) and to put in place the powers and funding support arrangements (see below) to provide a compelling case.

These considerations are reflected in the projected installation rates for each solution, as shown in Figure 5 below.

Figure 5: Projected installation rates for heat decarbonisation solutions



In this projection for installations, we estimate that 40,000 gas boilers will have been replaced like-for-like on the 'normal' replacement cycle in the first half of the 2020s. To achieve the net zero by 2030 target for heat, these 40,000 would still need to be replaced with the zero carbon option ahead of the end of their useful life to meet the net zero by 2030 target.[15]

Figure 6 below reveals the reduction in gas demand and the more than five-fold growth in electricity demand to provide heat as a result of this heat decarbonisation scenario. As a result of the use of heat pumps, the actual heat output delivered by this electricity use is just over 3 times higher than this input (in kWh).[16] The insulation installed by 2030 has reduced heat demand by 13% relative to the 2018 starting point.

It should be noted that this trajectory for reducing gas demand to zero by 2030 raises serious questions about the value of Ofgem continuing to support investment by Wales and West Utilities (WWU) (and the associated cost to gas consumers) in the upgrade of the gas distribution network in the city (by, for example, replacing ageing iron mains with new plastic pipes designed to last 40

15 See Rosenow (2019) for an exploration of the whole life carbon benefits (including carbon embodied in manufacture) of 'scrapping' a relatively new gas boiler and replacing it with a heat pump. https://www.raponline.org/blog/why-i-replaced-my-new-gas-boiler-with-a-heat-pump/

16 It should be noted that if resistive electric heating (direct electric like panel radiators or storage heaters) were installed instead of heat pumps as the heat decarbonisation 'solution', the demand increase will three times greater than this, increasing the challenge of decarbonising electricity (because more generation will be needed) and causing significantly higher heating bills.

years). While the safety of the network should not be compromised, it will be important to explore the extent to which such investment makes sense in the context of the network's likely future beyond 2030 and the risk of creating a stranded asset and incurring unnecessary costs.

Figure 6: Gas and electricity demand for heat production in selected scenario

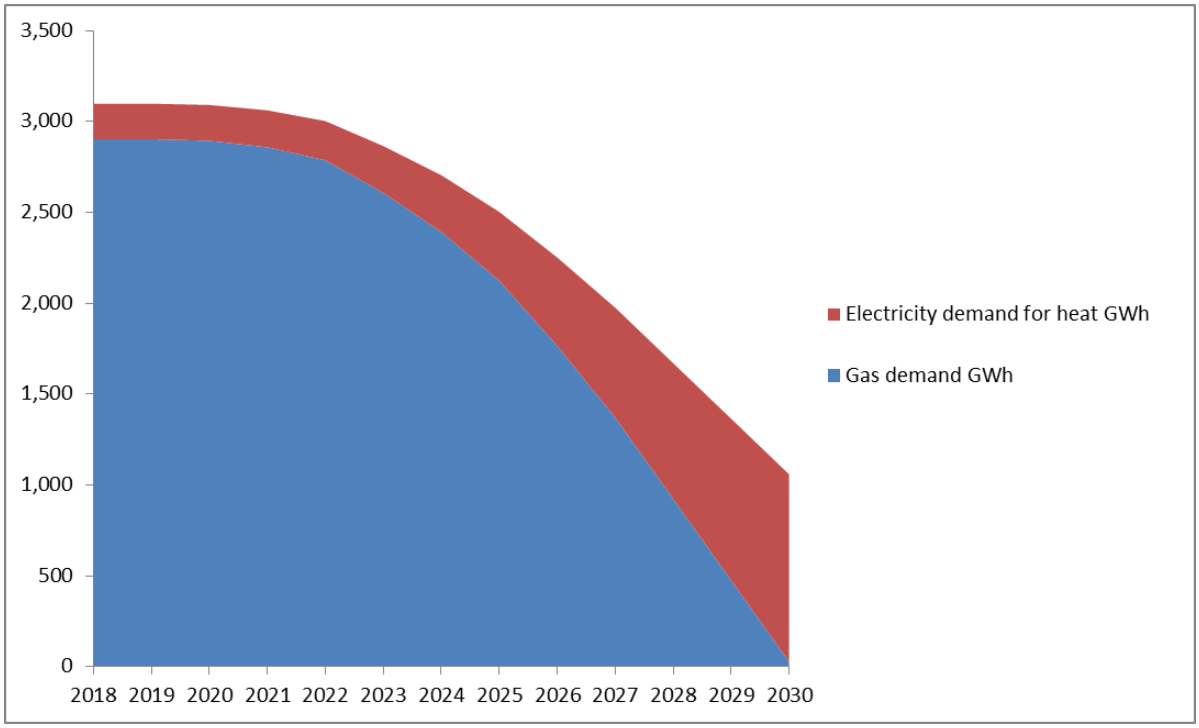
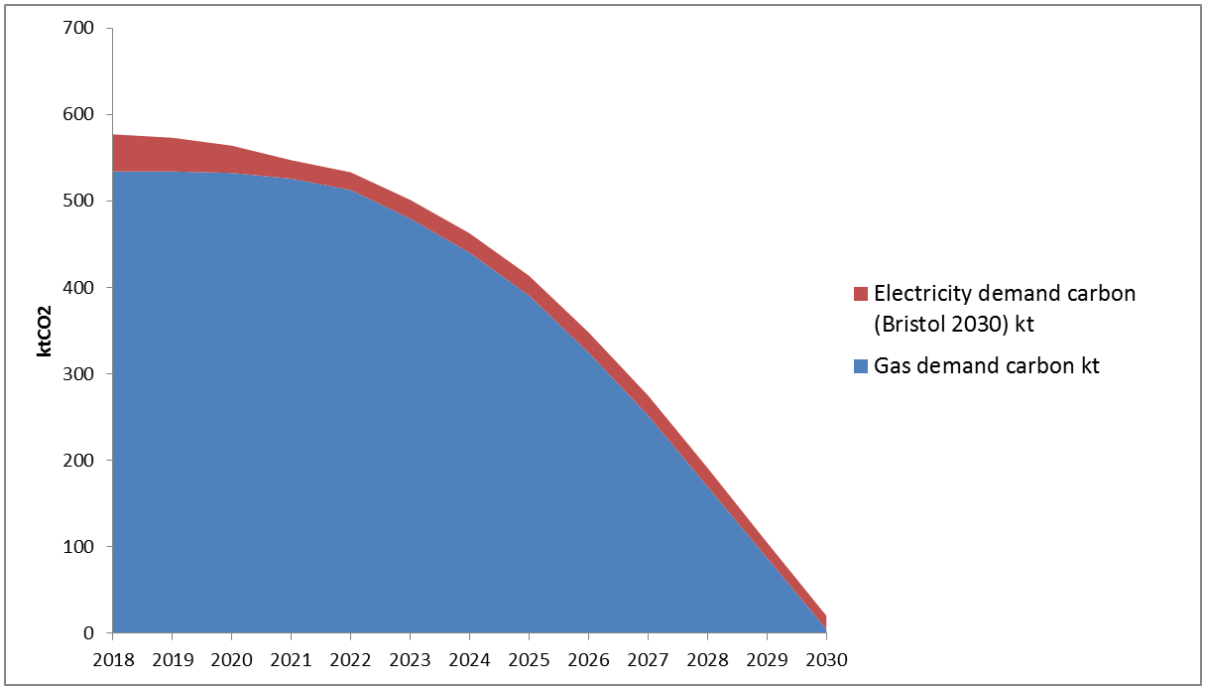


Figure 7: Carbon emissions from heat decarbonisation scenario ('full' electricity decarbonisation)



If the electricity system is only decarbonised according to the National Grid Future Energy Scenario '2 degree', carbon emissions by 2030 from heat will be 60 $ktCO_2$ rather than 20 $ktCO_2$ on the full Bristol 2030 decarbonisation scenario described in Section 2.1.

Indicative change in household heating bills: 20 – 30% increase cf current average gas bill

The analysis here was not designed to forecast future trends in the price of electricity or gas to predict unit costs of either in 2030. Aside from the well documented challenges of doing so with any useful degree of accuracy, it would have added further variables into an already complex analysis.

However, using current prices, it does suggest that, under this scenario, average household heating bills will on average be 20 – 30% higher (c.£100 - £150 at current prices) than current typical average costs with gas central heating. This will be partly offset by households avoiding the gas standing charge (typically £90 - £100 per year) when they are no longer using a gas supply.

However, it is likely that homes using ASHPs will need to use some additional direct electrical heating for the very coldest days of each winter. This would typically cost less than the saving achieved by no longer having to pay a standing charge for gas supply (c. £90 per year).[17]

There will also be costs associated with the electricity network reinforcement required to meet the additional electricity demand from electrifying heat and vehicles, and particularly the peaks typically associated with heat pumps. How these are recovered from consumers will influence the significance of these costs for Bristol's electricity users. A report for the Committee on Climate Change on accelerated electrification suggests that this (and the costs of any transmission system upgrades and 'smarter system management' operations) should add no more than 4% to the cost of a unit of electricity.[18] However, if the cost of Bristol's electricity network being upgraded earlier than current expectations (by 2030 rather than by 2040-2050) was charged just to electricity consumers in Bristol (rather than socialised across all consumers in Western Power Distribution's South West license area, as is currently the case), broad-brush estimates based on initial discussions on upgrade costs with WPD suggest this increase could be nearer 10% per unit.

17 While the use of Hybrid Heat Pumps (which twin a heat pump with a gas boiler which are then controlled so that the gas boiler only meets heat demand peaks) is presented as an option to address this peak heating challenge, these still rely on gas. The volumes of gas required are as much as 80% lower, questioning the commercial viability and consumer affordability of sustaining the gas network for such small volumes. For a 2030 net zero target, there are also significant doubts about the availability of sufficient non-fossil gas to meet even these reduced demands.

18 Vivid Economics and Imperial College (2018) https://www.theccc.org.uk/publication/accelerated-electrification-and-the-gb-electricity-system/ccc-accelerated-electrification-vivid-economics-imperial/. The report also suggests that more rapid decarbonisation of electricity will lower electricity costs compared with current plans and potentially more than compensate for this increase.

At first sight, these bill increases may be thought to aggravate existing levels of fuel poverty in the city. However, households will be able to achieve healthy temperatures in their better insulated 'net zero' homes for this expenditure. Currently, many of the fuel poor in the city living in poorly insulated homes and paying typical costs for heating with gas are not achieving healthy temperatures. As a result of the insulation improvements installed alongside the heat decarbonisation solutions, healthy warmth will be more affordable.[19]

This suggests a need to consider how current nationally determined fuel bill subsidies (such as Warm Homes Discount and Winter Fuel Payments) and various policies whose costs are currently recovered through the electricity bill (rather than less regressive general taxation) could be redesigned in future to provide more targeted discounts to those struggling to keep affordably warm.

Conditions required for success by 2030

There should be no doubt that these are very challenging rates of change to consider in a heating market consisting of systems and patterns of consumer and supply chain behaviour which have been dedicated to gas central heating since the 1970s. In addition, in current commercial and market conditions and against typical investment criteria (which are not shaped by the goal of decarbonisation), the identified heat decarbonisation solutions would not be described as 'cost-effective'. This is in spite of them representing the least-lifetime-cost solutions for achieving heat decarbonisation. This remains the case, whichever heat decarbonisation scenario is chosen for 2030.

To provide a sense of the challenge involved in the district heating included in this scenario, it would involve the installation of well over 1,200 km of heat distribution pipes over the next 10 years. By way of contrast, Copenhagen has installed more than 1,500 km of heat pipes, principally since the mid 1980s; these now provide more than 98% of the city's heat demand.[20]

The scale of required solid wall 'complex' insulation installations – which represent significant building work for any building – are, at 8,000 a year by 2024, significantly above levels previously achieved in the city.[21] However, from recent experiences with the Futureproof low carbon retrofit market development pilot in Bristol[22] and other local insulation initiatives, the main challenges are likely to occur less in generating sufficient demand and more in the availability and quality of the building trades supply chains to promote and deliver these building energy performance upgrades efficiently and to a high standard.

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19 It should be noted that heating bills would be significantly higher if the electric heating option selected were to be direct resistive heating (e.g. panel radiators or storage heating) because these do not provide the efficiency gains of heat pump technology.

20 For more details, see http://www.engineering-timelines.com/why/lowCarbonCopenhagen/copenhagenDistrictHeating_03.asp

21 This volume is roughly at the estimated rate of current 'significant building works' across the city (c. 1 in 20 buildings per year), which means that this volume would be met if all building refurbishment and heat upgrade work in future was designed to achieve net zero.

22 See https://www.cse.org.uk/projects/view/1357

The study team has applied the 'walking right round the issue' systems model (see Figure 2 above) to understand the conditions required for success in achieving the outcomes described above.

The over-arching condition – that the electricity used in Bristol is decarbonised by 2030 – needs to be met for the net zero target to be met. If progress on decarbonisation turned out to be more aligned nationally with the National Grid FES 2 degree scenario (which is broadly in line with the Committee on Climate Change plans for achieving the national 2050 net zero target for all energy uses), heat related emission would be cut by 90% from 2018 levels, as opposed to 97% in the full electricity decarbonisation scenario.

- **Technical**

Heat network designs will need to be drawn up, the capacity of the city's docks and waterways to support WSHP assessed, and delivery plans put in place and executed.

Similarly, solutions for zero carbon heating of individual buildings which are not identified for heat network connection will need to be designed on a building by building basis (in terms of the optimum heat pump and insulation package).

Electricity network reinforcement and associated flexibility and smart constraint management systems to deal with additional demand and peaks of heat pumps will need to have been undertaken.

Heat pumps will need to be reliably quiet and high performance and their refrigerant gases well managed (to avoid leakage of these potent greenhouse gases).

The best solutions to address peak heating needs which heat pumps will struggle to meet (for a few days each winter) will need to have been identified and incorporated into individual building solutions.

- **Capabilities, initiative-taking clout, data etc**

The programme of work for heat networks, individual heat switching and insulation-driven energy retrofits will need to have been planned and orchestrated across the city, with major building owners (in both domestic and non-domestic sectors) engaged to establish their heat decarbonisation plans.

The city's heating engineers will need to have been skilled up quickly to fit heat pumps and heat exchangers (instead of gas boilers) and local building trades will need to have been familiarised with the techniques and quality standards for solid wall insulation and other intensive zero carbon building retrofit measures. Both sectors are likely to need to scale up for the decade-long intensive installation programme, requiring a comprehensive apprentice training programme to grow capacity.

The city will need to have access to sufficient numbers of high quality heat network design engineers and installation contractors to deliver the heat network programme and the distribution network

operator will need to have sufficient power systems engineers and contractors to deliver the network upgrade.

Energy advice and technical support must be available to enable people – householders and businesses – to make the most of their new heating system and make informed choices about their building's insulation package.

- **Commercial/funding**

There will need to have been a comprehensive and compelling funding package put in place, mixing: subsidies and government grants/support; low cost capital and 'heat as a service' offerings. In combination, these can underpin both the long-term investment associated with building heat networks and to address the cost-differential to households between heat pumps and gas-fired alternatives. This will need to include the appropriate balance of costs between different stakeholders – the heat network owner and operator, the building owner and the building occupier (if different).

The cost-differential between ASHP and gas boilers will need to have been eliminated, initially through subsidy/grant initiatives then through cost reductions created by mass production (potentially stimulated by effective bulk procurement by leading cities) and installation skills efficiencies.

As mentioned below, there will also need to be adequate operating cost support for more vulnerable homes so that the anticipated 20 – 30% increase in heating costs associated with achieving net zero heating do not exacerbate fuel poverty.

- **Policy and regulatory**

There will need to be significant new powers and regulations in place – either nationally or devolved to local authorities – for this transition to have taken place including:

- Local authorities will need powers to require existing buildings to be connected to heat networks where they are being constructed (subject to some sort of cost/carbon guarantee).

- Adequate consumer protection will need to be in place for customers of heat networks (so that the inevitable monopoly arrangement is subject to regulatory oversight).

- New gas heating and existing boiler replacements will need to be banned in all buildings from 2025 onwards (or soon thereafter for existing boilers), with >200% efficiency standards (kWh heat delivered per kWh electricity) for heating to drive heat pump take-up and requirements for thermal storage (e.g. hot water tanks) for new build.

- Ofgem will have enabled Western Power Distribution to upgrade the electricity network and improve its active network management in the city to meet (and not constrain) the requirements of Bristol's net zero ambitions and plans.

- Energy efficiency (and more specifically carbon emission) standards for all buildings will need to have been significantly tightened up (or introduced in the case of owner occupied buildings) with a trajectory towards zero carbon by 2030.

- Appropriate approaches are put in place to support energy performance and decarbonised heating improvements to heritage buildings which enable change which respects each building's cultural value.

National fuel subsidy programmes for more vulnerable households (like Winter Fuel Payment and Warm Homes Discount) will need to have been refocused towards supporting costs for low income households shifting to zero carbon heating (or the funding devolved to local authorities to allow them to drive this targeting). Insulation installations could be targeted at these households first.

- **Socio-cultural**

The public and businesses will need to have been convinced that this 10 year transformation of how we heat our buildings is affordable, acceptable and necessary, leading to a long-term solution that delivers a zero carbon city and wider benefits (e.g. job creation, lower heat demand in homes). This public consent will also be necessary to create the political space for the regulatory revolution described above.

The disruption created by installing heat pipes and upgrading the electricity distribution network will need to well-managed.

SWOT analysis of current situation in the city with respect to heat decarbonisation

Strengths

- Bristol City Council Energy Services programmes (renewables, retrofit, district heating) and engagement with BEIS and HNDU and associated positive reputation.

- City Leap initiative and potential to bring extensive expertise and funding to the City to invest in zero carbon assets and enabling infrastructure.

- Extensive retrofit experience and understanding of the challenges involved in scaling up and skilling up building and heating trades' supply chains for zero carbon retrofit (particularly in domestic sector – Warm Up Bristol, Bristol Green Doors, Futureproof, The Green Register etc).

- Strong engineering consultancy and heat network know-how based in the city.

- A significant body of public opinion in favour of rapid decarbonisation in the city, with political leadership engaged with challenges.

- Extensive experience across the city of engaging with more vulnerable households to build their energy resilience, including upgrading the energy performance of their homes (particularly by social landlords) and supporting them to take control of new heating systems.

Weaknesses

- District heating commercials weak, particularly for retrofit, without longer-term signal of zero carbon future and associated capital funding support.
- Quality contractors in heating and building trades are already busy so have little time to skill up for heat decarbonisation options.
- Different interests and powers of tenants and landlords (particularly for private rented domestic and non-domestic buildings) create significant obstacles to decision-making about, and financing of, retrofit, with limited impact to date of nationally set Private Rented Sector Minimum Energy Efficiency Standards.
- Complexity of issue and lack of 'obvious' path or national policy direction leads to inaction and makes public engagement difficult, even though there are 'very low regrets' options (the best heat networks, solid wall insulation etc).
- Powers for local authorities to intervene and direct (and associated funding) are very limited.
- Policies and practices associated with heritage buildings (listed and in conservation areas) tend to block even sensitive improvements.

Opportunities

- Widespread recognition by experts, government advisors (the CCC) and senior politicians that heat decarbonisation is THE challenge in cutting carbon emissions, meaning there is a high degree of interest in supporting places seeking to take a lead on achieving such a transformation.
- Job creation from the accelerated programmes is likely to be significant, with expertise (particularly heat network installation and network upgrade) that would be transferable to other areas in due course.
- Western Power Distribution interested in how it can help Bristol achieve its ambitions.
- Ofgem potentially interested in local areas seeking more rapid transformation and potentially willing to allow for this in network business plans (but see Threat below).
- Private Rented Sector Minimum Energy Efficiency Standards represent a framework which, if promoted and enforced effectively and based on more effective energy performance building assessments, could provide a progressive driver for upgrading rented properties.
- Update and improve policies and practices on improving carbon performance of heritage buildings to balance better the need to tackle the climate emergency with the need to protect these cultural assets.

Threats

- Government funding to address cost differential (cf gas boiler) for zero carbon heating not sufficient to do the job.
- Common tendency to hope solutions will emerge (e.g. hydrogen, CCS) rather than get on with delivering on opportunities for transformation already to hand and understood, and associated reluctance to accept gas network may not have a future in a zero carbon city (so it distorts thinking on best approaches).
- Scale of change anticipated (no new gas boilers after 2025) creates public and business backlash if: additional costs of alternatives (both capital and operating) are not addressed; heat pumps prove unsatisfactory; heat networks suffer budget and timetable overruns, or; more vulnerable are not protected from bill increases.
- Huge inertia and resistance to changing the gas heating 'system' and role of 'distress replacements' (at point of boiler breakdown so no time to plan alternative).
- Ofgem may not allow Western Power Distribution to include rapid network upgrade in Bristol (both additional capacity and smarter operational management) within its RIIO-ED2 business plan, so delaying or slowing upgrade to 2050 timetable.

Key interventions to decarbonise heat in Bristol by 2030

Decarbonising heat in Bristol involves phasing out gas boilers by 2030 and replacing them with a combination of district heating and individual building heat pumps and improving the energy performance of buildings; it is a complex task. It involves supplanting with a new approach some 50 years of practice focused on gas as the dominant fuel for heating in the city (and more widely in Great Britain) with equipment supply chains, skills and training, and consumer expectations all deeply ingrained. It also involves tackling at scale for the first time the energy performance of older solid-wall buildings in the city which have not been suitable for the mass cavity-wall insulation programmes which energy suppliers have been required to fund over the last 20 years.

Establishing this new approach will require an orchestrated programme across the city which combines:

a. A detailed district-by-district costed plan for heat decarbonisation for the city, building on the analysis undertaken for this study (adding in the status of the electricity distribution network to assess network upgrade and/or smarter management needs). This should:

    - draw in key building owners (e.g. public sector organisations, commercial landlords, social housing providers) in each district to encourage them to develop and align their own heat decarbonisation plans;

- be underpinned by effective public engagement at local level to start to shift expectations and inform the nature and scale of support (financial and advisory) likely to be required to overcome obstacles associated with cost and unfamiliarity.

b. A funding programme (building on the plans for City Leap) which identifies public sector investment, building-owner contributions (towards the upgrade of their own buildings), and sufficient levels of grant subsidies (or other types of cost-support such as a boiler scrappage scheme) to finance the roll-out of district heating networks into existing buildings and to put the installation of decarbonisation solutions for heat in each building on an equivalent financial footing for the household or business as 'carrying on as normal' with gas boilers. This should include 'no upfront cost' approaches for lower income households.

c. Making the case to Government for the public sector investment and grant funding support identified in b above and for the creation and devolution of powers to enable the city to establish and roll-out **heat decarbonisation zones** in which:

    - existing buildings (commercial and residential, owner-occupied or privately or socially rented) can be required to connect to heat networks being constructed;

    - insulation upgrades and heat pump installations are available and co-ordinated on a street-by-street basis (to achieve any available benefits of scale);

    - progressive standards for improving building energy performance are applied across all tenures and both residential and non-residential sectors;

    - gas boiler replacements are phased out and further investment in upgrading the gas distribution network is stopped;

    - effective consumer protection rules are put in place for heat network customers and those taking up new approaches such as 'heat as a service' offers (as currently being trialled by Bristol Energy).

d. The realisation of opportunities for cross-city procurement to drive cost reductions in equipment like heat pumps, insulation materials, heat network equipment etc, building on opportunities which will arise in City Leap.

e. An extensive and sustained skills training and associated apprenticeship programme (involving the local Further Education colleges and specialist providers such as The Green Register, CITB, and equipment manufacturers) which:

    - re-trains gas heating engineers in fitting both district heating in-home heat exchangers and air source heat pumps and associated controls

    - upgrades the knowledge and skills of building trades to ensure they understand the appropriate techniques and choices of materials for improving the energy performance of buildings, taking a whole house approach

- strengthens the knowledge and skills that local architects and building technicians will need to provide building-by-building upgrade designs and costed programmes of work
- underpins advice services for households, building owners and a quality assurance scheme to sustain and enforce high quality installations.

f. A significant programme of public and business engagement to develop their understanding of the future of heating ('beyond gas') and the steps they will need to take (and by when and how they will be supported to do so), including public sector exemplars which show case the new solutions and promotion of the idea of shared heating solutions (district heating) in those areas where it is likely to be the dominant decarbonisation solution.

