Ricardo Energy & Environment

Shetland Islands Council - NZCR

Final report on baseline, business as usual and net zero pathways

Report for Shetland Islands Council

Shetland Islands Council

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Executive summary

The target set by Scottish Government is to be net-zero by 2045. With interim emissions reduction targets of 75% by 2030 and 90% by 2040 against 1990 emissions levels. In response to this, the Shetland Islands Council has made clear commitments on climate change within their corporate plan "our ambition"[1], describing the synergies between climate action and other strategic plans for the Islands such as sustaining and creating new jobs.

This report looks at the challenges and priorities facing the Shetlands Islands Council (SIC). The starting point is the Council's 2019/20 baseline emissions, upon which different scenarios have been developed that chart realistic options to progress the strategic decarbonisation of the Council towards achieving net-zero by 2045. This report should be read in conjunction with other reports produced for the Council including:

- The Shetlands Islands area wide net zero routemap (NZSR)
- Project Neptune WP3 final report
- Assessment of Shetland Islands Council Land Carbon Sequestration

The routemap for the Shetland Islands Council has been developed by considering three possible futures for the Council in the form of pathways towards net-zero emissions by 2045. Each pathway involves different combinations of decarbonisation interventions, providing costed options and timings for deployment of measures under those pathways.

Specific challenges for the Council that are covered in this routemap include:

- Confirming the boundary for appropriate emissions reporting as the Council has a vast array of assets
- Examining the current pipeline of projects and programmes already planned for by the Council
- Identifying key mitigation measures that the Council must implement at a minimum to achieve net zero
- Understanding the costs of potential measures, in the context of limited capital and revenue resources
- A framework and key considerations to allow the Council to develop a robust implementation plan and deliver on their net zero commitments
- Many low carbon technologies are currently in their infancy and as such, it is not yet clear how technologies will develop, and therefore which will be the most appropriate for the Council to adopt Analysis is therefore based on best available information at the time of writing and must be continually evaluated by the Council

The emissions baseline for the Council's net zero routemap is the 2019/20 financial year. Projected emissions against that baseline have been mapped out to 2045, using our current understanding of planned Council activities and the wider context of local, regional and national changes over that timescale.

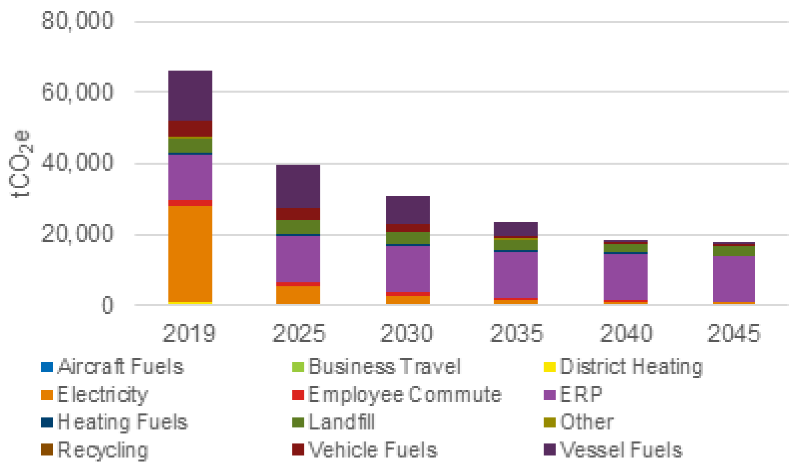

Figure 1 - Business as usual emissions by source

The emissions sources included in the baseline are heating fuels, transport fuels, electricity, district heating, refrigerant gases, water

[1] https://www.shetland.gov.uk/downloads/file/2586/our-ambition-corporate-plan-online-version

supply and treatment, the Council's landfill site, the energy recovery plant (ERP), waste sent to recycling centres, business travel and employee commuting.

In 2019/20, the Shetland Islands Council was responsible for emissions totalling **65,875 tCO2e**, which is projected to decrease by **47%** under the business as usual for the Council to **34,674 tCO_2e**.

Through discussions with the Shetland Islands Council, three net-zero pathways have been modelled, identifying three different routes to net zero. These are

2030 ambitious pathway – assumes that significant resources and budget are made available to allow the rapid implementation of measures by 2030. This approach looks to minimise carbon emissions by 2030 with technologies available over that time frame though does not look at decarbonisation beyond 2030 other than through factors outside of the Council's control, e.g. decarbonisation of the national electricity grid. For some emissions sources therefore, the selection of decarbonisation technologies is restricted by technology maturity.

2040 pragmatic pathway – assumes a pragmatic approach to the selection of decarbonisation measures whereby assets are replaced with low carbon alternatives at their end of life, and more cost-effective technologies and approaches are preferred and therefore modelled. All assets that approach their end of life within the scenario timeframe are assumed to be replaced with low carbon alternatives.

2040 ambitious pathway – assumes that significant resources and budget are made available to minimise the Council's emissions by 2040. For several emissions sources therefore, this is likely to require significant transformation to current services and operations.

The figure below shows the emissions trajectory for all pathways.