5 Energy generation, distribution and demand: powering decarbonisation for Bristol

Summary

Bristol's electricity demand is likely to increase by 50% by 2030 from current levels as a result of the electrification of heat and vehicles described in the adopted scenarios in this study. These new sources of demand out-run the continuing efficiency gains in other power uses which will more than compensate for the anticipated population growth. The evidence suggests that, with a significant new programme of solar PV installation on residential and non-residential buildings, Bristol could meet 20% of this increased demand from renewable electricity generation within its boundaries by 2030. Bristol will therefore need to undertake wider actions to support grid decarbonisation nationally to help meet this key dependency for Bristol's 2030 ambition. The analysis shows that:

- There is potential for 500 MW of new solar PV (at a cost of £600 million) across the city which generates a return of more than 5% (>300MW at >6% IRR) at current electricity prices (for export and avoided import) and latest 'post-subsidy' installation costs. Realising this (at 50MW of new installations a year) would result in nearly 1 in 2 (rather than the current 1 in 48) homes having some solar PV on their roofs by the end of 2030.
- The additional demand, and particularly the increased peak demand (even with smart, active management), will lead to a requirement to upgrade significantly the city's electricity distribution network and introduce more active management through the use of flexibility services and peak reduction initiatives.
- Beyond realising its own renewable energy potential within the city boundaries, Bristol can also help to accelerate grid decarbonisation nationally by businesses, public and voluntary sector organisations, and households (a) actively engaging in demand flexibility services and peak reduction initiatives and (b) contracting for genuine 100% renewable electricity tariffs to create new 'subsidy-free' market demand for more renewable generation.

These opportunities will be challenging to realise, given in particular (i) the collapse in recent years of the solar installation market following the end of the Feed in Tariff subsidies (though installation costs now appear to have adjusted to reinstate a reasonable investment case) and (ii) the tendency of the energy regulator Ofgem to limit the sort of anticipatory network investment that Bristol's net zero ambition would require from WPD. For these challenges to be overcome will require:

- The city's public, businesses and other organisations have been effectively supported to participate actively in value-adding demand flexibility services and demand reduction initiatives and to sign up for genuine 100% renewable electricity tariffs.
- WPD to have engaged with the city's net zero ambition and planned, costed and secured the regulatory approval for the accelerated upgrade of the electricity distribution network so that it enables 'net zero' by 2030, rather than current expectations of sometime in the 2040s.
- A major co-ordinated city-wide approach to promoting and realising the opportunities for solar PV across both the domestic and non-domestic markets with an associated rejuvenation and significant scaling up of Bristol's solar PV installation sector.

Bristol achieving net zero by 2030 will ultimately depend on the decarbonisation of the increasing amount of electricity that the city will consume as it displaces the direct uses of fossil fuels for heat and transport with electricity.

As explained in Section 2.1 above, this decarbonisation of Bristol's electricity in turn depends on the decarbonisation of the whole GB electricity system by 2030 (often referred to as 'grid decarbonisation'). While that outcome is not currently 'on track', there are official scenarios (e.g. the '2 degree' Future Energy Scenario from the National Grid System Operator) and expectations from the Committee on Climate Change that it will proceed apace in the 2020s and be achieved at some point during the 2030s.

However, these electricity decarbonisation scenarios are largely silent on what they expect of a city like Bristol and its citizens and businesses in terms of both:

- How important it is that the city realises its own renewable energy potential as a contribution to national grid decarbonisation.[23]

- How its collective political, commercial and consumer actions could stimulate and enable more rapid grid decarbonisation. For example through (a) engaging in smarter system services such as demand flexibility (to reduce the costs of renewables' variability) or battery storage, or (b) contracting directly for 100% renewable electricity supplies tariffs (to improve market pull for additional deployment).

This section explores how the demand for electricity in the city will change between now and 2030 in the context of the net zero ambition. It considers the potential implications for the electricity distribution network of the additional total and peak demands from the electrification of heat and vehicles. It also examines the contribution which the city can make to increase the likelihood that grid decarbonisation will be achieved by 2030 or soon after.

23 There is an argument (recently presented to one of the study team) that, if the grid is going to be decarbonised anyway by the mid 2030s, why should Bristol bother developing its own renewable energy potential? Why shouldn't it just take advantage of off-shore and on-shore wind and other renewables being deployed elsewhere? However, such an argument assumes that these decarbonisation scenarios do not require Bristol's contribution, which is probably not the case. The argument also ignores the 'tragedy of the commons' dimension; if everywhere 'free rides' like this, the common benefits that everyone is seeking – in this case decarbonised electricity – will not be achieved.

Growing demand for electricity as heat and transportation are electrified

Analysis for this study indicates that demand for electricity in Bristol will need to increase by 50% by 2030 as it is increasingly used to displace fossil fuel use for heating and transport.

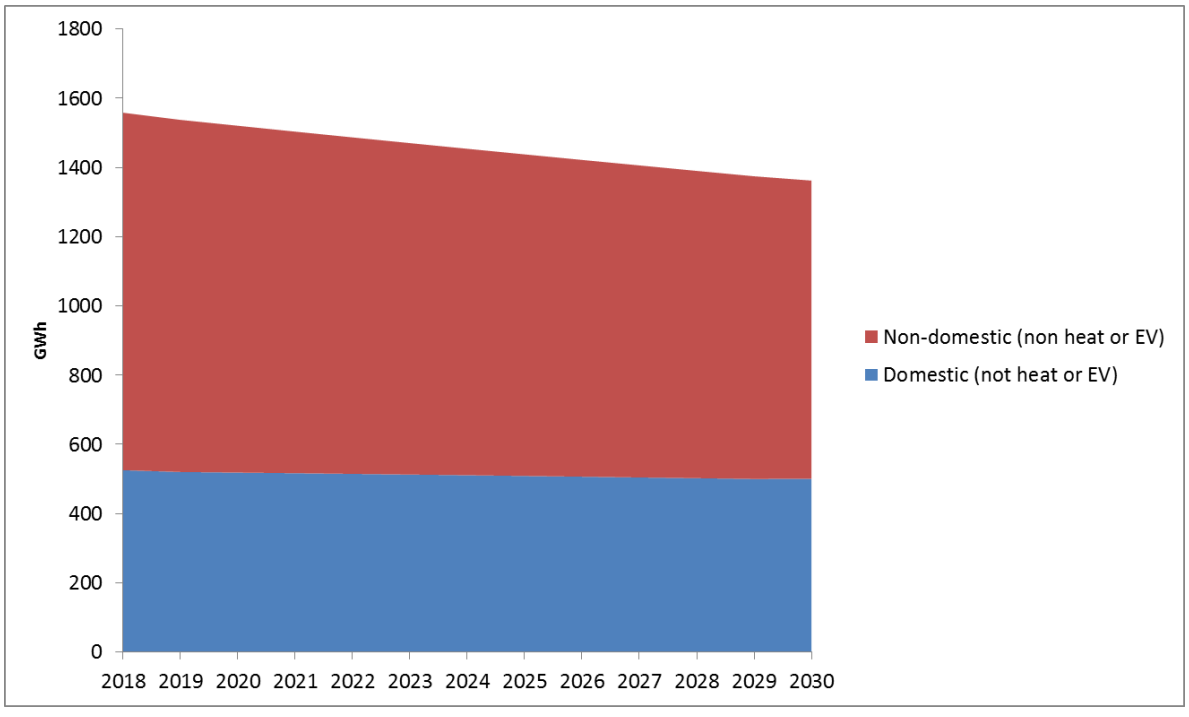
The electricity demands created by decarbonising heat and vehicle transport are analysed in Sections 4 and 6 and included in the analysis here.

This section examines the demand for non-heating or transport uses of power (like lighting, cooking, computing etc) which currently make up about 85% of the city's electricity use. Demand for these services will grow with the anticipated 13% increase in population by 2030. However, based on recent trends, this increase in demand for services is likely to be more than offset by continuing improvements in energy efficiency of appliances and equipment (driven by both a tightening of energy performance standards and associated innovation, particularly recently in LED lighting). The result is that the associated electricity demand can be expected to fall, even with the expected population growth.

Over the last 13 years, official statistics show that there has been an annual reduction of about 1.5% in the average domestic consumption of standard rate electricity (which, in contrast to Economy 7 use, can broadly be assumed not to be used for heating). A similar reduction has also been seen in average non-domestic electricity use.

For the purposes of this analysis, the study team has anticipated that this trend will continue. Taking account of the anticipated 13% growth in population (and therefore households) by 2030, this produces the trajectory for electricity demand not including heat and transport shown in Figure 8.

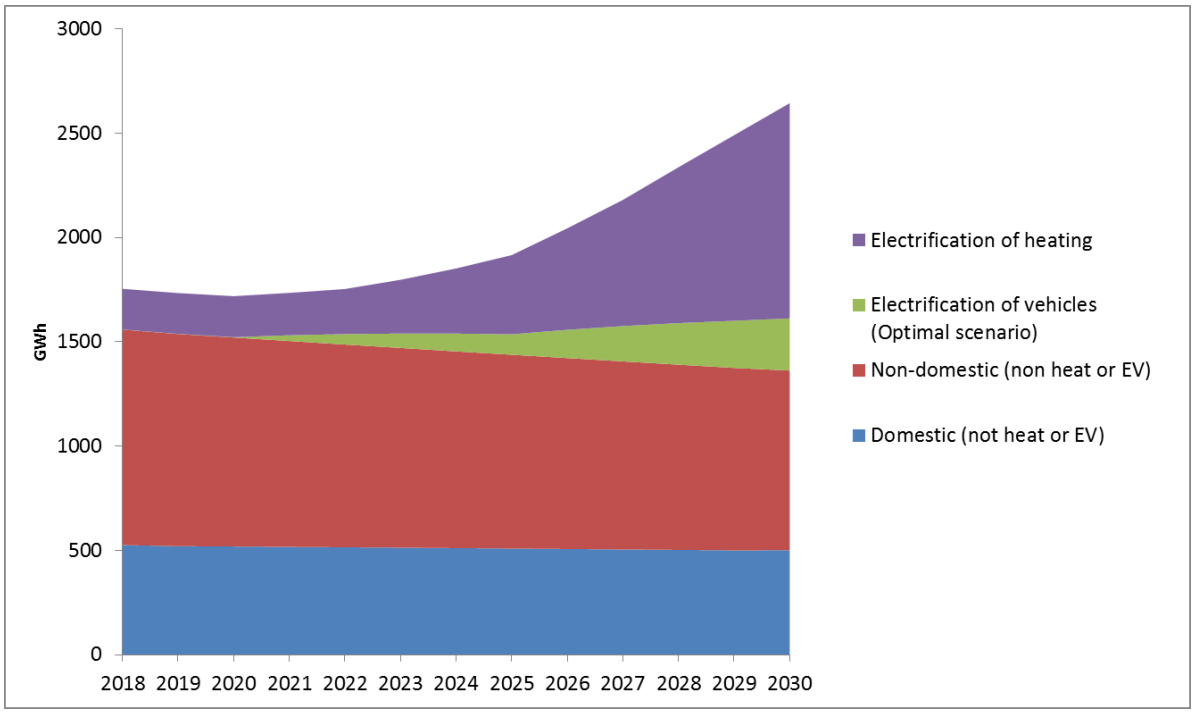
Figure 8: Forecast electricity demand for Bristol 2018-30 not including heat or transport



There are potentially interventions which should be undertaken to achieve and potentially accelerate this efficiency trend and drive further reductions in demand. These could include supporting the installation of LED lighting across the city and the procurement by the public sector and businesses of very high efficiency appliances and equipment, including IT. These are not included in this analysis but are considered in the conditions for success and key interventions.

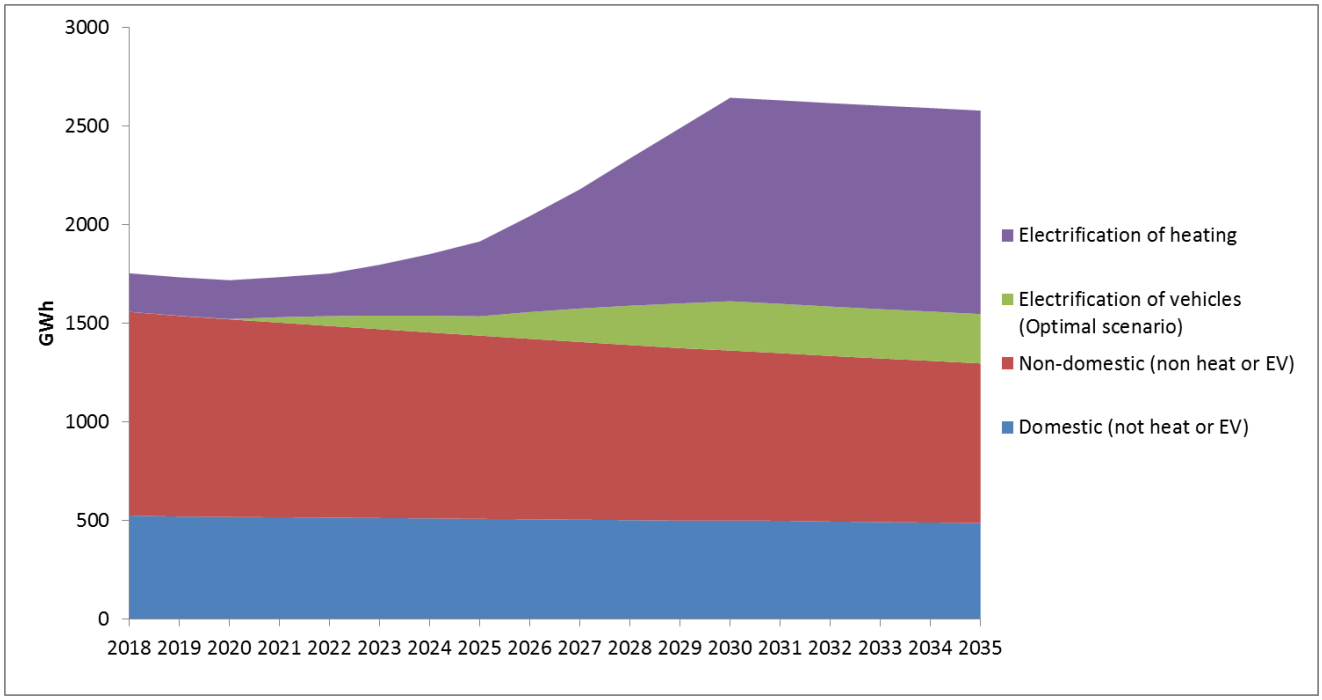
Combining this 'non heat or transport' electricity demand projection with the results of the analysis of the decarbonisation scenarios for transport and heating (described in Sections 4 and 6) reveals a **50% increase in electricity demand by 2030**. See Figure 9. Note that if resistive electric heating (direct electric like panel radiators or storage heaters) were installed instead of heat pumps, the demand increase will be at least double this and heating bills would similarly be very significantly higher.

Figure 9: Forecast electricity demand for Bristol 2018-30 with heat and vehicle electrification



Note that, while this trajectory looks like it would result in continuing growth of electricity demand, the scenarios developed for heat and transport both assume their electrification has been fully achieved by 2030. The longer-term trajectory for electricity demand beyond 2030 would therefore look more like that shown in Figure 10.

Figure 10: Forecast of electricity demand for Bristol including post 2030



Potential for growing Bristol's zero carbon renewable electricity generation

- **Current zero-carbon renewable generation in Bristol**

At the end of 2018, government statistics show that Bristol had:

- 27.2 MW of solar PV capacity across 4,179 installations, generating 26 GWh of electricity a year

Roughly 1 in 48 homes (n. 4,086) has a solar PV system, with an average capacity of 3.33 kWp. This represents half of the total solar capacity currently installed in the city.

- 36 MW of wind power capacity across 5 installations, generating 80 GWh of electricity a year.
- Electricity generation from using bio-methane from anaerobic digestion and sewage gas of 32 GWh a year.

This 'in area' zero carbon electricity generation amounts to about 8% of Bristol's current total electricity demand.

Note that, in any net zero scenario, the incineration of waste which includes plastic cannot be considered zero carbon. The new 15 MW incineration facility in Avonmouth, which generated 52.6 GWh of electricity in 2018, has therefore not been considered here as zero carbon (see Section 7 for exploration of this issue).

The principal opportunity for growing the city's production of zero-carbon renewable electricity is in realising the potential of roof-top solar across the city. This has been the main focus of the analysis by the study team and is described below, following a brief exploration of other opportunities for increasing renewable generation.

- **Repowering existing wind sites**

There are some opportunities to increase wind power production. However, these are principally from repowering existing sites with larger turbines when they reach the end of their existing lives (though most of these are beyond 2030). There are currently well-developed plans, being led by social enterprise Ambition Lawrence Weston, for a single 4.2MW wind turbine which is predicted to generate 13 GWh a year (0.7% of Bristol's current electricity demand). There are few additional sites for significant wind power production within the city council's administrative boundary.

If all of the existing wind farms were repowered with these size turbines at the end of their operating lives (assuming separation distances and potential wake effects are addressable), this could triple production at these sites (to perhaps 250 GWh a year, including the Ambition Lawrence Weston site). While this repowering would be unlikely to happen until the 2030s, if it did take place it would meet be roughly 10% of Bristol's increased electricity demand following electrification of heat and transport by then.

- **Bio-methane and other renewables**

The production facilities for bio-methane from digestion of both sewage sludge and food waste by Geneco at the Avonmouth sewage treatment works are reportedly at full capacity. Increasingly the gas is being used not to generate electricity (except for on-site use) but exported for use in bio-gas buses, which is likely to be a more carbon efficient use for the gas while it is displacing diesel buses.

There is potential for greater (roughly doubling) production of bio-methane in the city from collecting more of the commercial food waste produced in the city, though this will be tempered by the need to reduce food waste (which has positive impact on Scope 3 emissions). This is the subject of two academic studies currently being undertaken in the city (Sunex and FEW-ULL) which should help to inform optimal future strategies for reducing food waste, collecting more of what is still being produced for energy generation, and the most carbon efficient use of the bio-methane generated (for example, as 'green gas' injected into the gas distribution network for use in heating buildings, as fuel for peaking or back-up generators, or as fuel for biogas buses).

There are also some small opportunities to develop hydro power (e.g. Netham Weir); while a useful contribution, these are dwarfed by the existing solar and wind generation and their future potential.

- **Estimating and locating Bristol's solar PV potential**

To assess the potential for solar PV in Bristol, the study team has developed a modelling approach using Environment Agency LIDAR data to generate a 3D model of the city. This was first applied in a study for Birmingham City Council.[24]

The model produces an estimate of the amount of solar energy (kWh/year) striking each of the approximately 150,000 roofs in the Bristol city area. The estimate accounts for shading, orientation and pitch and has a precision of 1 square metre. For each roof, the model converts incident radiation for every tenth of its area into an electrical and associated financial yield, using panel size, efficiency and cost assumptions for different sizes of installation (< 10kWp, <100kWp, >100kWp). These assumptions were informed by industry sources who are installing PV systems in the post-subsidy market and cross-referenced against data from Bristol City Council Energy Service.[25]

There remains some uncertainty about the value of the electricity generated by solar PV, while the market response to the new Smart Export Guarantee arrangements is still unclear. Early indications suggest an export value of at least 5p/kWh be available. The value of electricity used on site is the 'avoided' cost of the retail price of electricity being paid by the consumer; that depends on the consumer's current tariff (but, for domestic, is typically above 15p/kWh). The total value of the generated electricity therefore depends on the balance between on-site use and export.

There are many different permutations of these variables. However, there is insufficient data available about the levels and patterns of electricity demand in each building to provide a good time-of-energy-use driven model. For the scenario described here, the study team has therefore adopted a value for PV electricity generated of 10p/kWh. For domestic sector, this reflects an assumption that they export half at 5p/kWh, and use half as it is generated at an avoided cost of 15p/kWh). For the non-domestic sector, this reflects an assumption that, because, unlike the domestic sector, the electricity use is principally during the day (i.e. when the sun shines), they would export less (30% at 5p/kWh) but their avoided cost is also lower (70% at 12.2p/kWh).

It should be noted that this analysis has not sought to exclude buildings which already have solar PV installed since that data is not currently available on a building-specific basis. However, the total estimates for additional solar PV potential have taken out the 27.2MW which has already been installed. In the time available for the study, the analysis has also not assessed the potential for

24 See https://www.cse.org.uk/projects/view/1331. For more details of how it was developed further for this study, see the separate Technical Annex (in press)

25 The detail is provided in the separate Technical Annex (in press). Note that the cost data was provided in October 2019 by a leading solar installer based on the prices it is charging customers for new systems of a wide range of sizes (from domestic to large commercial roof) which are being installed without the Feed-in-Tariff (FIT) subsidies. These are therefore costs which are no longer subject to the inflating effect which subsidies can create. (This is because the subsidies increase the revenue the installation generates and therefore makes the installation more valuable, and because supply chains, from component suppliers to installers, tend to price to value, not to cost).

ground-mounted solar in the city, though this is likely to be seriously constrained by existing land uses.

The output from this analysis is a building-by-building estimate of the rate of return (IRR) that would be generated from installing solar panels on no more than 50% that roof.[26]

These are summarised in Table 3 below and can also be mapped. Figure 11 below shows a 'zoom in' for the Cotham/Kingsdown area of Bristol. The paler colours are the buildings on which PV installations have higher IRRs (in the key, IRR at, for example, 0.051 is 5.1%).

Figure 11: Solar PV potential and projected IRR for Cotham area of Bristol

Note the red triangle (which has been added 'post-production'). This is Kingsdown Sports Centre where google earth reveals that there already is a PV installation on most of its roof, presumably earning its owners a return of between 7.5 – 9.8%.

The total PV capacity in the city with an IRR of more than 5% is shown in Table 3 below. Realising this total potential of 537MW across 96,000 roofs would generate nearly 560 GWh a year of electricity. Given current generation from solar, the ***additional*** potential is therefore just over 500MW on 92,000 rooves, generating 530 GWh, with a total capital cost of c. £600 million.

26 The model selects the best 1/10ths of the roof to use and assumes nothing with an iRR lower than 3.5% will be included.

If this was all realised by 2030, solar PV generation in the city would be meeting about 20% of the projected total electricity demand for Bristol for 2030 in these net zero scenarios. The city would be generating power from 1 in 2 homes (some having shared roofs) rather than the current 1 in 48. And Bristol would have an installed capacity of more than 100W per capita, putting it on a par with Honolulu in Hawaii.

Table 3: Solar PV potential on Bristol's roofs with IRR greater than 5%

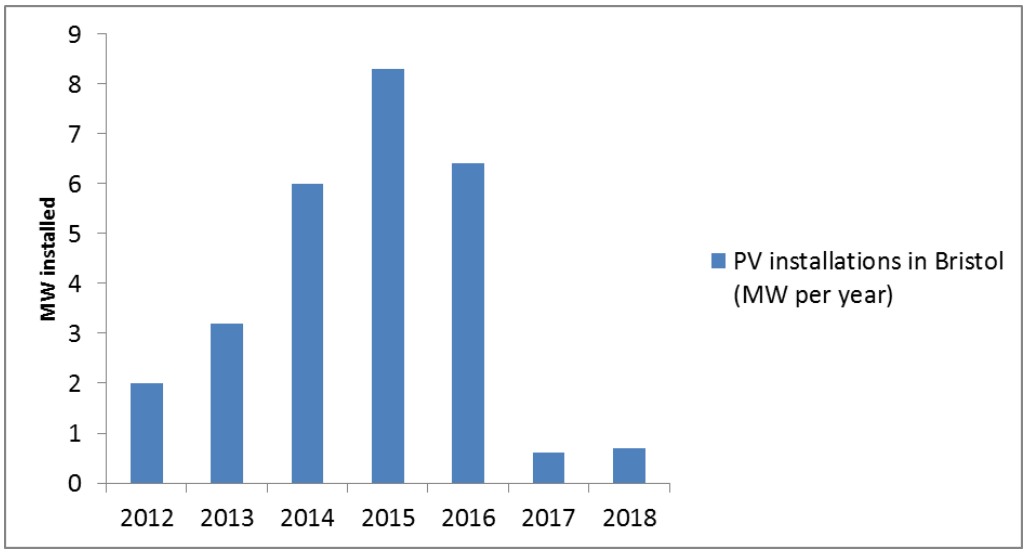
IRR	Number of installations	MW capacity	GWh annual production	Average installation size (kWp)	Proportion residential	Capital cost (£m)
5.01-6%	80,070	187	205	2.3	99%	276
6.01-7%	10,674	47	47	4.4	95%	58
7.01- 8%	3,455	83	82	24	51%	92
8.01-9%	1,139	41	42	36	23%	44
9.01-10%	146	25	23	168	24%	21
10.01-11%	465	121	120	259	8%	103
11.01-12%	134	35	36	262	5%	30
12.01-13%	1	0.37	0.37	368	n/a	0.3
TOTALS	**96,084**	**537**	**557**			**625**

The scale of the challenge

Achieving this potential by 2030 will be a challenge given it suggests a required installation rate of c 50MW of PV capacity a year. This is significantly higher than the peak installation rate (8.2MW per year) achieved across the city when the Feed in Tariff subsidy mechanism was available. Figure 12 below shows the rate of installation of PV (by MW installed) in the city of Bristol over the last 7 years[27].

27 Data disaggregated by local authority is only available for 2014 onwards so deployment rates for previous years are estimated, based on national pattern of installations and Bristol figure for what had been achieved by 2014.

Figure 12: PV installations in Bristol 2012-18 (estimated pre 2015)



However, this record should not be seen as an example of the limit of what is possible in a UK city. Over the same period in the area of Peterborough Borough Council, PV was installed in 1 in 10 homes, suggesting a 5-times higher per household rate of installation of domestic-scale PV across Peterborough than across Bristol in the same period.[28]

The ending of the Feed in Tariff for PV has undoubtedly weakened what had been a very strong commercial case for installing PV (and for being in the PV installation business). That said, the evidence from the analysis here suggests that (a) installation prices have now adjusted downwards to reflect the post-subsidy commercial realities, and (b) at these prices, there are relatively attractive returns available for a very large number of domestic and non-domestic PV installations (e.g. >300MW at >6% IRR).

Being smarter: flexibility and demand side response, storage and other 'grid services' which enable more renewable electricity

It was beyond the time and resources available for this study to assess the potential of the city for demand side flexibility provided by demand response or battery or other forms of energy storage. A report for the Committee on Climate Change[29] which draws on national level analysis has suggested

28 This appears to be the result of successful marketing initiatives by a range of installers which, in combination with a supportive Borough Council, created a strong new social norm for PV installation in the city. The Borough Council invested early (2012) and publicly in solar for its own buildings, providing endorsement for the technology; it also set up its own 'rent a roof free solar' scheme (Empower), though this appears to be responsible for less than 5% of all domestic installations. Peterborough was less successful than Bristol in achieving non-domestic installations, achieving only 20% of Bristol's installed capacity over the same period.

29 See Vivid Economics and Imperial College (2019), Footnote 18

that the maximum potential for shifting peak demand through flexibility is 41% for residential appliances and 10% for industrial and commercial electricity use. This suggests significant potential for participation in demand side flexibility which could be realised in Bristol.

It should be noted that increasing participation in demand side flexibility and installing energy storage across in the city will not lead directly to significant additional reductions in the city's Scope 2 carbon emissions (i.e. those associated with electricity generation).

However, it would contribute to enabling the electricity system nationally and the distribution network locally to accommodate more renewable electricity generation at lower cost. It would also support a more rapid phase out of fossil-fuelled back-up generators and 'peaking' generation which are not compatible with a net zero energy system. As such, it represents a contribution the city can make to enabling the achievement of a zero carbon electricity system.

In addition, it could reduce the scale of investment needed for upgrading the electricity distribution network for the city, provided the flexibility services were organised to serve local network operational requirements as much as national system balancing and stability needs.

Signing up for renewable electricity suppliers to supporting the deployment of zero carbon electricity elsewhere

There is a case for Bristol using its collective buying power (as households, businesses and public sector and voluntary organisations) to contract for energy supplies which are 100% based on renewable electricity. This could create greater market 'pull' for more renewable energy deployment across Great Britain and effectively underwrite the value of renewable generation to support project financing for new projects. To be a genuine driver of deployment, there would need to be a convincing resolution of how 100% renewable tariffs are assessed to ensure they have this market-pulling impact.[30]

Upgrading Bristol's electricity distribution network: a 'network for net zero'

The city's electricity distribution network will need to be upgraded and managed more actively and flexibly to cope with (a) the 50% increase in electricity demand, (b) the higher peak demand anticipated from the electrification of heat and transport as described here, and (c) integrating the significant increase in local solar PV electricity generation.

It was beyond the scope of this study to assess the scale and cost of this upgrade, though some preliminary discussions with Western Power Distribution (WPD) have taken place. These have

30 Many current '100% renewable' tariffs are based on the use of Renewable Energy Guarantee of Origin (REGO) certificates which are tradable independently of the renewable electricity itself. There are some doubts about whether this approach means that all such tariffs are genuinely supporting further deployment (as opposed to leaving energy consumers who have not signed up for such tariffs with 'browner' electricity than the grid average). See https://www.energysavingtrust.org.uk/home-energy-efficiency/switching-utilities/buying-green-electricity for a high level exploration of these issues.

explored the implications of Bristol's net zero by 2030 ambition for how the network might need to develop (see Section 4 for some discussion of potential impacts on electricity costs).

In essence, Bristol's network needs to be upgraded and managed more actively by 2030 to avoid it being a constraint on the city's ambition, rather than by sometime in the 2040s that would otherwise be in WPD's plans to meet the national net zero target by 2050. It is therefore important to Bristol achieving its goal that WPD designs and integrates an accelerated upgrade programme for Bristol's distribution network into its business plans and secures regulatory approval from Ofgem for them to be funded and implemented between now and 2030.

The scale of network upgrade and the need for improved network management are likely to be significant (potentially as high as £100 million a year over the next 11 years - for assets that would then last at least 40 years). The national level analysis undertaken for the Committee on Climate Change on 'accelerated electrification' concludes that "68% of network lines in urban areas and 61% in high density semi-urban areas would need reinforcing" in a rapid EV and heat pump rollout scenario (such as that planned for Bristol).The majority of the network reinforcement cost would be this line reinforcement, with the major component of that cost being digging up the roads to replace existing cables.[31]

There is currently only limited information available about the electricity network 'headroom' across the city (i.e how much more demand it could accommodate without reinforcement or more sophisticated demand management). The analysis has therefore not been undertaken on how local average and peak demands would change on a substation by substation basis (depending on the heat decarbonisation option for each building in the city identified by the analysis here). Undertaking this more detailed analysis and working with WPD to plan and cost a 'network for net zero' for Bristol for implementation by 2030 will be vital as an early stage action. Likewise, it will be important to engage with Ofgem to legitimise the WPD plans to support Bristol's ambition and to secure the regulator's endorsement for the 'accelerated' investment and a fair cost-recovery approach.

Conditions for success by 2030

'Walking right round' the issues explored in this section reveals the following conditions for success in achieving these outcomes:

- **Technical**

A major, co-ordinated programme of PV installation in both domestic and non-domestic sectors will have been undertaken, leading to 50MW a year of new installs taking place across the city from the early 2020s, integrated with storage and demand flexibility to optimise the value of the electricity generated.

31 See page 38 in Vivid Economics and Imperial College (2019), Footnote 18.

Energy efficiency improvements in equipment and lighting continue at least at recent rates and demand flexibility services will have emerged and be well-understood and well regulated.

The necessary electricity distribution network upgrades and improved system operation will have been put in place to enable the decarbonisation of heat and transport and to accommodate significant solar PV generation in the city.

Smart meters will have been installed in all businesses and households by the early 2020s, enabling engagement with demand flexibility services.

Plans will be emerging for the repowering (with much bigger turbines) of existing wind farms in the Avonmouth/Severnside in the 2030s to increase output from the same wind resource.

- **Capabilities, initiative-taking clout, data etc**

The solar PV installation sector in the city will have re-juvenated and scaled up in response to the emerging viability for subsidy-free installations, with a co-ordinated city-wide approach taken to promoting and realising the opportunities for solar PV across both the domestic and non-domestic markets.

Granular energy data and associated data analytics will be available locally to drive the development of and participation in demand flexibility services and storage and help target opportunities to improve and lower costs.

Public sector bodies will have used procurement power to drive continuing efficiency improvements in electricity-using equipment and appliances, including IT and, in particular, LED lighting.

WPD will have recruited and trained sufficient power system engineers to enable accelerated progress towards a 'network for net zero' for Bristol by 2030.

- **Commercial/funding**

The investment case for 'subsidy-free' solar PV will have been established early in 2020 because the price 'floor' available from the Smart Export Guarantee will create confidence in longer-term value of generation.

WPD will have developed and made the case to Ofgem for investment in upgrading Bristol's network and introducing more active management to ensure the electrification of heat and transport and the additional PV capacity can be accommodated on a timely basis.

Bristol businesses, public sector bodies and households will have, en masse, signed up for genuine 100% renewable electricity tariffs, creating strong demand for additional deployment and underpinning decent prices paid to new renewable generators in a 'post-subsidy' world.

Domestic-scale flexibility services will be developed and available in the market, alongside services for commercial consumers, so that Bristol households can participate and contribute positively to the decarbonisation of the national electricity system and more efficient local network operation.

- **Policy and regulatory**

Ofgem will have enabled Western Power Distribution to upgrade the electricity network and improve its active network management in the city to meet (and not constrain) the requirements of Bristol's net zero ambitions and plans.

Subsidies and tax breaks for fossil fuels will have been removed and the use of fossil fuels in back-up and peaking plant generators phased out.

Consumer protection will have been put in place to cover flexibility services, time-of-use tariffs, peer-to-peer trading etc.

Any planning constraints on PV in conservation areas will have been lifted with a more relaxed approach to installations on listed buildings where not material to heritage value.

- **Socio-cultural**

Increased numbers of solar PV installations will have made it normal and desirable, rather than niche, for households and businesses.

Public support and engagement will have been secured across the city through a sustained programme to develop understanding and involve people in shaping local responses to flexibility and renewable energy installation and purchasing opportunities.

Households and businesses will have been supported with advice to navigate and engage with the various opportunities to participate in demand flexibility services and demand reduction initiatives.

The costs and benefits of the shift to renewables and the upgrade of the local distribution network will have been shared fairly.

SWOT analysis of current situation in the city with respect to energy generation, demand and distribution

Strengths

- National policy and regulatory efforts are seeking to enable and drive the transition to a smarter energy system (and grid decarbonisation in particular) and to ensure that value which can be earned for providing demand flexibility reflects the value created for the energy system (in terms of avoided short and long-term costs).
- Experience of and engagement with smart energy innovation across the city (building out of Bristol Smart Energy City Collaboration, 2015-17), including public, private, academic and community sectors.
- City Leap initiative and potential to bring extensive expertise and funding to the city to realise smart energy and demand flexibility services, initially in public sector and with council's own tenants.

- Successful community energy initiatives focused on solar PV, with continuing activities to develop new business models integrating communal storage alongside PV installation and to develop large wind turbine, both with a focus on delivering benefits to more deprived households.

- Locally-based PV installation companies with good track records (which have survived the post-subsidy down-turn) and local expertise in wind development and operation.

- Strong understanding, commitment and capabilities locally to ensuring that more vulnerable households are supported, involved and benefitting from the transition to a smarter energy system.

Weaknesses

- Smart meter installation in the city (being led by energy suppliers in an uncoordinated fashion) is behind schedule, delaying consumers' abilities to be rewarded for participating in demand flexibility and peak reduction.

- End of Feed-in-Tariff subsidies for solar PV caused down-turn in market and undermined consumer confidence in business case for solar PV, even though system costs have now reduced.

- Limited availability of granular data to develop clear picture of demand flexibility market and network upgrade needs in Bristol.

- Scale, availability and value of commercial demand flexibility services still in relative infancy, with very little engagement with domestic sector

- Complexity and speed of regulatory and market developments make it difficult for innovators and those seeking to disrupt incumbent approaches.

Opportunities

- Western Power Distribution's (WPD) interest in innovation and engagement with City Leap and with opportunities in the city more widely to test demand flexibility, open up data and support more vulnerable households.

- Timing of Ofgem's price control setting regime (RIIO-ED2) provides an immediate opportunity for city to work with WPD to develop a detailed and well-justified plan for upgrading to a 'network for net zero' by 2030 and putting the case to Ofgem to allow that to be funded.

- City Leap initiative and potential to bring extensive expertise and funding to the city to realise smart energy and demand flexibility services, initially in public sector and with council's own tenants.

- Innovation funding available nationally (typically through competitions) for smart energy and demand flexibility initiatives, with opportunity for local/regional 'smart energy cluster'

- Cost reductions in solar PV now creating attractive investment propositions, particularly when combined with demand flexibility and/or storage at building or communal level.

Threats

- Necessary powers and funding are not devolved to local leadership, undermining the delivery of well-justified and widely supported local plans to achieve net zero.
- Unclear locus for action for leading engagement with WPD and Ofgem or for establishing 'smart energy cluster' could lead to lack of initiative-taking.
- Continued delays and poor delivery of smart meter rollout by national suppliers undermines opportunities to get involved early in innovative demand flexibility services and new business models for local energy generation, storage and supply.
- Vulnerable households are 'left behind' and end up carrying the costs of the transition to net zero while not being supported to enjoy the benefits available from doing so.

Key interventions for Bristol's contribution to decarbonise electricity and establish an electricity 'network for net zero'

Bristol's most significant contribution to decarbonising electricity will be to be actively engaged in the development, deployment and take-up of smarter, flexibility and demand side services (including storage) by households, businesses and public sector organisations across the city. This will support the grid nationally to decarbonise more quickly and at lower cost by enabling greater deployment of variable renewable energy generation like wind and solar. It will also reduce the scale of the requirement for upgrading the local electricity network to cope with the higher electricity demand which heat and transport decarbonisation will create.

Alongside this, the city's electricity consumers (domestic and non-domestic) signing up for genuine 100% renewable electricity tariffs will help to lower the cost of finance for new renewable generation projects by reducing power price and counter-party risk.

Enabling these contributions from the city will require interventions such as:

a. The development of a Smart Energy Cluster for the city, bringing together digital, data analytic, and smart energy capabilities to develop and pilot new smart energy analytics and services, link service providers with potential customers and create a hub for engaging households and businesses with emerging smart energy opportunities.

b. Establishment of specific services to engage, advise and support households (including special provision for more vulnerable households) and businesses to take up appropriate smart energy offers (such as time of use tariffs, flexibility and peak shifting technologies and services etc) as they become available.

c. The development of guidance on what constitutes a 'genuine' 100% renewable electricity tariff, engagement with Ofgem and BEIS to secure tighter controls on the labelling of tariffs as

'renewable', and orchestration of procurement by public sector organisations and larger businesses and householder 'sign up' campaigns by community energy organisations across the city to drive the market towards better practice and maximise the value of the city's buying power to support the growth of renewable energy generation.

The city can also increase the amount of zero carbon electricity generated within the city by developing initiatives to encourage the take-up of the significant potential for roof-top solar PV, particularly in combination with flexibility services such as battery storage and demand response to optimise the value of the generated electricity.

d. A programme to re-boot householder and business understanding of the commercial case for roof-top solar PV without subsidies, explore the potential (with City Leap) to secure the advantages of city-wide bulk procurement of solar PV equipment, and promote the opportunities to integrate solar PV installation with building-by-building heat decarbonisation solutions and with community battery and thermal storage and demand flexibility services.

To ensure the city's electricity distribution network is able to accommodate the increase in demand for electricity (for heating and transport), there will need to be a detailed and geographically specific assessment of the potential impacts and the requirements to upgrade the network and/or introduce smarter operations. This should lead to:

e. The development with Western Power Distribution of a costed upgrade plan to accelerate the upgrading of the network to achieve a 'network for net zero' by 2030.

f. Engagement by WPD and the city with the energy regulator Ofgem to make the case for this accelerated investment.

g. Engagement with Ofgem over whether there remains any justification for continuing upgrade to the gas distribution network (e.g. iron mains replacement) in the context of Bristol's net zero by 2030 target and the associated end to the use of fossil gas.

6 Transport (the end of the internal combustion engine)

Summary

The analysis shows that decarbonising Bristol's transport use by 2030 is potentially achievable with:

- A nearly 50% reduction in car miles and 40% reduction in van and lorry miles travelled in the city (returning them to levels seen in the mid 1980s). This would be driven by a significant effort to shift travel to public transport, cycling, walking (to a modal split more like Amsterdam) and to reduce demand for vehicle use through behaviour and system change, including freight consolidation and use of cargo and e-bikes, car-clubs and 'mobility as a service' initiatives.
- Switching almost all remaining vehicles (125,000 cf 220,000 now) to ULEVs (mainly battery EVs), including an increased number of buses and reduced numbers of cars, lorries, and vans.
- Installation of an extensive private and public EV charging network with an appropriate mix of standard, fast and rapid chargers, a proportion of which are dedicated to car club and shared mobility services so that households do not need off-street parking to access a charged EV.

This will require every new vehicle bought in Bristol from c. 2023 onwards to be ultra low emission, with a more rapid-than-normal scrappage of petrol and diesel vehicles persisting throughout the decade as drivers switch to EVs and more and more people choose not to own cars and instead use a balance of public transport, mobility services like car-clubs, and cycling and walking to get around.

For this to prove achievable (and aside from the over-arching condition that grid electricity has been virtually decarbonised by 2030), the following enabling conditions will need to be put in place:

1. Transport planning, strategy, and budgets for the city and the West of England region and the associated political and business leadership is refocused to achieve net zero emissions as described here, with appropriate additional powers and funding devolved to enable rapid modal shift.
2. An effective public and business engagement programme has been developed and sustained to secure positive buy-in to this public transport, walking/cycling, mobility services and EV-oriented future for the city, highlighting the co-benefits for safety, air quality, health and the public realm.
3. Public transport is cheaper (free for many users), more reliable and more convenient with an integrated ticketing system. Procurement at volume has helped secure lower cost ULEV buses.
4. The city has an extensive EV car club/share scheme and a freight consolidation system.
5. Road space freed up by modal shift is rapidly re-claimed for public transport and non-vehicle travel. Other car-restricting measures (e.g. parking levies and access limits) are introduced.
6. The government continues to provide fiscal and regulatory support for EV take-up and the installation of charging infrastructure so that EVs are cost-competitive to the users and the installation of charging infrastructure keeps pace with and suits the pattern of rapid growth of EVs in the city. The city's public sector has led the way and Bristol has taken a national lead.
7. The job-creating installation of local EV charging infrastructure is subject to effective co-ordination of the relevant stakeholders, with appropriate powers to the local authority, so as to ensure there is an optimised balance of public and private chargers and that EV charging is smartly managed across the city to limit impacts on the electricity distribution network.

6.1 Introduction

To achieve net zero emissions from Bristol's transport use, the city needs to stop using vehicles powered by petrol or diesel and there are essentially two ways to achieve this. These are not mutually exclusive:

1. Switch the city's road vehicle fleet entirely to Ultra Low Emission Vehicles (ULEVs) - principally battery electric vehicles and potentially bio-gas or hydrogen for buses and heavy duty vehicles.

2. Reduce overall car and van mileage through modal shift (towards public transport, cycling and walking) and behavioural and system change (towards freight consolidation, use of car-clubs or 'mobility as a service' initiatives, and a reduced number and length of trips taken by car).

The greater the reduction in vehicles operating and total road vehicle mileage in Bristol that can be achieved through the application of the second 'lever', the lower the burden on electrification will be. To understand the impacts on carbon emissions, electricity demand and EV charging infrastructure associated with different balances between these two levers for decarbonising transport, the study team developed and modelled two scenarios out to 2030 with a baseline derived from Bristol data.[32] These are not intended to be predictions of what will happen in Bristol, but an illustration of the potential costs and impacts associated with making different choices in the way transport decarbonisation is to be achieved across the city. These scenarios and their impacts were assessed for their appropriateness as a basis for a strategic approach for the city to decarbonise its transport use.

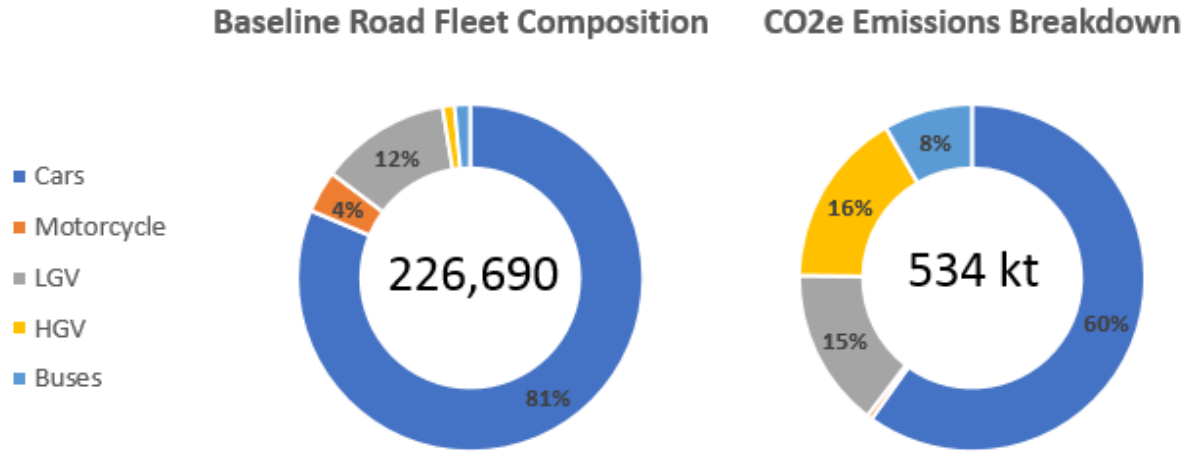
In so doing, the conditions for success required to enable the selected scenario – based on the 'walking right round the issue' approach – were identified. The study team then undertook a SWOT analysis of current conditions in the city with respect to transport and developed a set of proposed priority interventions. These reflect the scale of the transformation and associated effort required to create the conditions for success; they were informed by sector-specific knowledge about the impact of different approaches and an appreciation of national and local factors influencing transport infrastructure and modal choices.

6.2 Establishing a transport baseline and 2030 scenarios

Drawing on the Regen (2019) carbon baseline study from Bristol and more recently released data from the Department for Transport, the study team has established a baseline for Bristol's transport emissions in 2020 (see Figure 13).

32 Further detail on the methodology for this modelling is available in this report's Technical Annex: Transport (in press).

Figure 13: Baseline vehicle fleet and carbon emissions for Bristol 2020



Both scenarios electrify nearly all of the vehicles predicted to be in use in the city in 2030, with a faster rate of electrification in the second half of the timeframe (2025-2030). This reflects the need to install charging infrastructure and takes account of fleet turnover and the current availability of ULEVs for all end uses in the market. As described in

Table 4 below, the 'Technology' scenario focused on electrification of the vehicle fleet with modest modal shift and mileage reduction only sufficient to compensate for the predicted increase in vehicle miles from the 13% increase in Bristol's population by 2030[33]. By contrast, the 'Balanced' scenario adopted a strong approach to reducing vehicle miles undertaken in cars and commercial vehicles particularly in the early phase (2020-2025), resulting from significant modal shift and improved urban freight consolidation and planning. As a result, it was assumed in the modelling that there would be a corresponding reduction in the number of cars and vans operating in Bristol, influencing requirements for EV charging infrastructure.

Table 4: Summary of assumptions for each transport decarbonisation scenario

	Modal shift *% change relative to 2020*		**Electrification** *% share of fleet*	
	2025	***2030***	***2025***	***2030***
Technology	Zero net change in road vehicle mileage	Zero net change in road vehicle mileage	LDV - 25% ULEV HDV - 20% ULEV Bus - 40% ULEV	LDV - 90% ULEV HDV - 75% ULEV Bus - 100% ULEV
Balanced	36% net reduction in car mileage and 30% net reduction in commercial vehicle mileage	48% net reduction in car mileage and 40% net reduction in commercial vehicle mileage	LDV - 25% ULEV HDV - 20% ULEV Bus - 40% ULEV	LDV - 90% ULEV HDV - 75% ULEV Bus - 100% ULEV

The 48% net reduction in car mileage by 2030 in the Balanced scenario will require:

33 Regen (2019) used historical growth rates in population and vehicle miles to predict a 3.8% increase in vehicle miles by 2030 based on a 13% increase in the city's population. It should be noted that this is significantly lower than the increase assumed in Joint Local Transport Plan for the West of England Region.

- Modal shift to more efficient and lower carbon forms of road transport such as bus and motorcycle **and** a shift to active transport such as walking, cycling, scooters and other micro-mobility options.
- A shift away from private car ownership towards EV car clubs and car sharing, particularly for those without off-street parking, with responsive re-allocation of road space to avoid encouraging car journeys by space freed from modal shift.

The latest Joint Local Transport Plan highlights some transport trends over the past 10 years, and it is evident that across the West of England region there are already positive changes to how people are moving around; bicycle trips have increased 10% year-on-year, the number of bus passenger journeys has increased by more 30%, and rail passengers (since 2008) have increased by more than 50% (Travelwest, 2019).