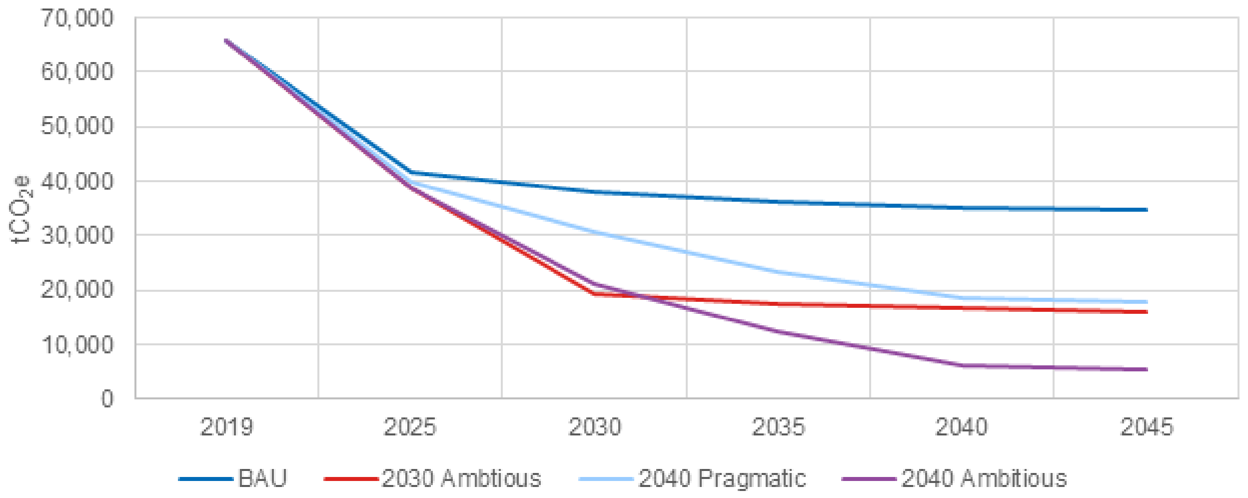

Figure 2 - Pathway comparison to 2045

The figure above demonstrates that all pathways ultimately lead to a reduction in Council emissions in 2045 that is significantly greater than the projected 47% emissions reduction under the business as usual (BAU) scenario. The key messages are as outlined below:

Key messages

The 2030 ambitious pathway achieves the most cost-effective rate of decarbonisation, costing approximately 50% less per tonne of carbon saved when compared to the two 2040 pathways. The 2030 pathway is able to achieve for this for four main reasons:

1. Pathway includes carbon capture at the ERP which is more cost-effective than most other decarbonisation measures
2. Pathway only includes a limited roll out of low carbon fuels to ferries and tugs, which require high capital investment
3. Pathway sets a target of 60% of domestic properties to achieve EPC B or higher. Domestic properties decarbonise significantly under the BAU scenario and as such, are not cost effective to decarbonise further
4. Measures are rolled out sooner, therefore where there is an operational cost saving, this is achieved over a longer time period

- The 2040 ambitious pathway has more than 10,000 tCO_2e fewer residual emissions in 2045 the other two pathways, which is expected to be significantly easier, and more cost effective to offset
- The 2040 ambitious pathway achieves 27% more cumulative carbon savings by 2045 than the 2030 ambitious pathway, and 76% more than the 2040 pragmatic pathway.
- The difference in cumulative savings between the 2030 ambitious pathway and the 2040 pragmatic pathway (+40%) demonstrate the benefit of taking early action, despite the two scenarios achieving similar levels of total annual carbon reduction in 2045.
- In each pathway, different measures contribute differently to total carbon reduction however there some key themes:
  - Vessels are a significant source of emissions in the baseline and continue to be under the BAU scenario. Decarbonisation of vessels is one of the biggest contributors to emissions reduction in each pathway and is therefore fundamental to achieving net zero for the Council.
  - The ERP is also a significant source of emissions. There are some key decisions that the Council needs to make around the future of the ERP, and subsequently the future of low-cost heat in Lerwick. Carbon capture, however, appears to be a relatively low cost emissions reduction measure and therefore does indicate one potential cost-effective decarbonisation pathway.
  - Decarbonisation of the Council's domestic building stock is largely achieved through decarbonisation of the electricity grid and therefore further decarbonisation achieves diminishing returns, despite requiring high levels of capital investment. As such, the focus for the Council's domestic building stock should be on achieving EESSH 2 compliance in a pragmatic manner, with a focus on minimising energy costs (whilst simultaneously not driving up rent costs).

As modelled in the three pathways, there are significant differences in the capital investment profile that arise through the mixture of measures selected, their year of installation and the corresponding cost savings primarily from fuel switching but also efficiencies in energy use overall. The pathways with the highest investment demonstrate a faster route to net zero, and a higher level of overall long-term savings.

The recommended pathway for the Shetland Islands Council to follow is the 2040 ambitious pathway, which addresses all major emissions sources, achieving a 92% reduction in emissions from the 2019/20 baseline by 2045.

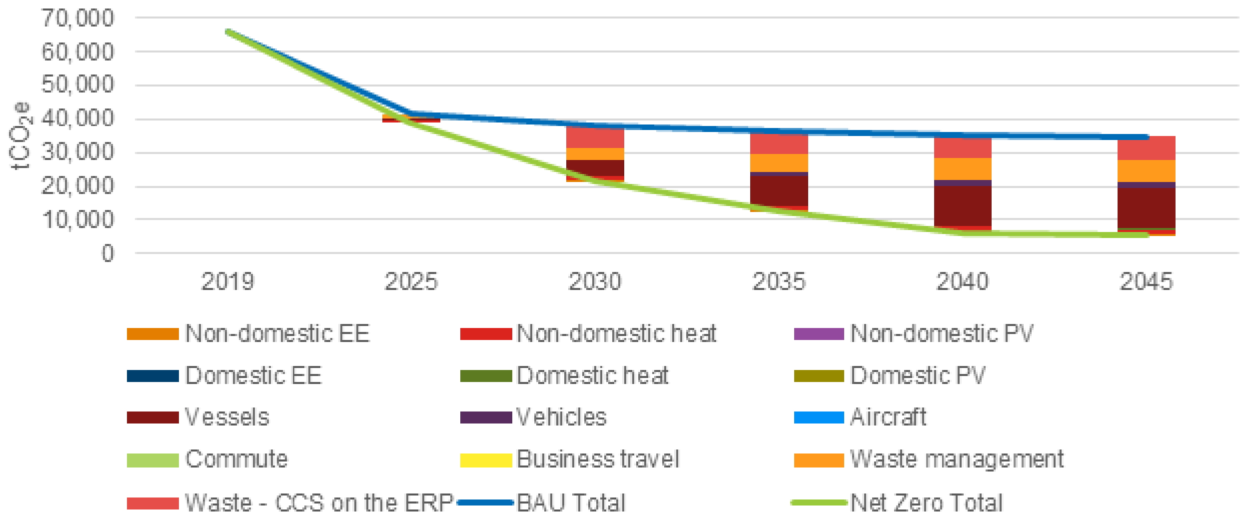

Figure 3 - Contribution of measures to the 2040 ambitious pathway

In spite of the risks and indicative costs outlined, Shetland Islands Council recognises that the public sector has a duty to lead on the investment in low and zero-carbon solutions, provided that it is given the appropriate funding. The SIC also recognise the role they play in driving climate action within the local area and leading by example. Strong policy direction and clear requirements for future low carbon technologies will give the market confidence to develop solutions and generate efficiencies of scale, paving the way for the rest of society to follow.

Most importantly, early adoption of low and zero-carbon solutions will lead to early cuts in carbon emissions and fuel costs which will have long term global environmental benefits, and immediate expenditure savings for the Council to use to either fund further decarbonisation or provide to other critical services.

The Shetland Islands Council must now set out a clear implementation plan that identifies the key actions, milestones and targets that will enable the Council deliver on their net zero commitments.

The Shetland Islands Council has a strong opportunity to achieve net-zero by 2040, with significant options to implement measures to reduce the need for expensive off-setting requirements beyond 2040.

To achieve net zero through divestment from all fossil fuels, it is recommended that the Shetland Islands Council implements/reviews the following measures at a minimum whilst continuing to investigate other technologies & emissions reduction opportunities where full information is not currently available.

General

- Develop an action plan for the implementation of measures outlined in the 2040 ambitious pathway, and set up strong internal governance by:
  - Setting up a Net Zero taskforce within the Council that has responsibility for driving the implementation of the measures outlined in the pathway, as well as monitoring the outcomes of these measures to continually provide lessons learned.
  - Mandating climate impact assessments at key project milestones to ensure that projects are in line with the Council's broader suitability objectives.
  - Maintain the routemap and action plans as live documents, with regular reviews of the measures recommended within the report, in particular at major investment decision points that would have a significant impact on emissions and ahead of reaching major milestones.
  - Setting a carbon budget for the Council to regularly report progress against

Non-domestic buildings

- Replace fossil fuel heating systems with low carbon alternatives. The 2040 ambitious pathway models the impact of electric heating systems such as heat pumps, electric storage heaters or a district heat network connection. However, over the next 20 years, emerging technologies such as hydrogen boilers are likely to become more competitive. The SIC must continue to monitor developments in low carbon heating systems and select technologies as appropriate based on the outcomes of feasibility studies
- Strategically upgrade building fabric to minimise heat loss. This is particularly important where potential low carbon heating systems would not perform effectively without fabric upgrades
- Replace all fossil fuels used for catering, likely with electric systems

Domestic buildings

- Replace fossil fuel heating systems with low carbon alternatives. The 2040 ambitious pathway models the impact of electric heating systems such as high retention storage heaters, heat pumps or a district heat network connection. However, over the next 20 years, emerging technologies such as hydrogen boilers are likely to become more competitive. The SIC must continue to monitor developments in low carbon heating systems
- Strategically upgrade building fabric to minimise heat loss.

Transport

- Replace all fleet vehicles including buses with low carbon models such as EVs or hydrogen fuel cell vehicles aligned with Scottish Government public sector fleet decarbonisation targets
- Replace ferries and tugs with low carbon alternatives. The market for low carbon vessels is emerging, however it is likely that alternatives utilising either hydrogen fuel cell, battery electric or dual fuel (hydrogen-biofuel) propulsion systems will be developed.
- Replace aircraft with low carbon alternatives. The market for low carbon aircraft is developing, however it is likely that alternatives utilising battery electric or hydrogen fuel cell will be available that suit the needs of the Council. An alternative potential opportunity is to begin using a sustainable aviation fuel blend.
- Ensure there is sufficient charging and hydrogen storage and refuelling infrastructure to enable the above.