The 40% net reduction in commercial vehicle mileage by 2030 can be achieved through:

- Fewer journeys due to freight consolidation and smarter logistical planning, as well as modal shift to bicycle freight options, including cargo bikes and e-bikes.

6.3 Scenario results – comparing approaches

Both scenarios deliver significant carbon reductions: Table 5 provides a summary of the impacts while further detail can be found in the figures below.

Table 5: Summary of scenario results

		Baseline (2020)	**'Technology' scenario** (2030)	**'Balanced' scenario** (2030)
Mileage	Car mileage (million miles)	1,078	1,078	560
	Total vehicle mileage (million miles)	1,443	1,443	858
	Net % mileage reduction		0%	40.5%
Fleet	Number of ULEVs	802	204,531	124,515
	Number of Petrol and Diesel vehicles	225,888	22,159	12,401
	Total fleet size	226,690	226,690	136,916
Power	Annual electricity demand from EVs (GWh)	1.4	373	250
EV chargers	Public chargers		2,334	1,261
	Public charger cost (£)		26.3m	14.3m
	Total chargers[34]		156,289	95,127
	Total cost over 10 years (£)[35]		244m	175m
Air pollution	NOx (kt)	291	38	24
	NOx emission reduction (%)		87%	92%
	PM2.5 (kt)	48	45	25

34 Including private residential chargers and depot/business charging for buses and commercial vehicles

35 Includes both cost for public chargers and private costs to residents, business and bus operators for private chargers. It does not include possible costs associated with any resulting need to upgrade the local electricity distribution network (see Section 5 x reference)

	PM2.5 emission reduction (%)		8%	37%
CO_2 emissions	Emissions after modal shift ($ktCO_2e$)	534	534	376
	Emissions reduction from modal shift (%)		0%	30%
	Total emissions ($ktCO_2e$)	534	94	62
	Total emissions reduction (%)		82%	88%

Figure 14 shows the annual carbon emission reductions achieved in each scenario. The Balanced scenario represents an 88% reduction on 2020 levels, leaving a residual 62 $ktCO_2e$. As shown in Table 5 above, there are also significant air quality benefits associated with both scenarios, with a 92% reduction in NOx emission seen in the Balanced scenario.

Figure 14: Bristol's annual CO2e emissions in the two scenarios with electricity decarbonisation sensitivity

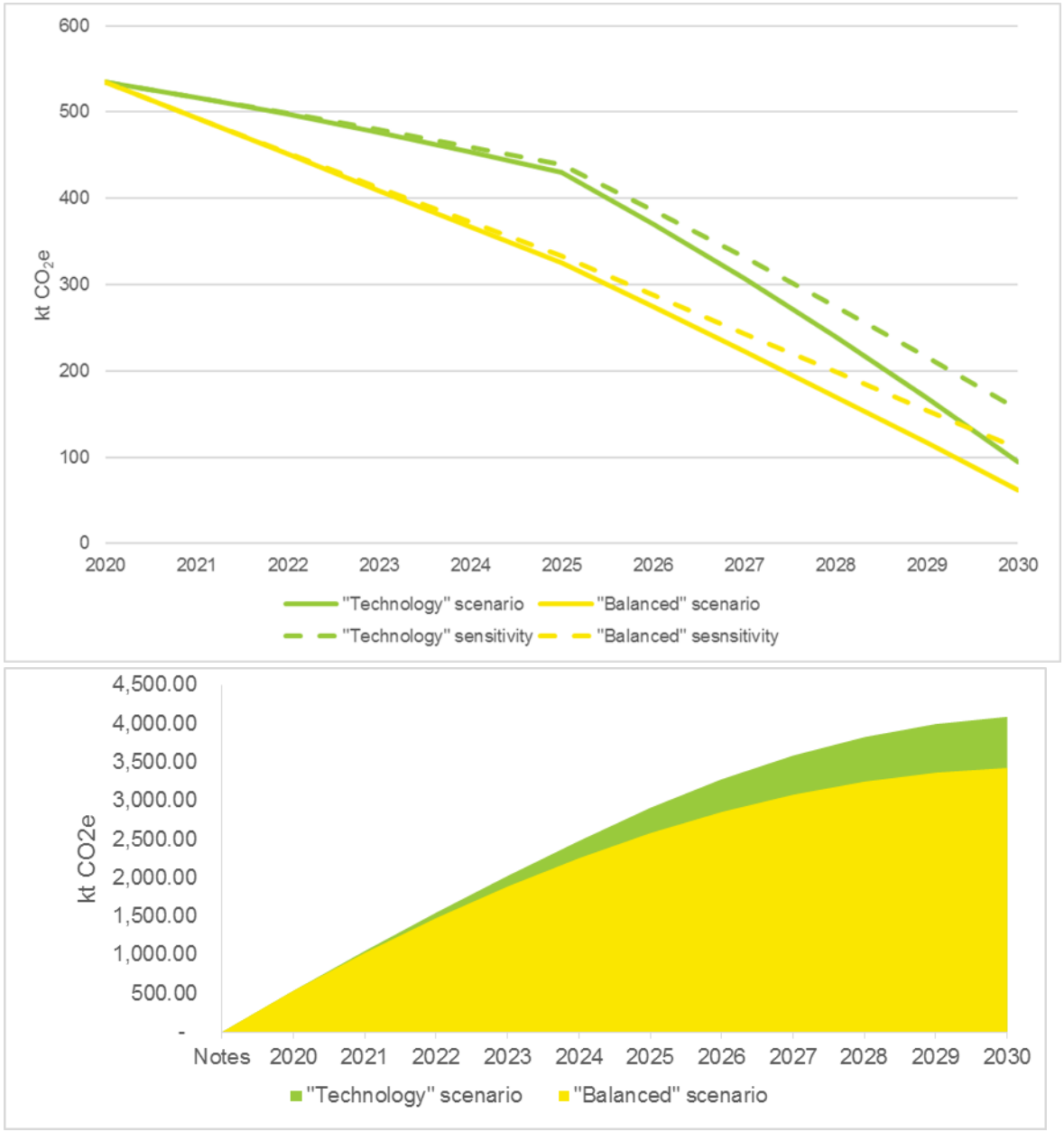
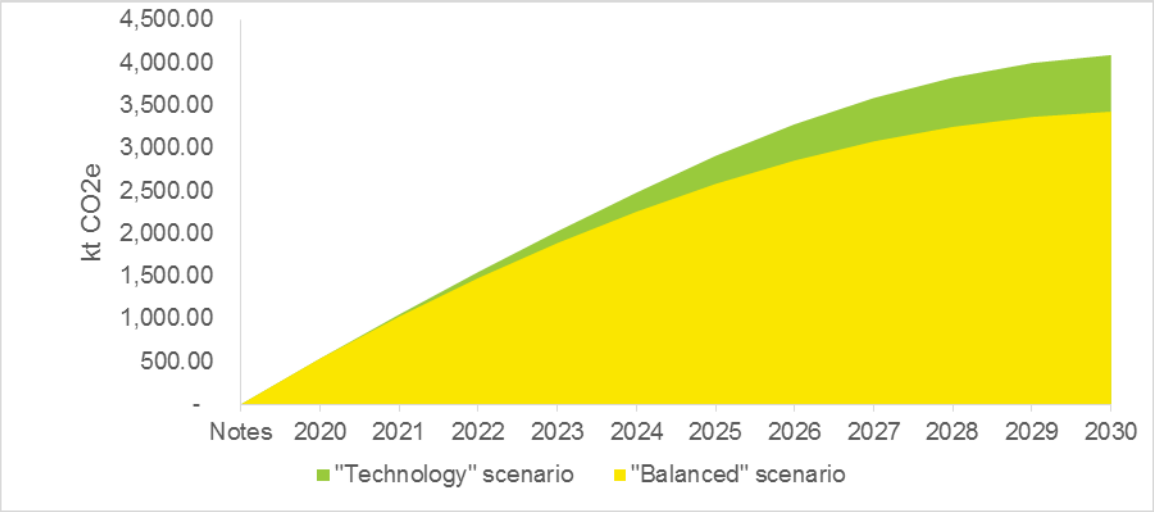


Figure 14 also shows the impact on emissions if grid decarbonisation progresses at the rate anticipated by BEIS' most recent projections for electricity emissions intensity (EEP 2018 in Figure 1) rather than the 'Bristol 2030 requirement' - the annual emissions for the 'Technology' and 'Balanced' sensitivity scenarios by 2030 are about 70% greater at 155 and 110 $ktCO_2e$ respectively.

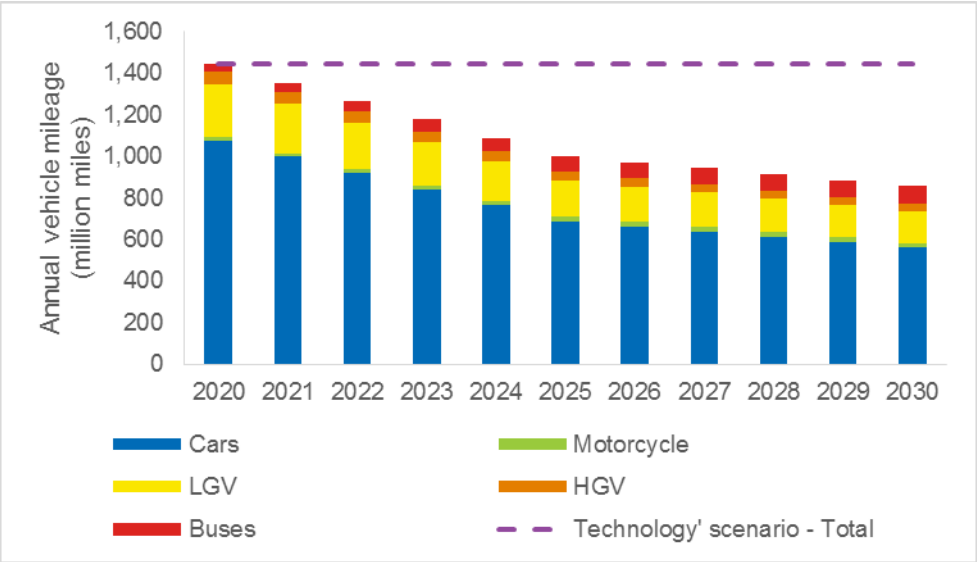
It is also important to consider the cumulative emissions over the 10-year period to 2030. Figure 15 shows that the modal shift assumed in the 'Balanced' scenario results in cumulative emissions savings of 16% or 650kt by 2030 compared to the 'Technology' scenario – roughly equivalent to an extra year of road transport emissions at 2020 levels.

Figure 15: Bristol's cumulative road vehicle CO_2e emissions in two scenarios



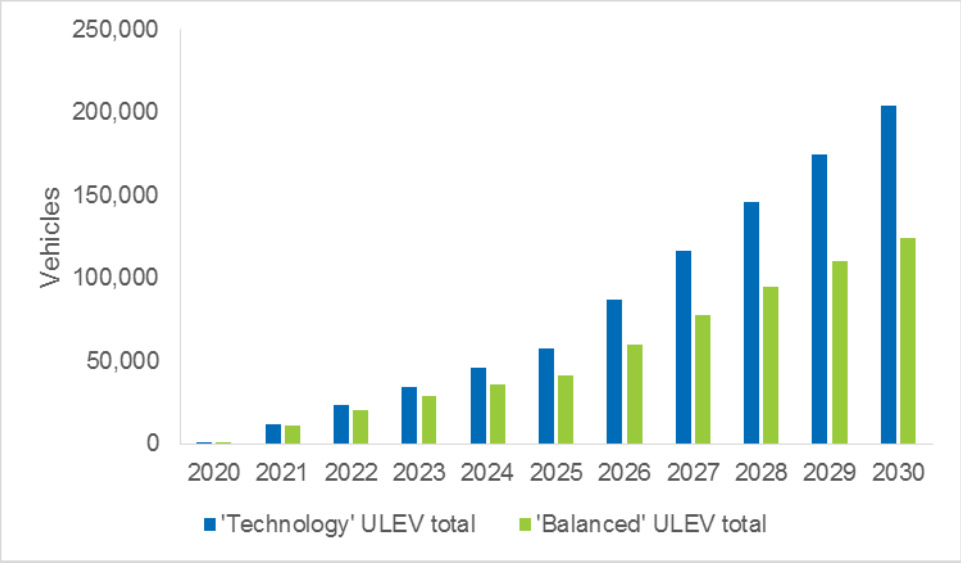
The most striking difference between the two scenarios is the annual vehicle mileage (Figure 16). In the 'Technology' scenario, there is no net modal shift with total vehicle mileage remaining the same. By contrast, in the 'Balanced' scenario there is a significant reduction in car mileage as people switch to other modes and emerging car usership models support a transition away from car ownership. LGV and HGV annual mileage also decreases between 2020 and 2030 while the mileage of motorcycles and buses increases.

Figure 16. Annual vehicle mileage in 'Balanced' scenario (million miles)



This reduction in the size of the vehicle fleet in Bristol has an important impact on the scale of electrification required by 2030 and associated electricity demand. In the 'Technology' scenario, the number of EVs operating in Bristol increases to over 200,000, while in the 'Balanced' scenario there are 120,000 (see Figure 17).

Figure 17. Annual number of ULEV vehicles operating in Bristol in each scenario

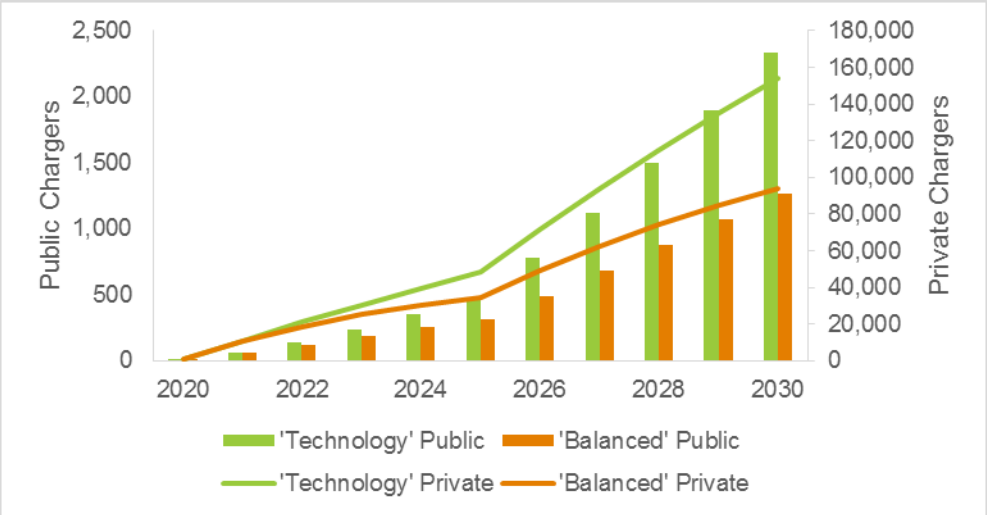


The annual electricity demand resulting from the modelling of these vehicle fleets is 370 GWh in 2030 in the 'Technology' scenario and 250GWh in the 'Balanced' scenario. At 2017 total electricity consumption levels in Bristol, the latter represents a 13% increase in demand. Assuming EV charging was all 'smart' and actively managed to avoid coincident peak demand, this level of increase should be manageable within the current capacity of the local electricity distribution network (though see comments on electric heating impacts of network capacity in Section 5).

The number of chargers required in the 'Balanced' scenario are expected to be significantly lower than in the 'Technology' scenario, reflecting the fewer EVs operating in the city as a result of

effective modal shift. As shown in Figure 18, charger requirement will increase steadily and then ramp up from 2025 as measures to support EV adoption take effect and fleet turnover introduce a significant share of EVs. Public chargers are required to support EV drivers without private home charging, which is expected to increase as a share of total electric car owners.

Figure 18. Private and public charger requirements in each scenario



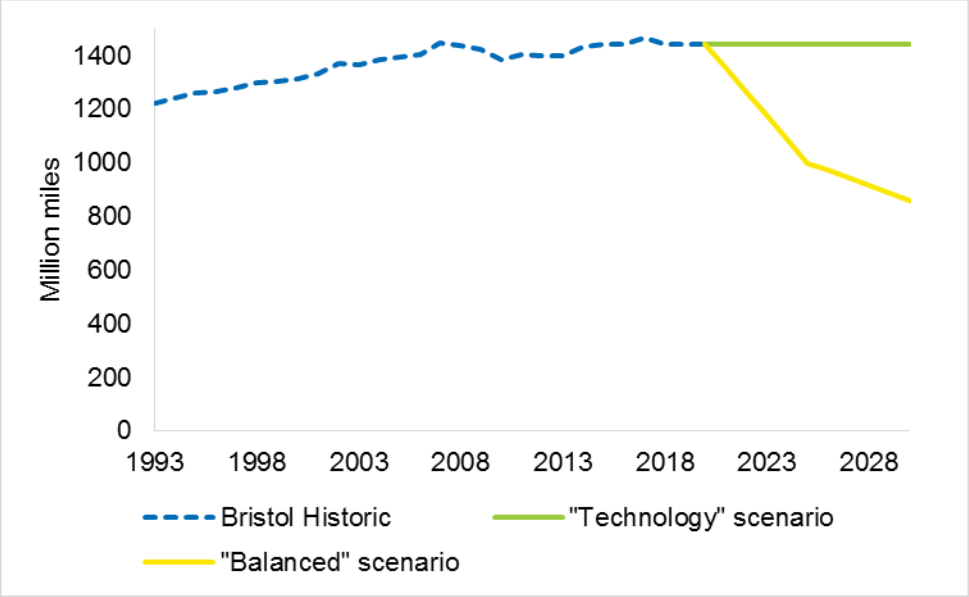
6.4 The scale of the challenge

The scale of the challenge associated with modal shift and demand reduction anticipated by the Balanced scenario is illustrated by Figure 19, which represents a sharp reversal of the historical trends. It points to a modal split for travel, particularly the dominance of public transport, cycling and walking, that is akin to Vienna, Berlin, Copenhagen or Amsterdam.[36] The projected vehicle mileage in Bristol in 2030 in the Balanced scenario is about the same as the levels seen in the city in the mid-1980s.[37]

36 See https://www.pbl.nl/sites/default/files/downloads/PBL-2016-Cities-in-Europe-2469.pdf pages 26 - 27

37 Based on an assumption that growth in vehicle miles in Bristol broadly followed the same growth rates as national growth as documented in table TRA0101 at https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra

Figure 19. Bristol total annual vehicle mileage



The Balanced scenario assumes a rate of 'giving up' of car ownership of an average of 9,000 households per year over the decade. Even once people have reduced their car usage, a key challenge will be to encourage a shift away from car ownership. Households with two cars are more likely to respond and scrap one of their cars. This scenario also assumes a significant and rapid shift to new cars and vans being EVs, with an assumption that by c. 2023 nearly all new vehicle registrations are plug-in. While the sales of EVs are on the rise across the country (2.2% of all new vehicle registrations in 2018, about twice the level in 2016), they still represent a very small proportion of the total fleet - around 0.4% in Bristol. This degree of electrification would be unprecedented in the UK, but changes on the scale have been seen elsewhere. The global leader in electric vehicle adoption is Norway, where over 60% of new registrations are plug-ins and almost 10% of the total fleet is now BEV or PHEV[38]. The rate of this change has also been impressive, with the EV fleet increasing from just over 3,000 in 2010 to almost 350,000 today[39]. The scale and rate of installation of charging infrastructure required in both scenarios are also unprecedented.

6.5 Aiming for the Balanced Scenario

There is a strong case for adopting a strategy that is broadly aligned with the 'Balanced' scenario:

i. The carbon emission reductions delivered by modal shift in this scenario are not fully dependent on full grid electricity decarbonisation.

ii. The scale and cost of the EV charging infrastructure is significantly lower (£175m vs. £244m), more likely to prove feasible to deliver in the timescale, and more suited to a city where an estimated 40% of the housing does not have off-street parking.

38 The Road Traffic Information Council (OFV), Norway. https://ofv.no/

39 The Norwegian Public Roads Administration. https://www.vegvesen.no/en/home

iii. The impact on Bristol's annual electricity demand is more modest at 250 GWh (equivalent to 14% of Bristol's current electricity demand) compared to 373 GWh (equivalent to 20% of Bristol's current electricity demand). Therefore, the associated requirements for electricity distribution network reinforcement and additional zero carbon electricity generation is lower.

iv. The burden on electrifying the vehicle fleet is reduced, with significantly fewer EVs operating in the Balanced Scenario . External environmental costs related to EV and battery are also avoided.[40]

v. The lower number of vehicles will provide greater improvements in air quality through further reductions in NOx and non-exhaust particulate matter pollution.

On this basis, the study team has considered the conditions for success required for this scenario, undertaken a SWOT in relation to current conditions, and proposed interventions designed to set Bristol on a path towards this version of virtually net zero transport by 2030.

6.6 Decarbonising Bristol's transport: conditions for success

The Balanced Scenario demonstrates the need for two key outcomes to be achieved by 2030; a **significant reduction in vehicle use** through modal shift and a comprehensive **switch from petrol and diesel to ULEVs** principally battery electric vehicles.

To understand the conditions required for success in achieving these outcomes, the study team has applied the 'walking right round the issue' systems model (see Figure 2). In general, transport planning in the city and across the West of England region will need to have switched its focus from reducing congestion and accommodating increasing demand to one driven instead by the achievement of a net zero transport system, requiring significant modal shift and road mileage reduction and a comprehensive switch to an electric vehicle fleet with supporting charging infrastructure. Other conditions for success are explored in the table below:

40 While these emissions would not count in Scope 3, they are relevant considerations in the context of a global effort to reduce greenhouse gas emissions. See for example https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf

Technical – engineering side	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
Modal Shift				
• Range of new modes of transport. • Technology supporting intermodality • Safe and attractive city/local centres avoiding use of cars	• Strong political support / local leadership • Transport engineering and design expertise • Coordination between relevant actors & stakeholders	• Finance for infrastructure and public transport provision • Affordable/cost-effective mobility alternatives • 'Car-free' developments	• Adequate powers for local authorities • Strong push/pull measures • Financial incentives to switch mode • Support for alternatively fuelled vehicles, including appropriate infrastructure (Links with 'electrification')	• Achievement of widespread travel behaviour change – widespread acceptance and understanding of the need to shift (from car) • Shift in beliefs/values – e.g. car-'freeness' 'Buy-in' to local improvements
Electrification				
• Strong EV performance • Available and reliable charging infrastructure with enforced smart charging and use of V2G • Decarbonised electricity supply	• Coordination across city/region on charging infrastructure • Open data flows • After-market servicing capacity	• Availability of new EVs • Upfront cost parity with ICE • Stable and strong Residual Values (RVs) • Diverse usership models • Appropriate charging solutions • Mature second-hand market • Availability of after-market services	• Public sector coordination with adequate powers for local government • Strong fiscal support for EVs • Effective local push/pull measures • Common method of EV charging access & payment + enforced smart charging • Market regulation to ensure safety and consumer protection	• Wide-spread acceptance and understanding of EVs – including EV market, performance, costs and charging • Expectations regarding charging

6.7 SWOT analysis summary

- **Modal Shift**

Strengths

Bristol is seen as a proactively green city, with strong support from the public on environmental issues. There are vocal anti-car groups and a higher proportion of trips use sustainable forms of transport than in other areas. There has already been investment in the MetroBus rapid transit scheme as well as walking and cycling routes. Cycling in particular is well supported in Bristol, with organisations such as Sustrans, Lifecycle UK and Better by Bike being active in the region. Bristol was the first Cycling City in the UK and recognised as one of Europe's most cycling friendly destinations, with rapidly increasing numbers of cyclists. There is also an emergence of new modes of transport such as e-bikes and cycle sharing schemes as well as transport planning tools and strategies such as Sustainable Urban Mobility Plans (SUMPs), the 3rd Joint Local Transport Plan (JLTP3) and the Bristol Local Transport Strategy.

Weaknesses

As with most cities, the current infrastructure focus is on private and commercial vehicles. Traffic planning and engineering skills focus on car flow and reducing congestion. Bristol is a major commercial centre in the region which means not only a high amount of commuter traffic but also a requirement for commercial and freight movements, especially with Bristol Port, Avonmouth and the Temple Quarter Enterprise Zone. Any transport strategy needs to consider the whole system and trips with origins/destinations outside the city. There is some reluctance to use other modes of transport – for examples, buses in Bristol are viewed as unreliable especially at peak times.