Infrastructure

- Target significant levels of waste reduction both within the Council and across the Shetland Islands to minimise emissions from landfill
- Continue investigating the opportunity to install carbon capture on the exhaust from the ERP

Other identified measures across all three potential pathways are aimed at reducing absolute emissions through efficiency improvements, better operating practices through implementation of policies, generating electricity from renewable sources, or replacement of existing equipment with high-efficiency models.

1 Introduction

1.1 What is net-zero?

Achieving net-zero is about reducing avoidable emissions as far as possible and then achieving zero-emissions by balancing unavoidable use of fuels, energy, transport and processes that generate greenhouse gases with projects that 'offset' the equivalent amount.

While there is no universally agreed official definition of net-zero, the key working principals agreed between Ricardo and the Shetland Islands Council are to 'balance greenhouse gas emissions through mitigation measures and removal from atmosphere, within your boundaries, over time'.

The definitions of Scope 1-3 emission sources are provided below for reference. In principle, absolute zero should be targeted for Scope 1 and Scope 2 emission sources by 2045 (other than unavoidable emissions, such as those from landfill when all options to reduce waste to landfill have been accounted for) and net zero when including Scope 3 emission sources.

Scope 1: from the activities of an organisation or under the organisations control. Including fuel combustion on site such as oil boilers, fleet vehicles and air-conditioning leaks.

Scope 2: from electricity, steam and heat purchased and used by the organisation. Emissions are created during the production of the energy and eventually used by the organisation.

Scope 3: from activities of the organisation occurring from sources that they do not own or control, such as emissions associated with business travel, waste and water.

1.2 What is a net-zero routemap?

A net-zero routemap provides options for the strategic decarbonisation of an organisation, a public body, an industry sector or even entire regions over a set timescale.

This routemap for the Shetland Islands Council (SIC) has been developed by considering three possible futures for the Council in the form of pathways towards net-zero emissions by 2045 that involve different combinations of decarbonisation interventions. This will enable the Council to engage strategically with teams responsible for key emission areas, as well as other delivery partners on their net-zero journey.

1.3 Why has the Shetland Islands Council developed a net-zero routemap?

The target set by Scottish Government is to be net-zero by 2045. With interim emissions reduction targets of 75% by 2030 and 90% by 2040 against 1990 emissions levels. In response to this, SIC has made clear commitments on climate change within their corporate plan “our ambition”[2], describing the synergies between climate action and other strategic plans for the Islands such as sustaining and creating new jobs. The key requirements guiding net zero for SIC are:

1. The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019
    a. The Scottish Government has set a legally binding target for Scotland to be net zero by 2045 with the latest interim emissions reductions targets of 75% by 2030 and 90% by 2040.
    b. The Act requires public bodies to exercise their functions in a way that contributes to delivering these targets.
    c. Councils are required to reduce their operational GHG emissions to meet a net zero target by 2045 at the latest.
2. The SIC’s Corporate Plan “Our Ambition 2021-2026”
    a. SIC have stated that they will “prepare and implement a Council net-zero plan and lead the preparation of a Shetland net zero strategy involving community planning partners and a range of energy-focussed businesses”.
3. Scottish Government’s Transport strategy issued in June 2020
    a. A 75% reduction in carbon emissions by 2030 and net zero by 2045.
    b. A net zero aviation zone to be developed across the Highlands and Islands
4. The £100 million Islands Growth deal provides a unique opportunity to ensure that future investment in Shetland will support the delivery of the net zero target.

1.4 What is included in the routemap?

The project workflow in developing the routemap is shown in the figure below.

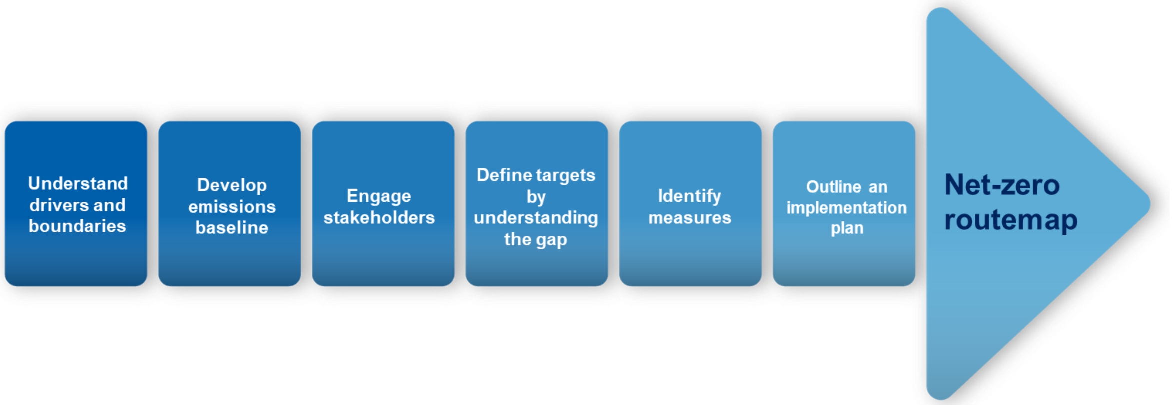

Figure 4 - Key stages in defining and developing a net-zero routemap

The routemap report itself covers four major steps:

1. Defining the 2019/20 emissions baseline for the Council’s operations.
2. Setting a ‘Business As Usual’ projection of those emissions to 2045, taking into account any known or planned interventions that will have an impact on emissions, including external factors outside the control of the Council.
3. Setting out pathways to net-zero that look at both technology and policy options to address the gap to net-zero.