Opportunities

New and future developments (both residential and commercial) can be designed with integrated walking, cycling and public transport. There are emerging technologies, not just types of transport (such as e-bikes), but also models of transport management and new mobility services that make public transport more attractive and reliable. There are also significant co-benefits to modal shift, including improved health from more walking and cycling. The existing railway service is being improved, with more regular services from January 2020 and there is a plan to reopen the Bristol – Portishead line.

Threats

There are local geographical constraints to the implementation of some of these alternative modes of transport - water courses, narrow streets and steep hills. Local infrastructure is also vulnerable to climate change related incidents such as floods and sea level rise. The rail network has been impacted by age and low capacity of rolling stock and the increased demand for rail travel has led to overcrowding. Congestion on Bristol's roads can have a financial impact on businesses and workforces in the area, it can also affect the reliability of public transport, leading to a reduction in its appeal. The perception of the safety and security of active travel often holds people back from using this form of transport.

- **Electrification**

Strengths

National: With global improvements in EV performance and falling costs, increased customer choice and wide-spread rollout of charge points - public opinion and sales are shifting towards electric vehicles. Smart charging and V2G trials are also in progress which will allow for a more flexible and reactive grid.

Local: In the public and private sector, Bristol is a progressive and environmentally engaged city, while the DNO is keen to support a shift to electrification of the transport system, evidenced by its innovative project 'DC share' and a new monitoring tool. Go Ultra Low West is also helping to support capacity building in the region and has activities aimed at improving the popularity of EVs.

Weaknesses

National: Recent supply constraints coupled with increasing demand have resulted in significant waiting times and delays across much of the passenger car EV sector. There is also concern that battery supply may struggle to keep pace with the rapid take-up of EVs that is expected[41]. The van and truck EV market is less mature and so there is less choice than for cars, and across the whole EV market there are knowledge and skill gaps in for sales and repair sectors.

Local: Bristol's public charging network is developing, although specific plans for further improvements have not yet been laid out.

Opportunities

National: There is an opportunity to become a world leader in EV technology, manufacture and utilisation. The Government will need to take powers through AEVA on EV charging to ensure reliability and maintenance standards and to mandate a common access method. The government also recently announced a £400 million investment in electric vehicle charging infrastructure.

Local: There is a high level of public/stakeholder interest and council support for climate change related activities and electrification of Bristol's fleet presents opportunities for job creation.

Threats

National: Net-zero Bristol is largely reliant on the UK achieving significant reductions grid carbon intensity. Brexit may impact EV availability and hinder innovation through uncertainty, reduced investment and interruptions to the supply chain. Breaches in the safety of the vehicle or protection of private data could also disrupt EV uptake. With the transition of the car industry, job security in traditional industry related jobs such as mechanics are at threat, while there is currently a lack of skilled technicians. With the rapid shift to new technology there is a risk that market development will outstrip policy, leaving the market vulnerable with a lack of supporting services/infrastructure.

Local: There is a risk that with a rapid increase in demand for EVs and an uncoordinated approach that the local grid will not cope. There will be high peak time demand. The DNO will need to be active and take control of the situation in order to be able to manage the supply and demand. Job losses in the car industry and those supporting sectors is a potential risk for the local economy.

[41] The Brussels Times, Battery shortage forces Audi Brussels to slow down production. https://www.brusselstimes.com/brussels/55536/battery-shortage-forces-audi-brussels-to-slow-down-production/

6.8 Key interventions

Ultimately, the decarbonisation of the road transport sector will be achieved through the electrification of the road fleet in combination with a decarbonised electricity supply. However, as demonstrated by the **'Technology'** and **'Balanced'** scenarios, the burden on the electrification of the vehicle fleet can be lightened by incentivising a shift away from private car use and towards public transport, walking and cycling. In doing so, a wide range of co-benefits can also be realised, including reduced congestion and improved public health.

The 'Balanced' scenario presents a route to net-zero transport in Bristol, while Section 6.6 outlines the conditions that will be necessary and reviews how well Bristol and the UK are placed to support the necessary transformation of Bristol's transport sector. Building on this analysis, we have developed a shortlist of **nine priority interventions** for Bristol to focus on as the 'first next steps'. These are key actions needed to kick start Bristol along the road to net zero, acknowledging the current state of play and areas where significant progress is required or where emissions reductions can be achieved in the short term. In most cases the interventions overlap with existing objectives or strategies that have been referenced in local and regional plans, but in all cases, we have ramped up the level of ambition in reflection of the task at hand. While many of these interventions may seem unrealistic, they are both necessary and achievable, given the right level of support from government, buy-in from the local population and effective engagement with the private sector.

It is important to note that there are significant interactions between interventions and that they are almost all complimentary with one another. For example, while it is important to encourage more people to use public transport, the service should also be made more reliable, which will in turn support further use of the service. A summary of the proposed interventions is provided in the text below and in Table 7.

Modal Shift: In the **'Balanced'** scenario that has been detailed in Section 6.5 of this report, significant levels of modal shift have been envisaged: 48% net reduction in car mileage and 40% net reduction in commercial vehicle mileage by 2030, relative to 2020. While there are numerous challenges and threats, Bristol is as well placed as any other city in the UK to overcome these and make significant strides to achieving net-zero transport and take full advantage of the wide-ranging co-benefits.

The interventions summarised below are highly complementary and have a common objective – to reduce the appeal private car use in favour of more sustainable modes. A **subsidised or free public transport system** would increase the attractiveness of using public transport, as already demonstrated by fare cuts in West Midlands[42]. while **an integrated transport ticketing and information solution** would further support the use of public transport as part of seamless door to door journeys. However, it is vital that the highway is managed effectively to ensure that adequate prioritisation is given to public transport so that buses can continue to operate reliably as usage

42 Arup – Greener Journeys. 2018. https://greenerjourneys.com/wp-content/uploads/2018/11/Greener-Journeys-Arup-FINAL-REPORT.pdf

increases, through **redistribution of highway space**. Highway upgrades have already been shown to increase bus patronage on certain West Midland corridors[42].

Cross-Cutting: Modal shift and electrification are intrinsically linked, with electrification required to realise the full emissions benefit of modal shift, while modal shift is able to reduce the burden on electrification. Both these measures require significant political leadership and public support to send strong market signals for companies to respond to. As a result, most interventions in the transport sector will have a direct or indirect impact on both of these measures. However, **information and awareness raising campaigns**, **public sector in Bristol leading by example** and implementation of one or two **Bristol freight consolidation centres** are seen as priority interventions that are particularly cross-cutting.

Electrification: As already discussed, a significant share of the vehicle fleet operating in a city must be ULEV for a net-zero target to be achieved. In the 'Balanced' scenario we have envisaged almost 90% of the total vehicle fleet operating in Bristol as ULEV by 2030: LDV - 90%, HDV - 75%, and Bus - 100%. This level of ULEV penetration into the fleet represents a significant increase on current uptake rates to a level that has not yet been seen in the UK. There needs to be a step change in national government policy and financial support for electric vehicles, and a considerable ramp up in EV manufacture. We have seen the majority of vehicle manufactures making commitments to an electric future and we can expect them to respond to demand, however the Government needs to strengthen and provide certainty over their policy and tax incentives for electric vehicles. In their assessment of the UK's progress towards their 'net zero' 2050 pledge, the British Vehicle Rental & Leasing Association (BVRLA) concluded the Government needs to supercharge its electric vehicle strategy[43]. **Deployment of EV charging infrastructure**, **ultra-low emission bus procurement** and **deployment of a city-wide electric car share scheme** are nearer-term key actions that Bristol City Council could take to lay the foundations and support significant ULEV adoption through to 2030.

6.9 High Level costing

For the road transport sector in Bristol to achieve significant emission reductions in line with a net zero 2030 target, considerable investments will need to be made by the public and private sector alike. However, this should come of no surprise to Bristol or the wider West of England region with the latest Joint Local Transport Plan (JLTP) costing its plans for transport improvements and schemes at £10bn over twenty years (though these plans are largely designed to accommodate forecast traffic growth rather than achieve net zero carbon emissions).

We have looked at the nine priority interventions that have been recommended as part of this report and developed a high-level bottom up costing that estimates total investment between 2020-2030. The total investment across both the public and private sector is £1.3 - 2.1bn over 10 years. The cost estimations do not consider discounting, nor do they include any revenue that result from the activity. Therefore, this value is likely to overestimate the real investment. Over 90% of this estimate comes from three interventions, 'Infrastructure supporting measures' and 'Free public

[43] Government's Road to Zero Strategy is falling short. https://www.bvrla.co.uk/resource/governments-road-to-zero-strategy-is-falling-short.html

transport initiative', and 'Ultra-low emission bus procurement' – Each of which would likely require significant public sector investment. Other interventions such as a 'Consolidation centre' and 'City-wide electric car share scheme' may require coordination or encouragement from a public body such as BCC, but the costs would most likely fall on the private operating companies, with upfront cost earned back over a period of time through traditional business models. Ongoing operating costs and revenue have not been accounted for.

Table 6 below presents the nine interventions, the cost estimate along with an indication of whether it would require public or private investment, and a description of the costing methodology.

Table 6: Rough cost estimates of nine interventions to enable transport decarbonisation

Intervention	Total cost estimate (2020-2030)	About	Source
1. Infrastructure supporting measures (Modal shift)	**£100-200m** Public sector investment	Highways are BCC's biggest asset at a total value of £5bn, and cost £7m to maintain each year. This cost estimate includes redistribution and prioritisation of highway space to encourage walking and cycling (~£5m pa, Ashden) and the use of the bus. Specific actions may include traffic light priority, lane priority, cycle lanes/tracks and dedicated busways (GreenerJourneys). It does not include large infrastructure projects like a mass transit system, which is estimated to cost £4bn in the Bristol Transport Strategy.	Bristol transport strategy Ashden Greener Journeys
2. Free public transport initiative (Modal shift)	**£0.78-1.5bn** Public sector expenditure	This cost estimate is derived from a high-level calculation of foregone annual bus fare revenue. It assumes the number of fares increases between 2020-2030 in line with the increase in bus miles estimated in the 'Balanced Scenario' (136%). The high end of the estimation assumed 100% of fares are subsidised, while the low estimation assumes 50% are subsidised. High range: 100% fares are free. 2020 - 42.3m (annual bus journeys in Bristol, DfT - BUS0109): 2030 – 99.8m journeys * £2 (average bus fare) = **£1.5bn**	DfT Tallin

		Low range: 50% fares are free. 2020 – 21.2m (annual bus journeys in Bristol, DfT - BUS0109); 2030 – 49.9m journeys * £2 (average bus fare) = **£0.78bn**	
3. Integrated Bristol transport ticketing solution (Modal shift)	**£25m** Shared cost investment between public sector and PT operators	An EU study on integrated ticketing systems highlights the requirement for high levels of investment. Evidence from other implementation case studies suggests costs in the region of ~£25m. Yorcard = gross cost £12.6m (Notts) Pop Card = £25m investment (Notts)	EU study Notts feasibility
4. Information and awareness raising campaign (Cross-cutting)	**£20m** Primarily led by public expenditure, although scope for contributions by businesses.	This intervention would need to go beyond what was delivered by the Go Ultra Low west scheme, which received funding of £7 million. The campaign would need to cover modal shift, electrification and engage businesses and the public. The biggest transport related campaigns usually focus on road safety. In 2013, DfT's budget for Road Safety campaigns was £3.5m, with expenditure as high as £18m in 2008/09.	DfT campaign
5. Bristol public sector leading by example (Cross-cutting)	**£15m** Public sector investment	This cost estimate assumes a public sector fleet of around 500 vehicles and an average EV cost of 30k. It assumes a residual value of current fleet of £0. Council = 400 vehicles 1 hospital = 136,688miles = ~15 vehicles. Assumed 100 vehicles across hospitals and university in Bristol. 500 vehicles * £30k = **£15m**	Nissan electric van
6. Bristol Consolidation Centre and increased local procurement (Cross-cutting)	**£500k** This could be a shared cost initiative between the local authority	Consolidation centres have achieved up to an 85% reduction in delivery trips for participating businesses. It is expected that at least two would be needed to deliver a significant reduction (40%) in freight miles in Bristol. Examples from feasibility studies indicated development costs of around	London feasibility study Freight Options for Oxford

	and participating businesses	**£100k.** Up to 10 delivery vehicles would be required, costing an additional £300k In Norwich, the Norfolk County Council contributed **£123,500** from the CIVITAS SMILE project budget which covered set up costs and promotion of their consolidation centre (London Study). Another feasibility study (Oxford) estimated first and second year marketing and development costs of **£80K-£100K** marketing and development costs while operating costs are **£250k pa.** 10 vans @ ~£30,000 (Voltia/Nissan Vans) = **300k**	Phase 1 Report
7. EV charging infrastructure deployment (Electrification)	**£15m** Shared cost investment between public sector and EV charger companies	This cost estimate has been made by considering the number of public chargers expected to be needed to support a complete EV fleet and the average cost of chargers. (This is assuming fast rather than rapid chargers) ~£15m for 1200 public chargers with no local authority grant.	
8. Ultra-low emission bus procurement (Electrification)	**~£300m** Private investment co-financed with public grants.	This cost estimate assumes a replacement of current bus fleet to EV and procurement of additional fleet. It is assumed that 25% of the additional bus miles predicted by 2030, can be taken up by the existing bus fleet. This results in 100% increase in buses (136%*75%). Current fleet = 400 buses Additional fleet = 400 buses £360,000 per bus * 800 buses = **£288m** A share of this cost may be included within the free public transport investment intervention above. New supporting infrastructure estimated to cost **£10-20m**. This includes depots and interchanges. Other supporting infrastructure such as bus stops and signage are covered in	Greener Journeys

		the infrastructure intervention above. New enclosed bus station building in Mansfield cost £8.5m (GreenerJourneys). Charging infrastructure costs are covered in the EV charger intervention above.	
9. Deployment of a city-wide electric car share scheme (Electrification)	**~£25m**	This cost estimate includes the procurement (lease) of 1,000 new electric cars along with charging infrastructure and scheme set up costs. Lease rates for eGolf = £2300 pa BCH. 2300 * 1000 = **£2.3m pa** Set up and marketing = 500k £20 marketing per new member (Ashden) * 25,000 (~10% of London ZipCar members) Charging infrastructure costs are covered in the EV charger intervention above, but would represent about £5m.	Lease Ashden Zipcar
Total	**£1.3 – 2.1bn**		

Table 7: Summary of Interventions

Intervention	Overview	Actors	Benefits	Cost to BCC
1. Infrastructure supporting measures (Modal shift)	Redistribute highway capacity away from the private car through a variety of actions. These are likely to include removal of on-street car parking spaces and increases in parking charges where parking in city/local centres remains; introduction of workplace parking levies; tightening of parking standards for new developments; minimising the provision of allocated parking in residential developments (encouraging car-free living); reallocation of road space to dedicated bus, taxi, alternatively fuelled-vehicle and cycle lanes and areas of pedestrianisation; and access restrictions for private cars on certain roads or areas of the city.	BCC, Bus Operators, Sustrans, Road User Groups, Local Businesses	Attract more public transport usage, increase reliability of bus services (i.e. reduced congestion/dedicated lanes), lock-in of benefits from reduced vehicle mileage	££
2. Free public transport initiative (Modal shift)	Provision of free or heavily subsidised public transport travel for Bristol residents through franchising of bus services.	BCC, WECA, Public Transport Operators	Increased modal shift to public transport, improved mobility for all citizens. Ability to work with public transport operators to help design optimum timetables, ensuring seamless trips and encouraging use further.	£££
3. Integrated Bristol transport ticketing solution (Modal shift)	Implementation of an integrated ticketing solution and single access point for information and journey planning, enabling users to plan and pay for journeys across a range of transport modes. Linked to an app/web service providing supporting service information and planning tools to facilitate seamless journeys.	BCC, WECA, Public Transport Operators, Bike Share, Car Clubs, Taxi Operators	Encourage shift away from private cars for journeys in the city through improving access to public transport services.	£
4. Information and awareness raising campaign (Cross-cutting)	Long-term information, awareness raising, and education campaign. Part of a broader initiative raising awareness of the net zero target including the other sectors. Incorporating a range	BCC, PR / Marketing Company, Local community &	Local buy-in to net zero vision and support to measures	££

	of actions, including advertising, local events showcasing alternatives, incentives to trial alternatives etc.	environmental groups, Businesses		
5. Bristol public sector leading by example (Cross-cutting)	Public sector institutions addressing their own transport emissions, committing to 100% ULEVs by 2030, promotion of sustainable travel by employees and review of supply chain and logistics operations.	BCC and other local public institutions	Contribute directly to emission reductions and support wider action in city. Lower operation/maintenance costs for fleets.	££
6. Bristol Consolidation Centre and increased local procurement (Cross-cutting)	Implement a local consolidation centre that uses ULEVs or bicycles for deliveries – private companies and/or public sector institutions in the city. Local procurement of goods.	BCC, WECA, Delivery & Logistics Companies, Local Businesses	Reduced vehicle mileage in the city and increased ULEVs/bicycles. Increased visibility and awareness of ULEVS/bicycles. Reduction in goods' carbon footprint.	££
7. EV charging infrastructure deployment (Electrification)	Support given to the deployment of charge points within the city, considering provision for residential developments (home charging), public charging (workplaces, trip destinations etc) and those aimed at car clubs, car sharing and EV taxis.	BCC, WECA, UK Govt., EV charging companies, WPD, Local Business	Support a growing EV fleet and encourage further uptake	£££
8. Ultra-low emission bus procurement (Electrification)	Procurement of zero carbon buses to ensure 100% of the bus fleet is ULEV by 2030.	BCC, WECA, Bus Operators & Manufacturers, WPD	Reduced emissions from buses, increased visibility and promotion of ULEVs	££
9. Deployment of a city-wide electric car share scheme (Electrification)	Support given to the development of a city-wide EV car share scheme, providing access to ULEVs to all residents.	BCC, WECA, Car Sharing Operators, EV charging companies	Reduce vehicles operating in Bristol, manage parking demand and support ULEV roll-out	0 - ££

7 Decarbonising waste: avoiding waste and an end to burning plastic

Summary

This study only considers the disposal of waste generated by the homes and business premises located in the city. It does not address the emissions associated with the production of materials which subsequently become waste or with emissions avoided through reducing, reusing and recycling (thus not creating more primary material). Nor does it include waste imported to the city for disposal.

The analysis shows that significantly decarbonising Bristol's waste stream by 2030 is potentially attainable with:

- Reduction of all waste with particular effort to reduce plastic and textile use and food waste (all of which lead to reduced Scope 3 carbon emissions and wider environmental benefits).
- The achievement of at least the 65% recycling target set by the EU's Circular Economy package across domestic and commercial waste created by the city (cf c.45% now for household waste).
- Removal of plastic films and other unrecovered plastic (derived from fossil fuels) from the waste stream, to be recycled or treated in a way which does not release carbon emissions to the atmosphere.

Based on experience from cities in other countries which are securing much higher recycling rates than Bristol, for this to prove achievable the following enabling conditions will need to be put in place:

1. A comprehensive and sustained communications and engagement campaign to educate and enable behaviour change across both domestic and business sectors, with particular focus on areas with high levels of waste production and low levels of reuse and recycling.

For commercial waste

2. Leadership from the public sector and businesses to reduce waste, increase recycling rates, and to publish and celebrate their performance to help create a zero-waste culture.
3. Public sector leadership to support re-use activities in the city, to drive demand for re-use items and to use procurement to build markets for goods made from recycled materials.
4. Legal requirements on businesses to sort waste for recycling is put in place (as is the case in Scotland and, shortly, Wales) together with effective enforcement of recycling and waste reduction requirements (with net cost reductions to businesses from lower disposal costs).
5. The awarding and use of greater powers for the city council to facilitate, license and enforce commercial waste collections, to reduce complexity, inefficiencies and enforcement challenges of multiple operators.

For domestic waste

6. A Pay as You Throw (PAYT) scheme is put in place (with appropriate regulatory powers from national government) to drive rapid increases in household recycling by creating a cost associated with the amount of waste which households do not recycle, together with restrictions on the amount of residual waste per household.

7. Effective enforcement of recycling and residual waste reduction requirements (with net cost reductions to businesses from lower waste disposal costs).

For both waste streams

8. Investment at regional level in additional food waste treatment capacity, textile reuse/recycling and in advanced pre-treatment plant to improve plastics recovery (particularly plastic film) from domestic and commercial residual waste, the incineration of which is the principal source of carbon emissions from the city's waste.

Carbon emissions associated with Bristol's household and commercial waste currently represent about 5% of the city's direct (Scope 1 and 2) carbon emissions, although the production of the materials which become waste accounts for additional (scope 3) emissions not considered as part of this study. These emissions largely arise from the incineration of residual waste and are associated principally with the plastic content of the waste streams. Reaching net zero carbon emissions from the city's waste by 2030 will therefore require a removal of the plastic from the residual waste stream or a cessation of incineration altogether.

7.1 What is the Current Situation?

- **Household Waste**

The Bristol City Council-owned Bristol Waste company collects and sends for treatment the waste collected from households. Treatment of residual waste is at several incinerator facilities. Current household waste in Bristol is 170,000 tonnes with carbon emissions c. 47,000 tonnes CO_2e (territorial basis, assuming electricity is zero carbon).[44] Quantities are measured in the UK's reporting system for household wastes.[45] The same data from the national reporting system shows the recycling rate is 45% using kerbside collection and household waste recycling centres.

Whilst some non-urban areas already reach 60+% recycling rates, Bristol is doing well compared with urban local authorities with similar populations. Existing kerbside systems perform relatively well, but as an urban area Bristol has the challenge of hard-to-reach properties such as student accommodation and multiple occupancy flats.

Bristol's current performance is lower than the current EU Waste Framework Directive target of 50% by 2020. There is a future target of 65% recycling under the EC's Circular Economy package (CE Package) which the UK remains bound by (although it may choose not to meet this following Brexit); it is not clear how Bristol will meet this higher target.

44 Emissions are calculated using the methodology set out in Section 7.2. Emissions calculations for incineration usually result in a credit being applied where the incinerator avoids the generation of energy elsewhere. However, such a credit would not be applicable where the electricity grid has been fully decarbonised.

45 Data on quantities and recycling rates from Waste Data Flow

- **Commercial and Industrial Waste**

The extent of commercial waste is unknown due to it being collected by an unknown number of private waste contractors with no national reporting requirements. Bristol Waste only collects a small proportion of the city's commercial and industrial waste.

With many different waste contractors in Bristol, who could send the collected waste anywhere, calculating commercial residual waste quantities is difficult. Therefore, it is estimated using a scaling down of national commercial waste estimates using the only data available via commercial waste surveys done relatively infrequently on a national basis.

Our method of estimating commercial waste tonnages relies on the national survey data being reapportioned to Bristol, on the basis of:

- the numbers of businesses based in Bristol across different business sectors; and
- further proportioned to take into account data on the size of the businesses.

On this basis the best estimate for commercial and industrial waste is 237,384 tonnes in total; of this, 158,422 tonnes is classed as municipal C&I waste (i.e. like household waste in composition). The remainder includes industrial wastes and waste that is highly uncertain in terms of composition. The total recycling rate for Bristol's C&I household-like waste is estimated at 37%, noting there is likely to be a higher recycling rate for the remaining non-household like wastes. This assumes Bristol recycles at the same rate as the rest of England. There is no data available for Bristol specifically on commercial waste recycling. Assuming the residual waste is incinerated, emissions from the household-like commercial waste alone are estimated at 32,000 tonnes CO_2e.

7.2 Net Zero Carbon by 2030 Scenario Options for Waste

- **Net Zero Analysis – Results**

- **Territorial-based Inventory**

Waste disposal impacts around 5% of territorial emissions currently (in CO_2e), with emissions largely arising from incineration of residual waste under a territorial inventory. Taking a territorial emissions inventory approach means that the focus is on the residual treatment of waste. At the time of writing, Bristol has just entered into a 10 year contract to incinerate its waste; there are no immediate plans to change this approach but such changes could be considered subsequently.

As the grid decarbonises, net carbon emissions from incinerated residual waste are expected to increase. An emissions credit is applied to the electricity generation to account for the benefit of avoiding electricity generation elsewhere. The size of this credit will fall as grid electricity decarbonises. However, emissions from the fossil carbon element of the waste stream remain.

Table 8 shows the emissions from incinerated household waste. The numbers are calculated based on the current composition of residual waste, taking into account levels of recycling. It can be seen that plastic film and dense plastic account for the large majority of emissions. The data has been calculated for a scenario in which the electricity grid is fully decarbonised.

The table also shows the current capture rate at the kerbside for recycling and the estimated capture rate required for Bristol to meet the European Commission's Circular Economy package target of 65%. These rates are estimated based on our knowledge of waste collection systems, including the typical performance of high performing European systems and the quantities of material available for capture. Even if the CE Package target is met a significant quantity of fossil carbon will remain within the waste stream which will need to be tackled to reach net zero.