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[2] https://www.shetland.gov.uk/downloads/file/2586/our-ambition-corporate-plan-online-version

4. Drawing conclusions from a comparison of the pathways and making recommendations for next steps.

At this stage, it is equally important to set out what the routemap **does *not* cover**, and why:

- *Carbon sequestration measures and detailed offsetting options* (such as greenhouse gas removal technologies). A separate project to calculate the carbon sequestration potential of the entirety of the Shetland Islands (The Assessment of the Shetland Islands Council Land Carbon Sequestration) has been undertaken during 2021/22. The outcomes of this study are referenced in this report.
- *Land use and land use change emissions* have not been included as an emissions source in this routemap as emissions arising from indirect land use changes are optional for corporate reporting[3] Land use emissions arising from Council landholdings have been assessed by the Council through The Assessment of the Shetland Islands Council Land Carbon Sequestration project.
- *Supply chain and procurement* are also not in scope as the level of emissions related data available is not in line with the quality of other data sets. Emissions from procurement related activities have been calculated and presented in Appendix A3 for completeness and context though not included in net zero pathway analysis.
- *Non-CAPEX and OPEX costs* of implementing measures are not included in the report, particularly in terms of staff resources for managing the implementation, procuring services to deliver the work, clearing out and/or moving of staff and equipment during the works etc. This 'unseen enabling cost' cannot be quantified at this level of granularity within the study. Where a measure is likely to incur significant disruption to normal operating procedures, this has been noted within the report.
- *Costs for current planned projects* are not in scope for this work as this is considered Business As Usual and does not impact on the additional emissions reduction measures modelled for the Council.
- *Public buses* have not been included within this routemap as they are not owned or operated by the Council, despite the Council having a significant stake in their procurement. Emissions from public busses are captured within the Shetland Islands Net Zero Routemap (NZSR).
- *Fixed links* This study has not assessed the impacts of fixed links in detail. Based on discussions with stakeholders and community members, it is likely that fixed links would result in more car journeys overall, with the potential to displace some ferries. Given the uncertainties around whether and how these different transport modes will decarbonise, the overall impacts from an energy and emissions standpoint are not clear. On the other hand, there are considerable social and economic benefits of fixed links. These could contribute to improving the community's resilience, in particular opening up a wider range of job opportunities, which will be important when having to adapt to the now-inevitable impacts of climate change. It is recommended that any consideration of fixed links should include a more detailed assessment of the potential embodied carbon impacts, along with the anticipated impacts on the transport network.

It's also important to note that measures identified in this assessment are not a finite list and how they have been applied to the three net zero pathways is not a commitment by the Council to a certain technology. Many low carbon technologies are currently in their infancy and as such, it is not yet clear how technologies will develop, and therefore which will be the most appropriate for the Council to adopt. The Council therefore must keep up to date with emerging technologies. As these technologies develop and begin to enter the market, the Council must engage potential suppliers to better understand practical and financial considerations and subsequently conduct feasibility studies where appropriate to inform their decision making. Only then can the Council commit to adopting technologies that are suitable and appropriate. In short, the Council is committed to reducing emissions, though is not at this stage committing to any specific technologies. The Council must conduct full financial and technical feasibility studies to fully understand the practical and financial implementation considerations before measures are committed to and implemented.

[3] SBTi-criteria.pdf (sciencebasedtargets.org)

2 Baseline assessment

Setting the emissions baseline for the 2019/20 financial year allows SIC to understand the position from which it is starting its net zero journey. This reporting year has been selected as it is the most recent and representative reporting year not impacted by the Covid-19 pandemic. It will also allow for comparison with island-wide emissions, for which the latest year data is available is 2019.

2.1 Methodology

2.1.1 Standard

The baseline for the 2019/20 financial year has been calculated using the Greenhouse Gas (GHG) Protocol Corporate Accounting and Reporting Standard developed by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI); this sets out a corporate accounting and reporting methodology for GHGs. These have also been calculated in line with ISO 14064-1. Note that as per the GHG Protocol, all emissions sources owned or controlled by the Council have been included in the Council's emissions baseline.

Emissions have been calculated by scope, defined below:

	Description	Emissions examples
Scope 1	GHG emissions arising from sources that are owned or controlled by the organisation. These emissions result from activities that the organisation has direct influence over through its actions	Diesel and gas oil for vehicles and vessels Burning and gas oil for building heating Refrigerant gas leakage Waste sent to landfill or incineration*
Scope 2	GHG emissions associated with the use of electricity imported from the grid or from a third-party supplier of energy in the form of heat or electricity.	All grid supplied electricity Heat provided by the Lerwick district heating network
Scope 3	GHG emissions arising as an indirect consequence of the use of goods or services provided to or by the reporting organisation, i.e. across its value chain, both upstream and downstream of its operations.	Supply and treatment of water Business travel Waste sent to recycling centres*

Table 1 - Summary of emissions scopes

*Note that waste sent to landfill or incineration are scope 1 emissions for the Council as these are SIC owned and controlled operations.

Biomass is burnt at a limited number of sites and is included in the baseline as a scope 1 emissions source. Within the scope 1 conversion factors for bioenergy, the CO_2 emissions value is set as net '0' to account for the CO_2 absorbed by fast-growing bioenergy sources during their growth. However, nitrous oxide (N_2O) and methane (CH_4) emissions are not absorbed during growth and as a result, the combustion of biomass does not have net '0' CO_2e emissions. As such, biomass is reported under scope 1 emissions in this report.

2.1.2 Emission sources

The emission sources included within the emissions baseline are outlined in Figure 5 and the supporting table below.

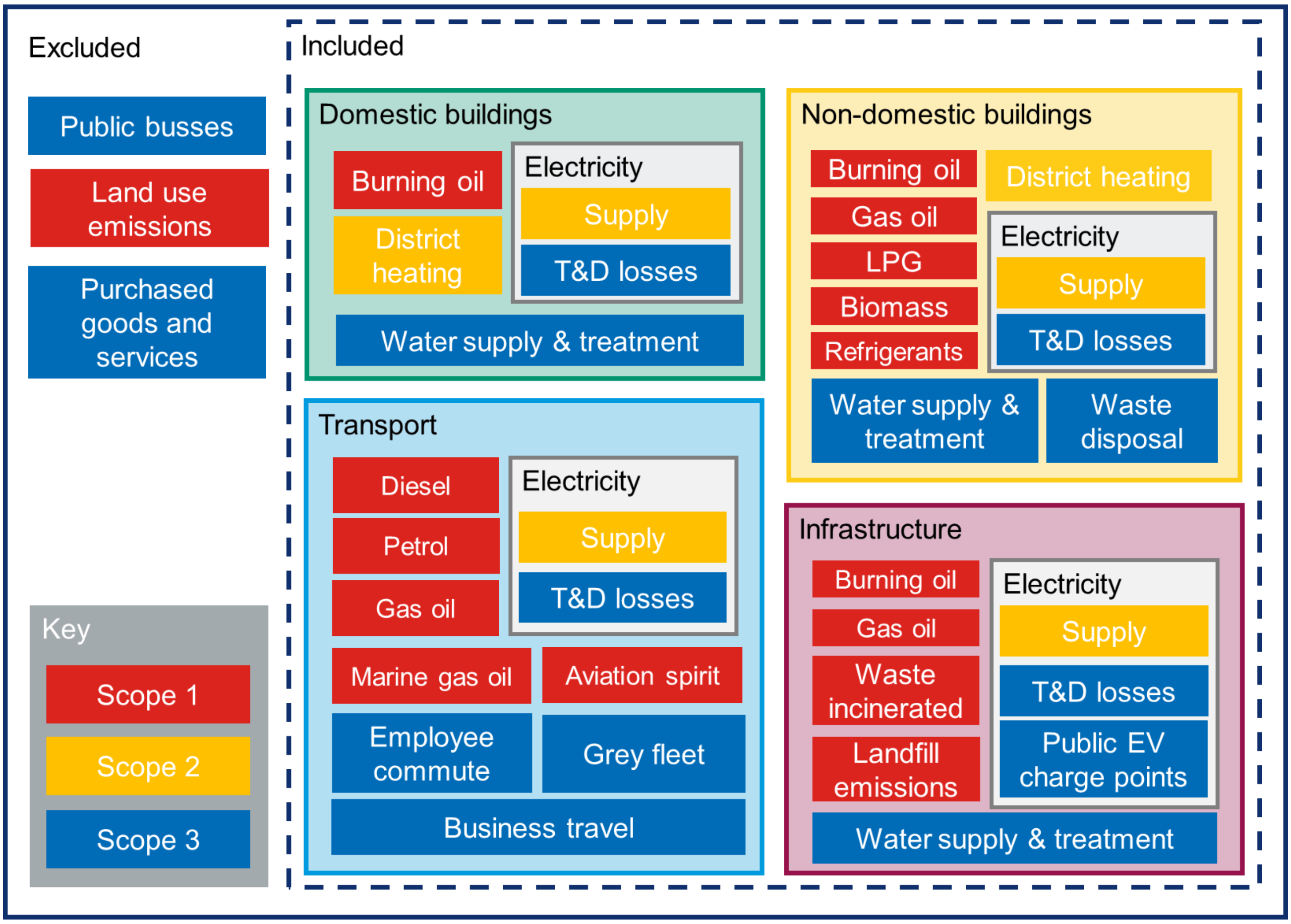


Figure 5 – Summary of emissions sources

These emission sources have been grouped into sectors, as per the table below. Note that any emissions source that is either owned or controlled by the Council has been included in SIC's scope 1 & 2 emissions. This includes the Council's housing and the Council's leased vehicle fleet.