Table 8: GHG Impacts of Household Waste and Capture Rates for Recycling

	Waste arisings – household kerbside (residual and recycling) Tonnes waste	Current emissions from incineration (household Kerbside waste only) tonnes CO_2e	Current capture rate for recycling (at Kerbside)	Indicative capture under 65% recycling
Food Waste	30,010	-1,621	39%	80%
Garden Waste	18,340	194	43%	80%
Paper	13,343	161	35%	75%
Card	12,768	49	79%	75%
Glass	12,275	31	85%	85%
Ferrous Metal	2,824	27	45%	57%
Non-Ferrous Metal	1,001	9	45%	57%
Plastic Film	7,658	19,007	0%	0%
Dense Plastic	10,485	15,561	39%	73%
Textiles	4,215	2,340	2%	33%
Wood	0	0	0%	33%
WEEE	1,079	17	7%	
Sanitary products	8,381	1,160	0%	
Other	9,525	3,122	0%	33%
TOTAL	**131,902**	**40,057**		

The equivalent data for commercial waste is presented **Table 9** for the commercial waste that fits the same categories as used above for household waste. As emissions arising from the non-household like commercial and industrial wastes cannot be modelled with any degree of accuracy, these have been excluded. The table shows a similar picture for the household-like commercial waste as for the household waste, in that the incineration of plastic dominates the emissions impact.

Table 9: GHG Impacts of Commercial Waste and Capture Rates for Recycling

	Commercial waste arisings (recycling and residual) – household like waste, tonnes	Current emissions from incineration (household-like C&I waste) tonnes CO_2e	Current capture rate for recycling	Indicative capture under 65% recycling
Food Waste	26,634	0	11%	80%
Garden Waste	4,746	-204	57%	80%
Paper and card	75,072	-7,521	50%	75%
Glass	6,250	0	78%	85%
Metals	5,856	0	15%	57%
Plastic	18,558	38,697	17%	37%
Textiles	855	342	0%	33%
Wood	7,880	-721	54%	33%
WEEE	1,082	0		
Other	11,488	943		33%
TOTAL	**158,422**	**31,535**		

- **The Emission Benefits of Waste Reduction and Recycling**

Under a consumption-based inventory, further benefits exist from recycling materials. These result from avoided emissions related to the use of recycled material in the plastics production process, resulting in emissions benefits of circa 1 tonne CO2e per tonne of plastic recycled.[46] Benefits are higher for purer plastic streams such as PET which is typically used to make plastic drinks bottles.

Benefits of plastic waste prevention are higher still, in the order of three tonnes CO2e per tonne of plastic where this is manufactured from virgin inputs. Food waste prevention results in higher carbon benefits still – at over four tonnes CO2e per tonne of food waste prevented, whilst textiles waste prevention may result in benefits of over 20 tonnes CO_2e.

[46] Data based on the Scottish Carbon Metric

7.3 Future Actions to Move Towards Zero Carbon by 2030

Upstream emissions – associated with increased recycling and decreased waste production – are not included within the scope of emissions calculations considered in this study. However, such activities yield additional emissions reductions benefits. As such, recommendations have been made on actions to reduce, reuse and recycle waste, before considering actions to tackle the carbon emissions associated with disposal of residual waste.

- **Overarching Actions**

The above analysis confirms that emissions of c. 19,000 tonnes CO_2e from household waste alone are likely to remain even if Bristol achieves a 65% recycling rate for household waste. This leads to the following pathways to reduce these emissions still further towards zero:

- Bristol City Council is about to enter a 10 year contract for incineration of waste with the option to extend for 10 more years. Achievement of a substantial reduction in emissions from waste - assuming waste continues to be incinerated – will require the following:
    - Pre-treatment of household waste to remove plastic film is required to reduce emissions. It is unlikely to be cost effective to remove such materials by recycling at the kerbside.
    - Since plastic is not completely removed through the pre-treatment system, plastic waste generation also needs to be minimised and the recycling of dense plastic needs to be maximised; this will result in additional up-stream emissions benefits (accounted for in a consumption-based inventory).
- There may be scope, under the assumed zero carbon electricity supply, for further emissions reductions if Bristol treats its residual waste by bio-stabilising it – typically achieved using a mechanical-biological treatment (MBT) system – prior to it being landfilled, rather than incinerating it. This reduces the amount of methane generated by organic wastes in landfill. Under such a system, plastics are no longer a source of emissions, as the carbon is instead sequestered in landfill.
    - The effectiveness of this system will be improved by high captures of food waste for recycling as well as high rates of paper/card recycling.
    - The advanced pre-treatment of residual waste will allow for additional up-stream benefits from the recycling of plastics and metals.

The pathway to action starts with the following preliminary actions:

- Take actions to improve recycling levels (see below).
    - Measures to improve plastics recycling will be required if the council continues to incinerate its waste.
    - Measures to improve food waste recycling will be helpful irrespective of which method is used to treat residual waste:
        - This will help generate more biogas which can be used to help with decarbonising transport or heat.

  - If the incineration route is taken then better food waste recycling will help improve the performance of the advanced pre-treatment system.
  - If the bio-stabilisation route is taken for residual waste then food waste capture will reduce landfill emissions.

- Bristol City Council should consider options for lower or zero carbon disposal of waste when its contract for incineration ends in 2030.Bristol City Council should consider options for pre-treatment systems for the removal of plastic film – this is particularly important if Bristol continues to incinerate its residual waste.

If Bristol City Council wishes to pre-treat household waste as above, this will require investment in an advanced pre-treatment system which will, in turn, require Bristol to act in partnership with the West of England, as alone the city won't generate enough waste for plant to be viable.

- **Actions to Improve Recycling Levels for Household Waste**

Bristol would need to achieve very high levels plastic recycling in particular if incineration remains the residual waste treatment system. The levels of recycling required would ideally exceed the targets in the CE Package; however, even meeting the targets is likely to be relatively challenging for a highly urban area under the current national policy regime.

To meet the CE Package targets, current levels of recycling need to increase from around 45% to in excess of 65% in just over a decade. This transition may be achieved more rapidly with the right financial drivers, in particular the introduction of pay-as-you-throw (PAYT) systems, in which Supporting the Bristol Reuse Network more to reuse items so that they do not end up as households pay more for residual waste collection rather than recycling. Chips on the bins are used to record the bins' weight and track them for individual householders.

Such policies have helped drive the high recycling performance of countries such as Germany, where the whole country recycling rate is already in excess of 60%. The introduction of such a system is outside Bristol's control; such activities are discussed further in Section X (where national actions are considered). To avoid this becoming a regressive charge, how the council uses any money it raises from PAYT becomes key. It could, for example, offer everyone an offsetting reduction in council tax; or the council could spend money on programmes that benefit poorer people, or cut council tax more for lower-banded properties. Items such as nappies might make up the large bulk of residual waste for some households and to prevent them being penalised, measures need to be put in place to provide nappy recycling and provision of re-usable nappy libraries. Improvements may also need to be made to the recycling collection provision of multiple occupancy buildings so that they have ease of access to recycling storage and are not forced to place most of their waste in residual and face higher PAYT charges. Enforcement may also be needed to avoid households placing residual waste in recycling collections to avoid fees. At present, there are no plans at the national level to reintroduce household enforcement powers at a local authority level.

Achievement of high levels of recycling requires all householders to participate in recycling services as well as taking steps to reduce waste where appropriate. In the absence of PAYT, actions to improve recycling focussing on carbon outcomes include:

1. Extensive communications campaigns to educate the public and businesses and increase participation, including continual effort over many years.
2. More investment in Household Waste Recycling Centres (HWRCs) – including smaller sites in denser areas (as is planned in Ljubljana, for example).
3. Increasing the scope of textiles recycling services offered by the council – to tackle the poorer quality materials not currently included within existing collection systems.
4. waste and support workshops to teach citizens how to fix things themselves. Demand for reused items - and those made from recycled materials – may come through Bristol city council's procurement processes stipulating the use of these products where practicable.
5. Restrictions on the amount of residual waste that can be put out by householders.
6. The use of fines on householders not participating in the recycling system.

It is important to note that actions to improve recycling rates tend to improve these rates across all collected materials at the kerbside (e.g. action to improve food waste recycling will also benefit plastics recycling).

- **Actions to Improve Recycling of Commercial Waste**

Although levels of commercial waste generation are not known with certainty, it is likely that there is at least as much commercial waste being generated in Bristol as there is household waste, and there is no evidence that the household-like commercial waste is being recycled at a higher rate than household waste.

A form of PAYT does exist for business waste, in that businesses separately contract for recycling and residual waste services. However, commercial waste generators do not have a significant financial incentive to recycle. While the existing legislation does in effect require businesses to respect the waste hierarchy, thereby requiring them in effect to take up recycling services, this is not enforced. Bristol could enforce this through extending the scope of existing business inspections undertaken by Environment Agency (EA) officers (see Section X). Such activity could run alongside co-ordinated communications campaigns to raise awareness of the need to take up recycling services.

Alternatively, Bristol City Council could lobby national government to put in place legislation which enshrines in law a requirement for businesses to sort waste for recycling – such legislation is already in place in Scotland, and will shortly be in place in Wales. (Section X considers the lobbying activities in more detail.)

One option is that the company undertaking the household waste collections takes on more commercial waste collection. This would allow for greater quantification of performance levels, as well as for improvements in logistics – since that company already runs collection vehicles across the area to collect household waste. Similar activities on communications to those for the household sector would also help improve performance.

An alternative to increasing the household waste collection company's role is that some restriction is placed on the number of private contractors offering waste services in the area. Restricting the number of contractors would result in improved logistics and clearer competition, which in turn would drive down waste collections service costs for waste producing businesses. However, it would mean many waste collectors losing out on work, and some might go out of business, depending on

how widespread the use of zoning turns out to be (see Section X). Restricting numbers of contractors relies on national legislation. This approach does not necessarily tackle the data availability issue; work with the contractors would be required to tackle this in the absence of a formal system being put in place nationally to collect the data.

7.4 Potential Costs

- **Additional commercial waste collecting by Bristol Waste (or under BCC direction)**

The ONS estimates the business population of Bristol, split by size band, to be:

0 to 4	5 to 9	10 to 19	20 to 49	50 to 99	100 to 249	250+
13,245	2,740	1,795	1,265	420	220	105

0–9 = Micro; 10–49 = Small; 50–249 = Medium; 250+ = Large

Most micro-businesses are not based in their own separate premises and generate little waste. Policies to improve the management of commercial waste therefore impact on a population of 6,000–10,000 business premises having 5 or more employees; but the scale of the impact depends on how vigorously the policies are pursued. In addition, to date, no local authority has attempted to enforce the waste hierarchy with businesses in England and Wales.

The goal could be for the household waste collection company to promote more recycling, especially source separated recycling and recycling of food waste. This should be cost neutral for Bristol Waste, as additional collections should be at commercial rates, and should make an income that exceeds the costs. Also, increasing recycling should reduce costs to businesses (since recycling collection is generally cheaper than residual collection). We could reasonably assume a 10% reduction on an average annual bill of ~£1,000 per business. This estimate is based on what has been achieved through market consolidation in Bath, but will depend how the household waste collection company's prices compare with those of its competitors.

- **Waste Hierarchy Enforcement**

Small and medium businesses should be targeted, as they are less likely than large businesses to be maximising their recycling. Many of these savings/costs should arise due to national policy from 2023, but enforcement will in any case be required at that point.

Enforcement of the waste hierarchy, requiring all businesses to recycle far more thoroughly (whether economically advantageous or not and without the benefit of market consolidation mentioned above) will involve deploying and training mid-level EA staff to visit premises and check on compliance. Staffing requirements are likely to be two people, on £25-30k/yr + on costs.

The costs to large and medium-sized business would be negative – i.e. implementing the waste hierarchy should generally save money. There may be a cost to micro businesses, if they have their own premises: for a similar Policy, Defra/WRAP has estimated a £162–£171 increase in costs per micro business per year (assuming they operate from their own individual premises – and many do

not.)[47] However, all other business size groups see savings, with small businesses saving £500–£700 per year, medium businesses £2,200–£3,400 per year and large businesses £8,100–£10,800 per year.

Residual Waste Treatment

- **Advanced Pre-treatment**

There is an estimated typical £27–£37[48] gate fee per tonne of residual waste, costs being cheaper for larger plant. Bristol currently generates around 81,000 tonnes of household waste whilst the estimated quantity of household-like commercial waste is around 100,000 tonnes. Costs for treating the amount of residual waste currently generated are therefore estimated to be £4.9-6.7 million. Costs are expected to decrease as recycling levels rise and the impact of waste reduction activities is seen on waste generation figures.

- **Mechanical Biological Treatment**

There is no reason that MBT should be more expensive than incineration, but costs are hard to come by and vary depending on the contract in place. Looking at CAPEX estimates in the most recent literature available, a 2013 Defra report states that:

"recent example estimates and actual costs for the construction of MBT plants fall in the range of £50m – £125m for MBT facilities in the capacity range 80 – 225ktpa"[49]

while a 2017 Tolvik report considers a 120ktpa, £42m capex facility, and describes a basic cost model which leads to a gate fee of £125–138/tonne.[50]

Costs will be lower if the Government is lobbied and convinced to provide a lower rate of landfill tax for MBT stabilised waste. Coupling this with advanced pre-treatment would also lower costs as less residual waste is sent to landfill.

7.5 Action needed by Government

If incineration remains the residual waste treatment method, Bristol should work with other local authorities to seek funding for new regional advanced pre-treatment plants which will improve

47 Source is p41-43 of this: https://consult.defra.gov.uk/environmental-quality/consultation-on-consistency-in-household-and-busin/supporting_documents/recycleconsistencyconsultia.pdf

48 TOMRA

49 Defra (2013) Mechanical Biological Treatment of Municipal Solid Waste, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/221039/pb13890-treatment-solid-waste.pdf

50 Tolvik (2017) 2017 Briefing Report: Mechanical Biological Treatment –15 Years of UK Experience, https://www.tolvik.com/wp-content/uploads/2017/09/Tolvik-2017-Briefing-Report-Mechanical-Biological-Treatment.pdf

plastics recycling by allowing the recovery of plastic film. There is an opportunity here for funding through City Leap.

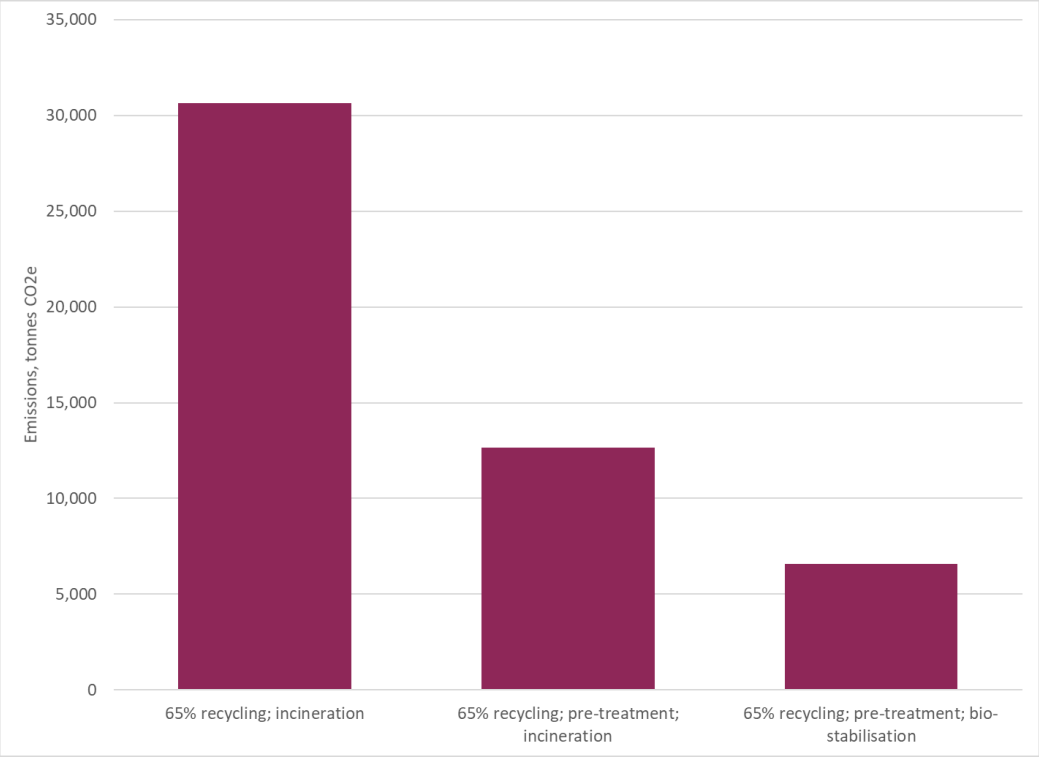
Bristol is more likely to reach recycling rates in excess of 65% quickly if the right national policy framework is in place. For household waste, action is needed by the UK Government to put in place PAYT systems which will provide financial incentives for householders to recycle.

For commercial waste, PAYT systems already exist but do not yet provide the required financial incentives due to the relatively poor logistics at a local level. Action is needed by the English government to implement a requirement to be placed on businesses to sort their waste, as is the case in Scotland and will shortly be so in Wales. Defra is also understood to be considering the development of a "zoning" approach to commercial waste, whereby the number of contractors operating waste services in a given area is restricted so as to improve local logistics. Action is needed by the UK government to bring about the required changes.

7.6 How Close to Net Zero Do We Get?

Figure 20 shows the carbon emissions associated with three different options for treating Bristol's household residual waste in a situation where the electricity grid has been decarbonised. There is scope for some further reduction through additional recycling, reuse and waste prevention activities. The latter will require action by businesses to reduce, for example, the amount of packaging used in goods consumed by households.

Figure 20: Emissions from Household Wastes



7.7 Other Points to Consider on Recycling

Bristol's territorial GHG inventory will not be positively impacted by increasing recycling because it does not produce what it consumes, so emissions savings will be accounted for elsewhere. The benefits from recycling are not accounted for other than what is recovered from residual waste plant. There are upstream benefits from reducing the use of virgin inputs. Food waste prevention especially has lots of upstream emission savings related to the production, transportation and storage of food which will not be accounted for at a Bristol level.

There are also some social co-benefits which arise from improved recycling and reduced waste generation, which would be enjoyed by Bristol residents:

- Addressing food waste could also benefit people's health by increasing food consumption awareness and changing what people eat, especially as unhealthy food has a tendency to be more highly packaged.
- Fun community and street level interventions could decrease loneliness and increase community cohesion in some areas especially in multiple occupancy buildings where it might be difficult for people to be sociable.
- Reducing a throw away culture can increase aware and connection to nature and improve mental and physical health.

7.8 Conditions for Success and SWOT analysis

The conditions for success and SWOT analysis tables are presented below. Key issues that will need to be considered include:

- National government's resistance to PAYT for over a decade and lack of wider support for changes to waste collection and recycling measures.
- The potential apprehension of Bristol City Council to additional pre-treatment to capture plastic film from the waste stream, stemming from negative views of pre-treatment plants following operating issues at the New Earth Solutions treatment plant. It is important to note that these issues predominantly relate to the energy generation aspect of the plant. However, the older sorting technologies were less efficient at recovering recyclate from residual waste than is the case with the newer technologies.

'Walking right round the issue' Conditions for success / SWOT Session: *Waste sector*

This analysis will underpin the design of a comprehensive roadmap of interventions with clear guidance on who is best placed to act and what support and initiative-taking is required from others.

Outcome 1 – Fossil carbon emissions reduced to near zero from household waste stream

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
Conditions for success & key dependencies	***Conditions for success & key dependencies***	***Conditions for success & key dependencies***	***Conditions for success & key dependencies***	***Conditions for success & key dependencies***
One of the best performing household waste collection systems in the EU without a significant financial lever, pay as you throw (PAYT), to drive performance.	Partnership working with the West of England to make the additional investment in pre-treatment infrastructure stack up. Successful national (or regional) lobbying resulting	Capital investment in additional high-performing pre-treatment facility in the West of England. Capital investment in sanitary products recycling system regionally or nationally.	Authority continues with in-house operation of services. Changes in national legislation to allow local authorities to implement PAYT collection systems would make success more likely. In the absence of	Socio-economic groups which traditionally participate less frequently in recycling services will need to do so, and achieve relatively levels of participation.

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
Investment in waste pre-treatment - also needed for outcome 2 (resulting in the collection of plastic film). Investment in sanitary products recycling system regionally (or nationally). Extension of existing textiles recycling service to include recycling of low-grade textiles.	investment sanitary products recycling service.		this, Bristol must make use of its powers to tackle households that do not participate in recycling services. National government does not rescind the powers which Bristol will need to use to achieve this.	
Strengths Already one of the top performers in the UK for household recycling, with food waste collection services in place, and well-designed dry recycling collection services. Plans already in place for significant waste reduction from households (although has held back from putting in place some measures deemed politically sensitive). Already has a biogas plant producing gas for transport fuel.	***Strengths*** Already one of the top performers in the UK for household recycling within its socio-economic group. Existing relationships with the other authorities in West of England.	***Strengths*** Existing relationships with the other authorities in West of England. City Leap offers a potential method for bringing about investment in pre-treatment.	***Strengths*** Bristol is a unitary authority, so has greater control over the operational of services and facilities than is the case in two-tier areas. It also has an-house collection service which gives it greater control over service operation.	***Strengths*** Already one of the top performers in the UK for household recycling within its socio-economic group. Strong environmental ethos and well-established community networks. This will help with e.g. further development of local re-use activity (for textiles), and in growth of refill shops. High awareness nationally of issues surrounding plastics pollution; this should improve participation in plastics

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
				recycling services, and help with plastics waste prevention.
Weaknesses Dense urban area, with a high proportion of flats or "hard to reach" properties. These properties are associated with lower recycling rates. Local authorities have only a limited control over packaging design and use, and do not have direct control over many aspects of household waste generation.	***Weaknesses*** Tendency for local waste policies in Bristol to be weakened for political reasons, which has held back progress in recent years.	***Weaknesses*** Bristol is a relatively small authority, so is dependent on the partnership working and national lobbying to make the commercials stack up for investment in the treatment facilities.	***Weaknesses*** Bristol does not have complete control over waste policy as a local authority. Bristol has very little control over packaging as a local authority; waste will flow into the area from other surrounding areas reducing the extent of Bristol's control. Investment in the sanitary products recycling plant likely requires national action and/or investment.	***Weaknesses*** Bristol has a relatively high proportion of the socio-economic groups which tend to participate less in recycling services.
Opportunities Improved food waste collection will produce more biogas which could assist in decarbonising the transport and heat sectors which are challenging to decarbonise. Further emissions savings (over and above those seen from reducing plastics to residual	***Opportunities***	***Opportunities*** Further opportunity for financial savings from improved, more efficient recycling systems with greater participation. Opportunities for local businesses to offer shopping options with reduced plastic	***Opportunities*** Climate emergency could be used as a reason to lobby government to introduce a national PAYT waste policy, which would make it easier for Bristol to achieve its goals (in line with many of the best performing systems in EU).	***Opportunities*** Bristol can further cement its reputation as a leading UK authority in environmental services.

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
waste treatment which form the basis of the territorial emissions savings) arising from recycling activities. A Deposit Return System (DRS) is an opportunity because it will boost recycling and frees up space on vehicles - expected for 2023.		packaging (i.e. growth of refill shops). Opportunities from Extended Producer Responsibility (EPR), which will provide potential new funding to improve/extend services and comms so that recycling (esp. of packaging) can be increased.	Higher recycling targets will come into play over the next decade due to EU policy which the UK is likely to remain committed to achieving. Reform of extended producer responsibility system and introduction of single-use plastics policies will assist in reducing the amount of plastics sent for residual waste treatment.	
Threats Treatment systems for sanitary waste are novel, increasing the likelihood of operating issues. DRS is a threat because it could necessitate changes to vehicles - expected for 2023.	***Threats*** Other authorities in the West of England may choose to take a different route to tackling emissions from residual waste, and therefore decide not to invest in pre-treatment facility.	***Threats*** Bristol has already invested in a pre-treatment facility which did not operate well, so may be reluctant to do the same again. Continued austerity may prevent further investment in collection services. Recycling markets for plastics make the economics of plastics recycling commercially	***Threats*** Brexit may result in the weakening of the circular economy package when this is implemented in the UK, making the national policy landscape less favourable to achieving high recycling rates.	***Threats*** Enforcement of participation in the recycling services may be required, but undertaking enforcement activity is currently challenging, and may be become more so - depending on the attitudes of central government in this area, which has blocked progress on this in the past.