Sectors	Notes	Emissions Sources & Scope		
		Scope 1	Scope 2	Scope 3
Domestic	All Council owned domestic properties. Whilst energy supplies are managed by tenants, the properties themselves are owned by SIC, as such power and heating consumption are included in scopes 1 & 2. Note that water consumption is based on Energy Savings Trust's estimates per households.[4]	• Burning oil	• Grid electricity • District heating	• Electricity T&D losses • Water supply & treatment

[4] https://www.energysavingtrust.org.uk/sites/default/files/reports/AtHomewithWater%287%29.pdf

Sectors	Notes	Emissions Sources & Scope		
		Scope 1	Scope 2	Scope 3
Non-domestic	All Council owned non-domestic properties and sites including schools, offices, care centres, ferry terminals, public toilets etc.	• LPG • Burning oil • Gas oil • Wood pellets (biomass) • Refrigerant losses	• Grid electricity • District heating	• Electricity T&D losses • Water supply & treatment
Transport	All transport, vehicle and mobile machinery emissions including Council fleet (ferries, tugs, vehicles & leased vehicles, council operated buses), grey fleet, business travel and employee commuting.	• Diesel • Marine Gas Oil • Gas Oil • Petrol • Aviation fuel	• Grid electricity	• Electricity T&D losses • Petrol (grey fleet) • Employee commute • Business travel
Infrastructure	All Council owned and operated infrastructure including Scord Quarry, the Energy Recovery Plant (ERP), landfill, street lighting etc.	• Burning oil • Gas oil • Waste disposal	• Grid electricity	• Grid electricity (for public EV charge points) • Electricity T&D losses • Water supply & treatment • Waste disposal (recycling)

Table 2 - Summary of emissions sources by sector and scope

2.1.3 Location and market-based reporting for scope 2 emissions

According to the GHG Protocol, scope 2 emissions can be reported through location-based and/or market-based methods as per below

- **Location-based method**
  - This method reflects the average emissions intensity of electricity grids where energy consumption occurs. For the Shetland Islands electricity grid, there is no official emissions factor, as such an emissions factor for electricity has been sourced and developed from the Pure Energy Centre[5].
- **Market-based method**
  - This method reflects the supplier specific emissions factor for any electricity purchased. Energy suppliers in the EU are required, by law, to disclose to consumers the fuel mix and GHG emissions associated with their portfolio or tariffs.

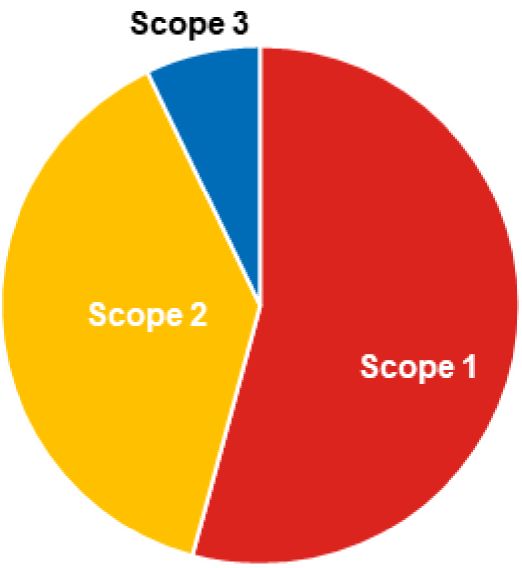
[5] Pure Energy Centre's "Shetland Energy Source Analysis 2020 Refresh – Summary of key findings"

Under GHG Protocol and UK Government best practice, organisations are encouraged to use location-based grid emissions factors. As such, location-based reporting has been used for SIC's net zero baseline, BAU and net zero pathways.

2.2 Results

The figure below provides a breakdown of SIC's baseline emissions by scope. Note that emissions from purchased goods and services have been excluded as an emissions source within the net zero routemap. This is because at this stage, due to availability of data, emissions could only be estimated based on the Council's procurement data. Procurement data provides a rough, high-level indication of emissions, the detail of which is not in line with other Council emissions data. As such, emissions from purchased goods and services have not been taken forward for further analysis in the BAU and net zero pathways as more detailed data is required to provide credible decarbonisation scenarios. For an indication of the Council's baseline emissions including purchased goods and services, see Appendix A3.

Note that any emissions source that is either owned or controlled by the Council has been included in SIC's scope 1 & 2 emissions. This includes the Council's housing and the Council's leased vehicle fleet.



	FY 19/20 GHG Emissions, tCO_2e	Breakdown
Scope 1	35,709	54%
Scope 2	25,457	39%
Scope 3	4,709	7%
Total	**65,875**	

Figure 6 – Breakdown of FY 19/20 emissions by scope

The figures below show the breakdown of the emissions baseline by sector (Figure 7), sub-sector (Figure 8) and emissions source (Figure 9).