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
		challenging at present, and this may continue / get worse.		
Other Bristol should consider the use of an alternative residual waste treatment system – MBT based on biostabilisation – which could result in lower emissions than is the case with the use of incinerator.		***Other***	***Other***	***Other***

Outcome 2 – Fossil carbon emissions reduced to near zero from commercial waste stream

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
Conditions for success & key dependencies Investment in waste pre-treatment - also needed for outcome 1.	***Conditions for success & key dependencies*** Partnership working with the West of England to make the additional investment in pre-	***Conditions for success & key dependencies*** Capital investment in additional high-performing pre-treatment facility in the West of England.	***Conditions for success & key dependencies*** Authority continues with in-house operation of services, and extends its current service offerings to commercial waste	***Conditions for success & key dependencies*** Businesses will need to achieve high levels of participation in recycling services without

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
Sufficient biogas treatment capacity to treat the biogas arising from increased food waste collection from businesses.	treatment infrastructure stack up. .		generators, offering a wider range of recycling services.	strong financial or legislative drivers being in place.
Strengths There is already a financial incentive for businesses to recycle.	***Strengths*** The council has a commercial waste service it can grow. Existing relationships with the other authorities in West of England. Strong local business networks e.g. well-developed business improvement districts – this will help with introduction of cost-effective services for small businesses.	***Strengths*** Existing relationships with the other authorities in West of England. City Leap offers a potential method for bringing about investment in pre-treatment. Relatively strong local economy.	***Strengths*** Bristol is a unitary authority, so greater control over the operational of services and facilities than is the case in two-tier areas. It also has an-house collection service which gives it greater control over service operation.	***Strengths*** Bristol has businesses with a green-ish mindset that want to recycle. Strong environmental ethos and well-established community networks. Many early adopters which will help normalise the take-up of recycling services by businesses. High awareness nationally of issues surrounding plastics pollution; this should improve business participation in plastics recycling services, and help with plastics waste prevention.
Weaknesses The financial incentive for businesses to recycle is not	***Weaknesses***	***Weaknesses*** Bristol is a relatively small authority, so is dependent on	***Weaknesses*** Bristol does not have complete control over waste policy as a	***Weaknesses***

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
strong enough or business owner's do not understand it. Local authorities have only a limited control over packaging design and use and control over the practices of commercial waste collectors in particular is relatively weak. Hard to measure success – no data on commercial waste.	The council has only a limited role in commercial waste collections. Tendency for local waste policies in Bristol to be weakened for political reasons, which has held back progress in recent years (this may be less of an issue for business waste).	the partnership working and national lobbying to make the commercials stack up for investment in the treatment facilities.	local authority. Local authority control over commercial waste in particular is relatively weak. Bristol has very little control over packaging as a local authority; waste will flow into the area from other surrounding areas reducing the extent of Bristol's control.	Waste / recycling services are not a high priority for many businesses.
Opportunities Increased participation in food waste collection will produce more biogas which could assist in decarbonising the transport and heat sectors which are challenging to decarbonise. Further emissions savings (over and above those seen from reducing plastics to residual waste treatment which form the basis of the territorial emissions savings) arising from recycling activities.	***Opportunities*** To grow the Bristol Waste commercial waste service through a more intensive sales effort.	***Opportunities*** Local businesses may save money on their recycling services as participation increases. Business opportunities for local waste collection service operators offering recycling services. Further opportunity for financial savings from improved, more efficient recycling systems with greater participation.	***Opportunities*** The government's proposals for greater consolidation of the commercial waste market from 2023. Climate emergency could be used as a reason to lobby government to introduce legislation to require businesses to sort waste, as is the case in Wales and Scotland. Costs of business waste recycling services could be reduced by additional legislation aimed at controlling	***Opportunities*** Bristol can further cement its reputation as a leading UK authority in environmental services. Bristol businesses can capitalise on success in this area.

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
		Opportunities for local businesses to offer shopping options with reduced plastic packaging (i.e. growth of refill shops).	the number of companies offering commercial waste services in a given area. Higher recycling targets will come into play over the next decade due to EU policy which the UK is likely to remain committed to achieving. Reform of extended producer responsibility system and introduction of single-use plastics policies will assist in reducing the amount of plastics sent for residual waste treatment.	
Threats	***Threats*** Other authorities in the West of England may choose to take a different route to tackling emissions from residual waste, and therefore decide not to invest in pre-treatment facility.	***Threats*** Bristol has already invested in a pre-treatment facility which did not operate well, so may be reluctant to do the same again. Recycling markets for plastics make the economics of plastics recycling commercially challenging at present, and this may continue / get worse. There is no strong financial driver for businesses to take up recycling services in the	***Threats*** Success is partially dependent on the Environment Agency fully enforcing existing policies (e.g. waste hierarchy). Austerity / budget cuts may restrict its ability to undertake the relevant enforcement activity, limiting success. Brexit may result in the weakening of the circular economy package when this is implemented in the UK, making	***Threats***

Technical	Capabilities/initiative-taking	Commercial	Policy / regulatory	Socio-cultural
		absence of the legislation to require businesses to sort waste - although businesses will in some cases save money, particularly as logistics improve by virtue of greater service take-up.	the national policy landscape less favourable to achieving high recycling rates.	
Other Bristol should consider the use of an alternative residual waste treatment system – MBT based on biostabilisation – which could result in lower emissions than is the case with the use of incinerator.		***Other***	***Other***	***Other***

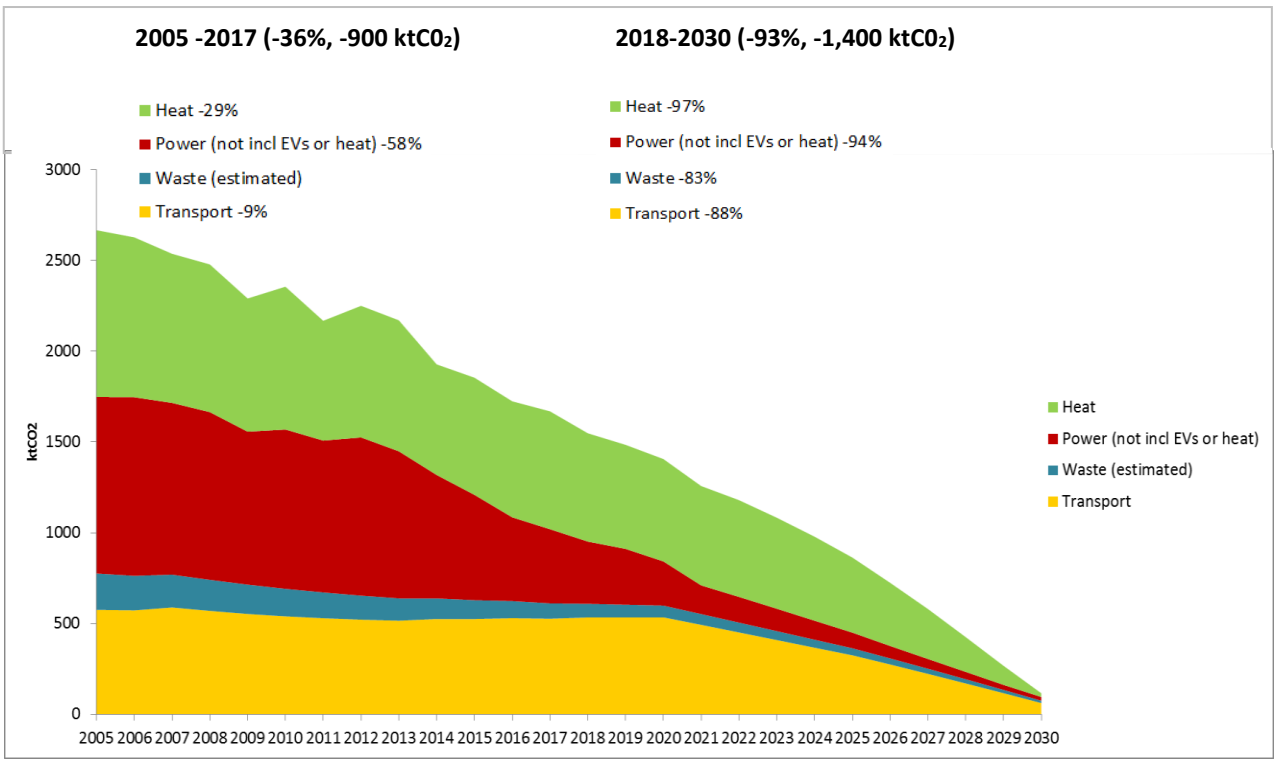
8 The gap: what Bristol needs to do above and beyond current national and local commitments and plans

The scale of the additional effort required in Bristol to achieve net zero for scopes 1 and 2 carbon emissions by 2030 can be revealed by drawing on the analysis here and the Bristol Carbon Neutrality Baseline undertaken for the City Council earlier in 2019.[51]

As revealed in Figure 21 below, Scope 1 and 2 carbon emissions caused by the city have been reducing over the last decade, with 36% reduction between 2005 – 2017, totalling 900 $ktCO_2$. The left hand legend in Figure 21 shows how that historical reduction has been achieved unevenly between different sectors, with particularly weak reductions in transport. The heat and power reductions are largely down to the widespread adoption of low cost insulation measures (like cavity wall and loft insulation), the establishment of effective energy efficiency standards for appliances and equipment (including gas boilers) and the significant growth of renewable energy generation and displacement of coal on the electricity system. In this context, the 'easy stuff' has been done.

Projecting forward from 2018-2030 using the scenarios presented in this study for heat, power, transport and waste decarbonisation highlights the scale of the challenge which the city faces. Bristol needs to cut its carbon emissions over the next 12 years at an average rate of c 120 $ktCO_2$ of carbon saved per year, which is **1.6 times faster** than the annual average of 75 $ktCO_2$ over the last 12 years.

Figure 21: Historical and projected reductions in Bristol's scopes 1 & 2 carbon emission reductions



51 See Footnote 2

It is instructive to examine what is involved in achieving this reduction to achieve net zero by 2030 and how it compares with (a) current practice, (b) improvements that can be anticipated based on current national and local policies up to 2030 (the 'committed' trajectory from the Baseline assessment), and (c) the improvements that would be required to achieve the legally binding national target of net zero by 2050 (the 'Target 2050' trajectory from the Baseline assessment).[52]

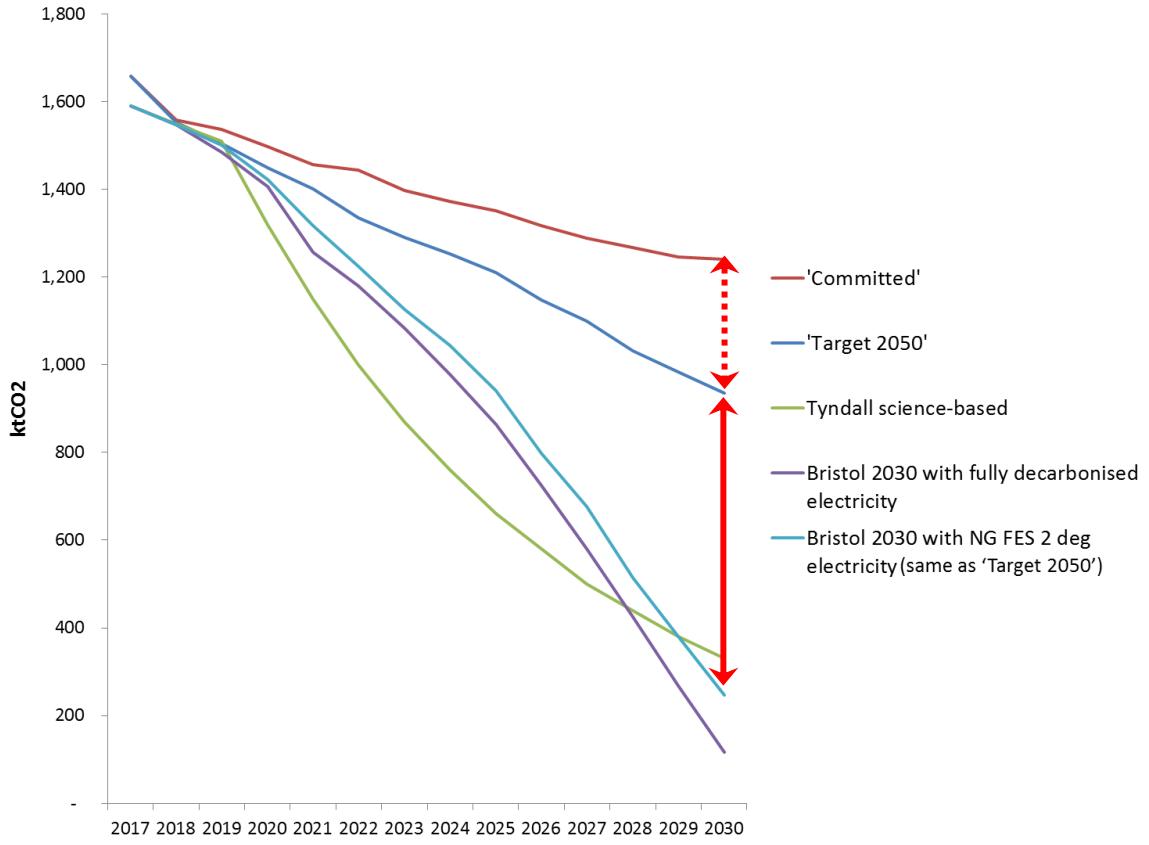
This reveals the scale of the accelerated decarbonisation effort required in the city to achieve net zero by 2030. Helpfully, the 'Target 2050' trajectory anticipates that electricity decarbonisation will follow the National Grid's Future Energy Scenarios '2 degrees' pathway (as discussed in Section 2.1). By applying this same national electricity decarbonisation scenario to the sector-by-sector decarbonisation scenarios developed for this study, we can reveal more precisely the infrastructure and system changes within the city that will be required to achieve net zero by whenever the grid is fully decarbonised. (On the FES '2 degrees' scenario, carbon dioxide emissions per unit of electricity are down to 48g by 2030 – having been more than 700g per unit in 1990 – and would be down to near zero within the following few years).

These different trajectories are shown together in Figure 22, together with (the green line) the Tyndall Centre's assessment of what would constitute a fair carbon budget for Bristol in the context of the UN Paris Agreement's aim of limiting global warming to 1.5°C from pre-industrial levels.[53] This represents a yardstick to judge whether Bristol is 'doing its part' within this global setting.

52 The Committee on Climate Change has repeatedly highlighted that current 'committed' policies and associated funding are insufficient to put the UK on the right trajectory to achieve net zero by 2050. Hence the difference between 'committed' and 'target 2050' trajectories in Figure 22.

53 See Footnote 8

Figure 22: Bristol scopes 1 and 2 carbon emission trajectories, revealing the gap in action required



The vertical red lines on Figure 22 represent the gaps between (a) current 'committed' delivery and what is required to be on track to meet the legally binding national target of net zero by 2050 (dotted red line) and (b) the action required by 2030 to reach net zero by 2050 and that required to meet net zero by 2030 on the same electricity decarbonisation scenario (FES '2 degrees') (solid red line).

Translated into the required levels of installation of some of the measures explored in the scenarios here demonstrates the significant acceleration of activity required to hit both 2030 and 2050 net zero targets compared with the current situation (see Table 10 below). The right hand column shows the scaling up required to achieve net zero by 2030 compared with 2050.

Table 10: Scaling up of activity required (cf current situation) to achieve net zero by 2050 or by 2030

Measure	Estimated current situation	'Target 2050' (by 2030)	'Bristol 2030' (by 2030)	Scale up necessary for net zero by 2030 (cf 2050)
Individual heat pumps	<200	27,000	**96,000**	3.5
District heating connections	< 1,000	21,000	**68,000**	3.2
Insulation upgrades (complex: solid wall etc)	<5,000	73,000	**73,000**	Same (but still at least >20 times higher than current rate)
Electric vehicles	<1,000	57,000	**124,000**	2.2
Vehicle mileage reduction	0% (recent years)	-5%	**-40%**	8
Solar PV installations	28MW	c.200MW	**>350MW**	>1.5

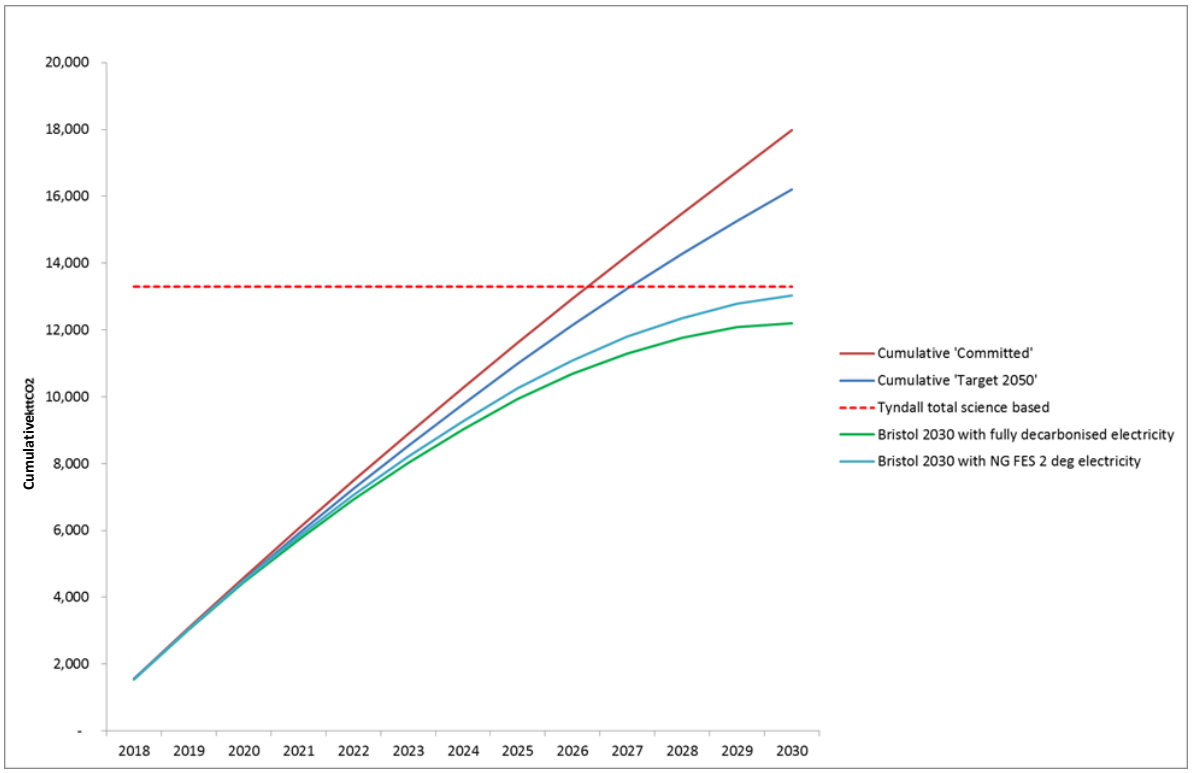
As discussed throughout this report, the acceleration of change and scaling up of activity required for either scenario (Target 2050 or Bristol 2030) is enormous compared with current activity and current plans (both locally and nationally).

The principal distinction between the scenarios is not the nature of the changes required or of the key interventions to achieve them. They are broadly the same whether the goal is net zero by 2050 (in line with the UK national target) or by 2030 (in line with meeting the Tyndall Centre's fair carbon budget for the city). The principal distinction is the speed with which initiatives are introduced and the rate at which they are scaled up.

Aside from the moral and scientific case for Bristol aiming for net zero by 2030, there are unlikely to be significant downsides from starting sooner and going faster than required by the national 2050 target or than supported by current national policies. Indeed, political scientists might well argue that it will need leadership by cities such as Bristol to pursue their 2030 ambitions in order to create the political, technological and cultural momentum to enable the UK as a whole to achieve its 2050 target.

As shown in Figure 23 below, only by aiming to achieve net zero by 2030 will Bristol's cumulative emissions remain within the Tyndall Centre's Bristol's 'fair share' of the remaining global carbon budget (the dotted red line) to meet the Paris Agreement's aim of preventing warming above 1.5°C.

Figure 23: Bristol cumulative scopes 1 & 2 emissions against the Tyndall Centre's fair remaining carbon budget



9 Ten key interventions to set Bristol on course for net zero by 2030 (and the first next steps to achieve them)

For each of the different sectors analysed for this study, the study team has described a set of interventions which it believes will establish the conditions for success required for Bristol to achieve net zero by 2030 for scopes 1 and 2 emissions. These are brought together and summarised in this Section as ten key interventions, as outlined below.

In combination these would create the radical and transformative approach required to address the gap between what is currently likely to happen to reduce carbon emissions and what this analysis shows the city needs to do to achieve its net zero by 2030 ambition.

A city <u>for</u> net zero: fostering shared purpose and enabling active participation

1 A sustained and extensive programme of public and business engagement to foster a strong sense of shared purpose and to support and enable the whole city to participate meaningfully in achieving Bristol's 'net zero' future.

This participation will range from low carbon retrofit of buildings and swapping out gas boilers to switching to active travel or public transport, EV car clubs and consolidated freight and reducing food and plastic waste. The programme should also include appropriate advice and support for different communities and needs within the city's population to ensure no one is left behind.

FIRST NEXT STEPS:

- Establish a working group, reporting to the One City Environmental Sustainability Board, to bring together organisations already active and engaging the public and businesses on these issues and those with extensive reach, including large employers (such as the NHS and the Council) and faith groups, to agree some simple key initial messages (the city's '**net zero hymn sheet**'), develop a long-term engagement plan and identify potential funding sources for its implementation.
- Commission some market segmentation analysis to understand the interests and motivations of different types of household across the city, how they may respond to and engage with different types of approaches and messages, and how they are distributed across the city.

A city empowered to achieve net zero: securing powers & capacity

2 The securing of new powers (to organise and require action and raise levies) and devolved (additional) funding, with national backing for '2030' pioneers to accelerate investment.

The powers which Bristol needs are far reaching – from establishing net zero heat zones and setting progressive energy performance standards for the upgrade of existing buildings to being able to co-ordinate effectively the local roll-out of EV charging infrastructure, oversee public

transport, require within-city freight consolidation and extend influence over commercial waste collections and raise levies on excess residual waste. They also include planning policy and building standards for new developments (see 4 below). Most of these powers are not currently in place nationally to be devolved but they will need to be put in place (and potentially devolved to enable locally relevant approaches) to achieve the legally binding net zero by 2050 target. To achieve net zero by 2030, Bristol will need to be granted these powers and provided with the additional funding to jump start the transformation by addressing the cost differentials between current conventional activities and net zero solutions.[54]

FIRST NEXT STEPS:

- Building on existing joint work with the Core Cities network, the Council should work with the One City Boards (led by the Environmental Sustainability Board) to develop, endorse and present the city's (rather than just the council's) case to national government for the granting of these powers and associated funding, seeking the endorsement of the Committee on Climate Change as part of the process.

3 An extensive skills and capacity development programme to enable delivery at scale and capture the jobs created for city.

There are specific training and capacity development requirements associated with, for example: installing heat pumps (retraining gas heating engineers); designing and installing heat networks; fitting EV charging infrastructure and the upgrading and smarter operation of the electricity network; waste reduction and repair skills; engaging households and businesses in significant system and behavioural change.

FIRST NEXT STEPS:

- Establish a **net zero skills and capacity development task force**, linking in with the One City Economy Board and the Inclusive and Sustainable Growth Strategy process. This should bring together key relevant employers and their trade associations (e.g. Western Power Distribution, Federation of Master Builders, Heating and Ventilation Contractors' Association, Energy Institute and energy managers association, leading EV charge point installers etc) and training providers (FE colleges and relevant expert training providers such as The Green Register).

4 Effective powers to set and enforce local planning policies and building standards to ensure all new build developments achieve meaningful net zero carbon standards and are aligned with the city's approach to decarbonisation.

54 In the absence of these powers being put in place, Bristol can still set out and initiate its transformational decarbonisation programme. But its realisation will depend, at least initially, more on persuasion and good will than formal powers to organise and require action. That said, if those formal powers were established but were not accompanied by meaningful public engagement and consent for change, there would be a risk that democratic processes will tend to work against their use. It is therefore likely to be the case that there will need to be clear and widespread signs of such consent for change before national and local political leaders are prepared to grant and implement such powers. Hence the importance of Key Intervention 1 above.

To ensure that new developments contribute positively to wider city efforts to decarbonise, the city needs to have the powers be able to ensure that all new build developments both achieve net zero standards and do so in ways which align with the city's wider approaches to decarbonising heat (e.g. heat networks and heat pumps rather than resistive electric heating) and transport (e.g. EV infrastructure, car clubs, reduction in vehicle mileage, within-city freight consolidation) and supporting a smarter electricity system. This will require powers for the city which national planning policy currently limits.

FIRST NEXT STEPS:

- The Council planning department, working with experts and other interested parties (including members of the One City Housing Board), should review the analysis presented here and draw up guidance for what a city-wide decarbonisation strategy will require of new developments (a) in any setting and (b) in specific locations identified for development.
- The Council, along with other core cities, should respond to the Future Homes consultation demanding that local powers to set higher energy performance targets and associated decarbonisation requirements for new build are retained and strengthened, irrespective of any national changes to building regulations.

A city with net zero infrastructure: installing the technology we need

5 Orchestrated city-wide programmes for insulation & heat pump retrofit and for district heating installation, on district-by-district basis (as 'net zero heat zones').

Building on the analysis undertaken for this study (adding detail about the status of the including electricity network – see 6 below), a more detailed district-by-district plan will enable the establishment of 'net zero heat zones' with far more specific building-by-building analysis and 'solution design'. This should be underpinned by appropriate household, business and landlord engagement to prepare the ground for the phase out of gas and the adoption of the appropriate heat decarbonisation solutions by building owners. The City Leap programme represents an opportunity to demonstrate this approach at an early stage.

FIRST NEXT STEPS:

- Working with Western Power Distribution and other key stakeholders across the city, the Council's Energy Service should undertake a more detailed heat decarbonisation options analysis, informed by more detailed understanding of the potential electricity network upgrade costs associated with different options in different parts of the city.
- Communications initiatives such as Bristol Green Doors (now part of the Futureproof programme) and Bristol Open Doors should showcase those buildings in the city which have been or are being retrofitted to achieve high energy performance standards and stop using gas for heating.

6 An accelerated electricity distribution network upgrade programme (incl. smarter operation) for a 'net zero' city.

The required upgrade to an 'electricity network for net zero' for the city needs to be designed and planned with Western Power Distribution within the next 12-18 months to ensure it is included and justified in the next regulatory business plan to be agreed with energy regulator Ofgem (together within any upstream implications for National Grid). There should also be exploration with Ofgem of the validity of any case being made to continue to invest in upgrading the gas distribution network (e.g. the replacement of iron mains), given the city's ambition to end the use of fossil gas to achieve net zero by 2030.

FIRST NEXT STEPS:

- Building on the heat decarbonisation analysis mentioned in 5 above, engage with Western Power Distribution and Ofgem on what an investment programme to achieve a 'network for net zero by 2030' would look like and how it can be integrated into business planning by WPD for the forthcoming new price control (RIIO-ED2).
- Explore with Wales and West Utilities (gas distribution network operator) and Ofgem the scale of network upgrade investment anticipated in the forthcoming new price control (RIIO-GD2) and the potential of it creating unnecessary costs in the context of Bristol's heat decarbonisation plans.

7 A major investment in transport modal shift (public transport & active travel infrastructure) to secure a rapid reduction in vehicle miles, reclaiming road space from private vehicles, encouraging freight consolidation, and discouraging car journeys into and around the city.

Alongside redesigning and re-engineering the city's road and traffic control network to support cycling, walking and public transport and reduce provision (including parking and for private cars and vans, this is likely to require subsidised public transport fares and integrated ticketing, and leadership from the city's public sector institutions.

FIRST NEXT STEPS:

- The Bristol One City Transport Board needs to adopt the Net Zero by 2030 goal and revise the city (and regional) transport strategies and the plans and investment to reflect this, including development of within-city freight consolidation.
- A visit to the London Borough of Waltham Forest's 'Mini Holland' project[55] would enable the Board to see transformation in practice and hear about how very vocal opposition was addressed.

8 A controlled but accelerated approach to EV charging infrastructure roll-out, aligned with a sustained push for EV car clubs and mobility as a service.

While the take-up of EVs by households and businesses can be expected to accelerate rapidly in the coming years as they become 'normal', there will need to be a city-wide approach to establishing a smart charging infrastructure which fits with Bristol's transport decarbonisation

55 This transformative initiative to redesign road layouts to favour cycling and walking, which initially faced very vocal opposition, is described at https://www.ashden.org/winners/london-borough-of-waltham-forest and https://www.enjoywalthamforest.co.uk/.

plan. This will require controlled co-ordination of the various companies currently involved across a wide range of commercial and grant-funded initiatives to install home, street, work-place and 'hub/fuelling station' EV charging points, potentially building out of the existing Go Ultra Low initiative being led by Bristol City Council. In part to address the needs of some 40% of Bristol's homes which do not have off-street parking and in part to help reduce car use and ownership, this charging infrastructure needs to include provision for an extensive network of car club EVs.

FIRST NEXT STEPS:

- Establish an **EV charging task force**, building on the Go Ultra Low initiative, including the companies already installing charge points in the city (both public and private), Western Power Distribution, major fleet owners in the city, and car club operators, with the aim of establishing a shared and co-ordinated city-wide plan for rolling out EV charging infrastructure and putting together a bid for investment.

A city enabled for net zero: sector-specific initiatives to enable change

9 A significant drive to reduce, re-use and recycle, with particular focus on food waste, plastic use and recovering plastic from residual waste from both household and commercial sectors to avoid carbon emissions from its incineration.

This will need to include: an extensive and sustained communication campaign across residential and commercial sectors; investment in a wider network of smaller household waste recycling centres, and; greater emphasis on reducing food waste, addressing textile consumption, re-use and recycling, and avoiding plastic. It will also require a mechanism for establishing and enforcing restrictions on residual waste (or charging for it in the household sector) and investment in extracting residual plastic waste prior to incineration.

FIRST NEXT STEPS:

- Refocus the Council's waste strategy on achieving net zero emissions from the city's waste by 2030.
- Explore options to extend influence on commercial waste collection businesses in the city and to simplify the local system so that there is a more consistent service explicitly aligned with the net zero by 2030 ambition.

10 A dedicated programme to involve businesses & households in developing and taking part in smart energy initiatives, signing up for genuine 100% renewable tariffs, and installing PV.

The most significant contribution Bristol can make to the decarbonisation of the electricity it uses is to be a smart, flexible demand on the system that contributes usefully to the greater system balancing requirements of having higher levels of variable renewable generation (particularly wind and solar). While this can be expected to develop gradually nationally, Bristol's combination of digital, data analytics and smart energy capabilities create an opportunity to create a smart energy industry cluster in the City and accelerate progress and engagement with smart energy services by businesses, public sector organisations and

households.[56] Encouraging the take up of genuine renewable energy tariffs by households, businesses and public sector organisations in the city will stimulate a more financially robust market for new renewable energy projects across the country.

56 See for example the 2015 report on the Bristol Smart Energy City Collaboration

10 Funding Bristol's route to net zero: reassigning expected investment and accelerating additional investment

Achieving net zero for scopes 1 and 2 carbon emissions in Bristol by 2030 will require a very significant level of investment of the order of at least £5 billion across the city over the next decade in: heat networks; building energy performance improvements and individual heat pumps; the upgrade and smarter management of the electricity network; electric vehicles and associated charging infrastructure; public transport improvement and expansion and; re-design of road layouts to reclaim space from private vehicles and encourage modal shift.

It will also require sustained year-on-year funding for the human capacity and resources required:

- to orchestrate and enable this activity, building and supporting appropriate delivery partnerships and governance structures
- to seek out and secure the funding required
- to engage the public and businesses to understand the scale and nature of change underway and to participate in programmes and initiatives and to commit to taking actions in their own homes and lives and work-places.

Based on the analysis here, the estimated total funding required between 2020-2030 for the different elements is shown in Table 11 below.

Table 11: Estimated total funding required 2020 - 2030 for Bristol to achieve net zero by 2030

Measure	Capex (£m) (incl c.10% opex)	Opex (annual costs) (£m)
Heating networks	£1,950m	Covered by heat sales
Individual building heat pumps	£580m	Covered by electricity bills
Insulation retrofit	£650m	N/A
Roof-top solar PV	up to £625m	Covered by electricity sales
Transport modal shift	£1,000-2,100m	Operations (incl. subsidised travel) covered by ticketing & road-user/parking levies
EV charging infrastructure	£175m	Covered by EV charging costs
Electricity network upgrade	up to £1,000m?	Covered by electricity bills
Waste decarbonisation	Depends on approach	Covered by levies?
Smart energy engagement initiative		Up to £1m a year to facilitate
Culture change programme		up to £2m a year
TOTAL	**£5 – 7 billion** + any major new public transport infrastructure	**£2-3 million a year 'new'**

As noted in Table 11, this does not include the investment that would be required if Bristol were to establish a new mass transit scheme (e.g. tram or metro) to increase public transport capacity rather than simply adding extra buses.

While this total funding requirement is significant, it is important to recognise that some of this investment and expenditure – perhaps as much as half – should not be considered 'new' or 'additional'. Instead it can be viewed as a reassignment of investment which could have anyway been expected in the course of the next decade in 'conventional' approaches, for example: replacing gas boilers with new gas boilers; buying new petrol or diesel vehicles; refurbishing, extending or upgrading buildings (but without achieving high energy performance standards); building new developments which do not achieve net zero standards; improving roads to accommodate traffic growth; establishing smarter management and operation of the local distribution network; reducing residential and commercial waste arisings and improving recycling rates to hit recycling targets.

One of the challenges is therefore to secure this reassignment of conventional investment towards the required net zero solutions from the householders, landlords, businesses, and public and regulated bodies who can be expected to be providing it. The 'net zero' solutions need to become the default rather than the exception. This will require a mix of regulatory requirements (e.g. effectively enforced minimum energy efficiency standards for buildings), new powers for the city, changes to market rules and carbon pricing, skills development and re-training initiatives, and a major public and business engagement programme.

However, the net zero solutions are generally more expensive than the current default 'conventional' options listed above. Indeed, a significant proportion of the required total investment to achieve net zero by 2030 is unlikely to prove 'cost-effective' in a conventional commercial sense under current policies and market rules and in a fossil fuel pricing regime which fails to reflect the full risks associated with their use.

Securing these solutions to achieve net zero carbon emissions by 2050 (in line with the legally binding national target) will therefore require additional investment to combine with the existing 'reassigned' investment and cover the anticipated additional costs of net zero solutions. In the context of Bristol's goal of achieving net zero by 2030, this could be considered 'accelerated additional' investment.[57]

This accelerated additional investment and expenditure and the efforts to reassign conventional investment can be justified simply on the basis of enabling the city to play its full part in addressing the climate emergency. Avoiding the existential threat represented by unmitigated climate change (and thereby avoiding an inestimably huge economic and social cost) should be justification in itself.

57 It will also require the other conditions for success described in each section of this report (such as new regulations and powers, skills and capacity development, consumer engagement etc) to be put in place to address non-financial barriers to take up – some of which will influence the reassignment of 'conventional' investment (by creating barriers for these 'solutions') and others of which will improve the commercial viability of the net zero solutions. The more effective the efforts to remove non-financial barriers to take up, the lower the cost differential with 'conventional' solutions will become (as they become increasingly difficult to undertake and net zero solutions become more straightforward and commonplace).

However, unless there is a major shift in carbon pricing or new and strictly enforcement regulatory requirements, it should not be expected that private sector investment will be readily forthcoming at sufficient scale (either from formal investors investing in new assets for a market-level return or from home-owners and building owners investing in improvements to their own buildings on an 'energy bill saving payback' basis to achieve net zero).

That is because the principal benefits of the investment in achieving net zero would not be a stream of income (or reduced energy bills) which could repay a loan or generate a return for an investor. Instead the benefits are principally 'common' or 'public' goods, such as a reduced risk of future catastrophe and the wider co-benefits of the actions to cut carbon emissions such as job creation, reduced air pollution and associated health benefits of this and more active travel choices, more affordable warmth for vulnerable households, and an improved public realm less dominated by vehicles. These 'public good' benefits could justify a significant public sector investment and funding support to secure these improvements.

In the absence of an imminent national commitment to such major public sector investment and funding on the accelerated timescale Bristol requires, the city will need to make a start by:

- Focusing on those investments in net zero solutions which do prove cost-effective in reasonably conventional terms, particularly where the city's public sector organisations have access to low cost borrowing and can make investments for long-term benefit – as intended for the City Leap programme.
- Resourcing a funding team to identify and secure on behalf of the city different sources of public funding that are made available to support, for example, innovation, pilot initiatives, technical assessment and planning, public engagement etc.
- Encouraging and showcasing those businesses and households who, as part of their own commitment to cut their emissions to net zero by 2030, are investing in improving their buildings and changing their vehicle and travel choices (often in spite of the apparent lack of a conventional business case). This will start to nor malise such 'positive public benefit' investment.
- Exploring opportunities to raise funds locally from citizens for a 'Bristol net zero fund' to commit to early stage investments in city net zero projects, recognising that the financial returns to reward such public benefit investments will be lower than current 'conventional' investments.
- Making the case to government for accelerated public sector investment in city-scale decarbonisation by Bristol as a 'pioneer' or 'vanguard' city (shifting beyond piecemeal 'pilot' funding that is at insufficient scale to shift local markets or underpin the development of local skills and capacity or build the long-term momentum and city-wide public and business involvement necessary to deliver a sustained response to the climate emergency).

11 The potential co-benefits of action to achieve net zero by 2030

The actions described in this report to achieve net zero from scopes 1 and 2 emissions across the city by 2030 can also bring with them local benefits associated principally with enhanced employment and skills, air quality and health, and a reduction in fuel poverty.

This section briefly explores each of these co-benefits and highlights the additional considerations which will be needed in programme design to ensure that they are realised for the benefit of the people and businesses of Bristol.[58]

Some of these co-benefits are the more-or-less inevitable consequence of taking the steps described in this report to reduce carbon emissions to nearly zero by 2030.

This applies to the **employment impacts** which would result from making the huge investment in infrastructure and system change which achieving net zero will require. However, ensuring this supports high quality jobs for Bristol's population will require both the provision of appropriate skills training and apprenticeship schemes in the city and the careful orchestration of these with the planned investment profile different investment programme to ensure the growth in demand for key skills can be met as it emerges.

This 'inevitable consequence of the investment' also applies to the **improvements in air quality** which would result from cutting vehicle miles and phasing out petrol and diesel vehicles (some of which would be replaced by EVs). Alongside the health benefits of cleaner air, there would be health benefits associated with more of the population engaging with active travel (walking and cycling) and a likely drop in collisions from accidents from fewer vehicles.

Other co-benefits are potential, but not inevitable, consequences of taking the steps described in this report. These include:

- **Tackling fuel poverty** (and achieving the associated health and social benefits) can be achieved through the proposed improved energy performance of homes and support to enable more vulnerable households to participate in smart energy initiatives. However, as discussed in Section 4, the scale of the impact on fuel poverty will also depend on the cost of heating that more efficient home with a heat pump or through a connection to a heat network (and the avoided costs of no longer paying a gas standing charge).

58 It was beyond the scope of this study to examine in detail the scale of co-benefits associated with achieving net zero (e.g. calculating the full health benefits associated with cutting NOx emissions from vehicles by 92% or predicting precise levels of reduction in fuel poverty by 2030 from improvements to the energy performance of homes when fuel poverty is also determined by income levels, fuel prices and tariff choices). These co-benefits have been usefully explored elsewhere (e.g. https://www.ashden.org/programmes/co-benefits) and the aspects they touch on (particularly air quality and fuel poverty) are currently being explored more directly by the Council in their own right.

- **Improvements to the public realm** should be possible because of the reducing traffic levels, freeing up space for active travel and 'green infrastructure' such as trees, planters and other growing spaces. That said, it will need to be planned with design for a higher quality public realm in mind, since traffic reduction measures will not inevitably lead to this outcome without deliberate effort.

Achieving these 'not inevitable' co-benefits will require a more purposeful approach to ensure that their value is factored in to the relevant programme designs so that the opportunities are realised. These are discussed briefly below.

Employment and skills

The level of investment required to decarbonise Bristol can be expected to support at least 75,000 – 100,000 person years of employment over the next decade.

In the same way that, as discussed in Section 10, some of the investment would effectively be reassigned from 'conventional' purposes towards 'net zero' purposes, some of this employment is likely to be through redeployment of the associated 'conventional' jobs which will be less in demand or phased out along with the carbon-intensive activity with which they are currently engaged.

Jobs for which demand would increase significantly in a city making the changes to achieve net zero by 2030 include:

- Building trades able to deliver low carbon retrofit of buildings
- Heat pump installers (rather than gas boiler installers)
- Heat network design engineers, pipe layers, road diggers, and system operators
- Power systems engineers (for network upgrade & smarter operation) & joint-fitters for doing the 're-wiring'
- Smart energy innovators and data analytics
- Solar PV system installers
- EV charging infrastructure installation and maintenance
- Bus drivers, cycling instructors & maintenance
- Freight consolidation scheme operators and drivers
- Recycling operatives
- Household, community & business engagement and advisory skills.

This list features a wide range of skills and associated educational qualification requirements. This means that achieving the net zero by 2030 ambition is likely to have an inclusive impact on the city's employment rates. It creates the potential for engaging a workforce in the process of decarbonising the city's energy, transport and waste which is representative of the whole city.

However, some jobs will significantly reduced. Given the lower number of vehicles in the city and the lower mechanical maintenance requirements of EVs, there will be far less work for car mechanics (and probably also car sales people as car numbers drop). Other jobs would be phased out altogether

in the scenarios described in this report. These include gas heating engineers (who could retrain to take on heat pump installation and maintenance) and those engaged with gas network maintenance and operation (who are likely to have skills relevant to heat network construction and operation).

Air quality and the associated health benefits of cleaner air and more active travel

The scenario for decarbonising transport outlined in Section 6 is projected to reduce NOx emissions from vehicles in the city by 92% from current levels and PM 2.5s by 37% (EVs still produce particulates from tyre, brake and road surface wear). This should translate into a significant improvement in the city's air quality and should therefore significantly reduce the ill-health caused by poor air quality (currently 300 deaths a year in the city are attributed to air pollution).[59]

Alongside the health benefits of cleaner air, there would be health benefits associated with more of the population engaging with active travel (walking and cycling). More than half of the city's adult population is overweight or obese and 27.5% of the population is physically inactive (physical inactivity contributes directly to 1 in 6 deaths in the UK). There is also likely to be a reduction in injuries caused by accidents as a result of fewer vehicles and improved public realm.

Tackling cold homes and alleviating fuel poverty

It is the ambition of Bristol, as set out in the One City Plan, that by 2030, nobody in Bristol will suffer from a cold home due to fuel poverty or their inability to have the necessary insulation and heating. Roughly 1 in 11 households in Bristol are living in fuel poverty according to the government's definition. The current situation is described in the Fuel Poverty chapter of the Joint Strategic Needs Assessment (JSNA) for the city.[60] The JSNA also outlines the significant impacts on health of fuel poverty and cold homes and therefore the potential health benefits of successfully addressing this problem. The cities ambition to tackle cold homes is being addressed through the development of a Fuel Poverty Strategy and Action plan which is currently in preparation.

The insulation programme to upgrade the energy performance of the city's buildings described in Section 4 would have a significant impact on these numbers (recognising that, as mentioned above, a dwelling's energy performance is only one of several factors influencing a household's ability to keep affordably warm in winter). However, it is not inevitable that this will be the outcome if the needs to address fuel poverty are not taken into account in achieving the decarbonisation of heat. This is because the shift away from gas heating is likely to increase heating costs.

At current prices, gas central heating provides the cheapest way to heat most homes per unit of warmth provided. It therefore (not unreasonably) tends to feature strongly as a measure to install and maintain

59 As reported in Bristol City Council's 'State of Bristol 2019: Key Facts' and https://www.bristol.gov.uk/documents/20182/32947/State+of+Bristol+-+Key+Facts+2018-19.PDF and in Bristol Transport Strategy 2019 – 26 at https://www.bristol.gov.uk/documents/20182/3641895/Bristol+Transport+Strategy+-+adopted+2019.pdf/383a996e-2219-dbbb-dc75-3a270bfce26c

60 See https://www.bristol.gov.uk/documents/20182/34772/Fuel+Poverty+JSNA+Chapter+%282018%29.pdf/46359d3e-74cd-524e-819f-d27c86a692ae

in programmes to tackle fuel poverty. However, because of the progress achieved in decarbonising electricity, each unit of gas being used now causes higher carbon emissions than a unit of electricity used for heating. This differential is set to get far greater and is even more significant if that unit of electricity is used in a heat pump serving an individual home or a district heating network (thereby generating perhaps 2.5 – 3 units of heat for each unit of electricity consumed). Gas central heating is now a higher carbon option than electric heating; this creates a tension between the challenge of achieving affordable warmth for every household and the challenge of decarbonising heat.

The analysis in Section 4 suggests that the heat decarbonisation solutions of a combination of insulation and heat pump or heat network connection would result in fuel bills some 20%-30% (£100-150 a year) higher than the average gas bill (both at current gas and electricity prices). That said, the insulation improvements would ensure the household had a far better chance of achieving healthy temperatures for the expenditure and the cost increase would potentially be offset by avoiding the need to pay the gas standing charge (c. £90 – 100 a year). It may therefore be possible to achieve heat decarbonisation and a significant reduction in cold homes without increasing overall heating bills and exacerbating fuel poverty.

There will need to be a decision by those designing and running (and funding) schemes to tackle fuel poverty about the date in the future when it is no longer appropriate to install a new gas boiler as the heating 'solution' for a fuel poor household. It would be appropriate to ensure that the heat decarbonisation solutions were fully available before that was done (see Section 4 for discussion of required rate of growth in installations from the low starting point of current practice), suggesting 2022 or 2023 as a possible suitable date.

In this scenario and to achieve net zero by 2030, there would need to be some subsequent replacement of the gas boilers which had been installed in the meantime. It would also make sense to consider how the gas heating installations anticipated over the next few years could be designed to be 'heat pump' or 'heat network connection' 'ready' to avoid the need for significant remedial work as the gas boiler is next replaced.

Improving the public realm

Reducing levels of traffic and deliberately reclaiming road space for cycling and walking creates the opportunity to significantly enhance the public realm across the city. Evidence from many cities and localities where this has been the deliberate intent of a traffic reduction scheme (notably recently in London Borough of Waltham Forest's 'Mini Holland' programme)[61] suggest that this may be a more obvious leading feature for proposals to support transport reduction than the impact on decarbonisation. Some thought will need to be given to how EV charging infrastructure is installed to enhance rather than diminish the quality of the public realm (by, for example, not assuming that charging points should take up pavement space).

61 See https://www.ashden.org/winners/london-borough-of-waltham-forest and also https://www.enjoywalthamforest.co.uk/

12 Conclusion

This study shows that there is a route for Bristol to achieve net zero in its scopes 1 and 2 carbon emissions by 2030.

Securing this route needs a truly radical and transformative approach to how the city heats its buildings and uses energy, how people and goods get about, and how we reduce and treat our waste. It requires an unprecedented rate and scale of change, applying technologies and techniques and establishing and maintaining levels of public and business engagement which are currently the rare exception rather than the commonplace rule.

This includes achieving by 2030:

- much better insulated buildings heated by heat networks and individual electric heat pumps to enable the end to the use of gas for heating;
- far smarter use of electricity across the city and growth in roof-top solar PV to support the decarbonisation of electricity generation nationally;
- a significant shift to public transport and active travel (walking and cycling) and a switch to electric vehicles (EVs) for the remaining fleet to accelerate the phasing out of petrol and diesel vehicles in the city;
- a significant reduction in waste, greater re-use and recycling, and the removal of plastics from residual waste.

The co-benefits of action are significant, particularly in employment (some 75,000 – 100,000 person years of work ranging from semi-skilled to highly technical) and air quality, health, fuel poverty, and an improved public realm as a result of reduced traffic.

Creating the conditions for success will require concerted action for change, with aligned leadership and extensive effort right across the city's public, business and voluntary sectors, communities and individual households. This will need to start now and scale up rapidly, building on the city's current strengths and addressing its weaknesses in addressing the challenges of decarbonisation.

Over the next decade (and mainly the next few years), the city will need:

- sufficient funds for infrastructure investment and for skills and capacity development (in the region of £5 – 7 billion between now and 2030 from private and public sources, about half of which would be reassigned from anticipated 'conventional' investment, such as in new gas boilers or petrol cars)
- new local powers to organise and require action
- better national policies, regulations and market rules
- a sustained culture change programme to establish new, shared expectations of how we will each live, work and travel in the city.

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