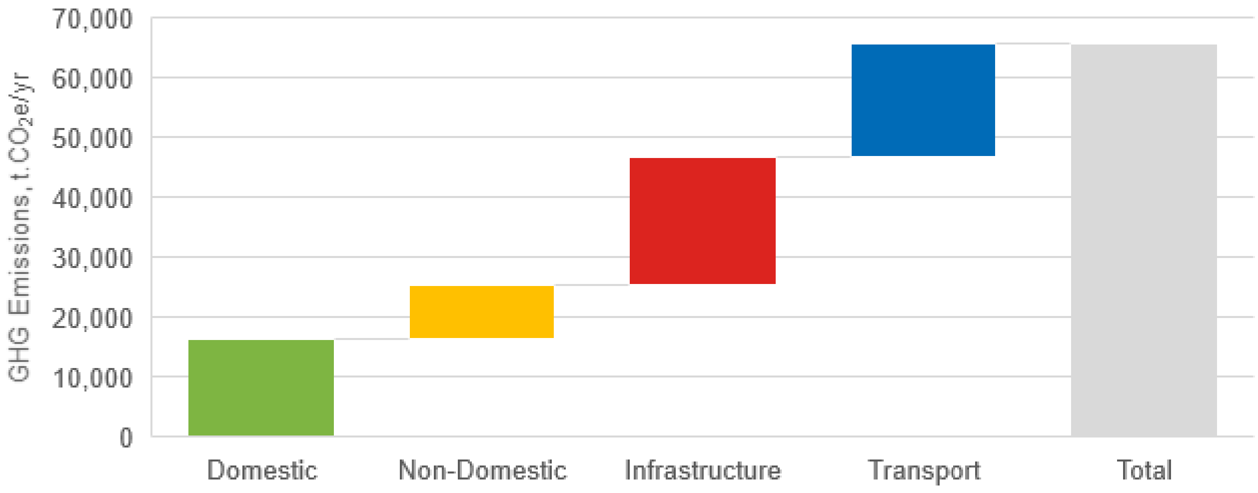


Figure 7 - Breakdown of FY 19/20 emissions by sector

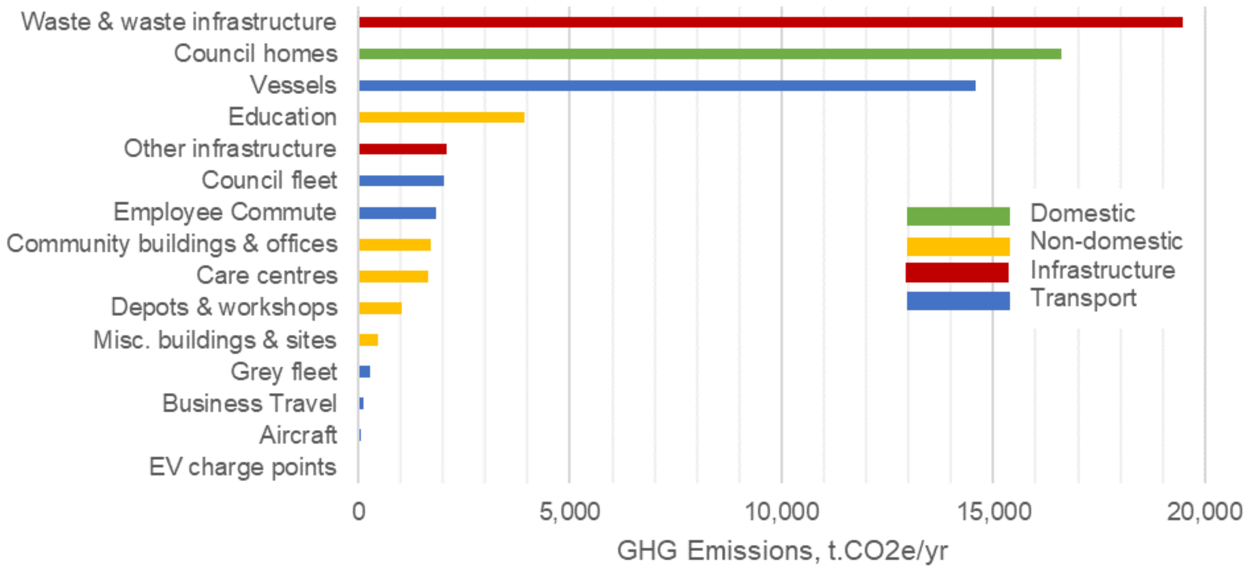


Figure 8 – Breakdown of FY 19/20 emissions by sub-sector

The figure above demonstrates that the most significant source of emissions is the Council's waste infrastructure (including the energy recovery plant and the landfill site) followed by the Council's domestic properties. Whilst these properties are owned by the Council, energy supply is managed by the tenants and as such, consumption data is not available. As a result, heating and electricity consumption have been estimated based on OFGEM's Regional Typical Domestic Consumption Values (TDCVs) and applied to the Council's domestic properties based on the existing heating systems. It should be noted that the Council's Energy Efficiency Standards for Social Housing (EESSH) database indicates that the majority (90%) of the Council's domestic properties are heated electrically. The breakdown of emissions by sector is detailed in the table below.

	Sub-sectors	Notes	FY 19/20 GHG Emissions, tCO_2e	Breakdown
Domestic	Council homes	Energy consumption has been estimated based on OFGEM's Regional TDCVs database. Water consumption based on Energy Savings Trust estimates per household.[6]	16,612	25%
Non-domestic	Care centres, community buildings & offices, depots & workshops, education and misc. buildings & sites	Misc. buildings & sites includes toilets, garages, cemeteries etc.	8,798	13%
Infrastructure	Waste & waste infrastructure, other infrastructure and EV charge points	Other infrastructure includes Scord quarry, street lighting, navigation lighting etc..	21,555	33%
Transport	Vessels, Council fleet, grey fleet, & business travel	All vehicles included in transport (e.g. refuse collection, small plant etc.)	18,910	29%
Total			**65,875**	

Table 3 - Summary of emissions by sector

Figure 9 below demonstrates that the fuel responsible for the greatest emissions in the base year is grid supplied electricity. The majority of electricity supplied to the Shetland Islands electricity grid is from diesel generators. As such, grid supplied electricity has a significantly higher emissions factor than that of mainland UK. Projections for the emissions intensity of grid electricity are detailed in the BAU section of this report.

[6] At Home with Water (energysavingtrust.org.uk)

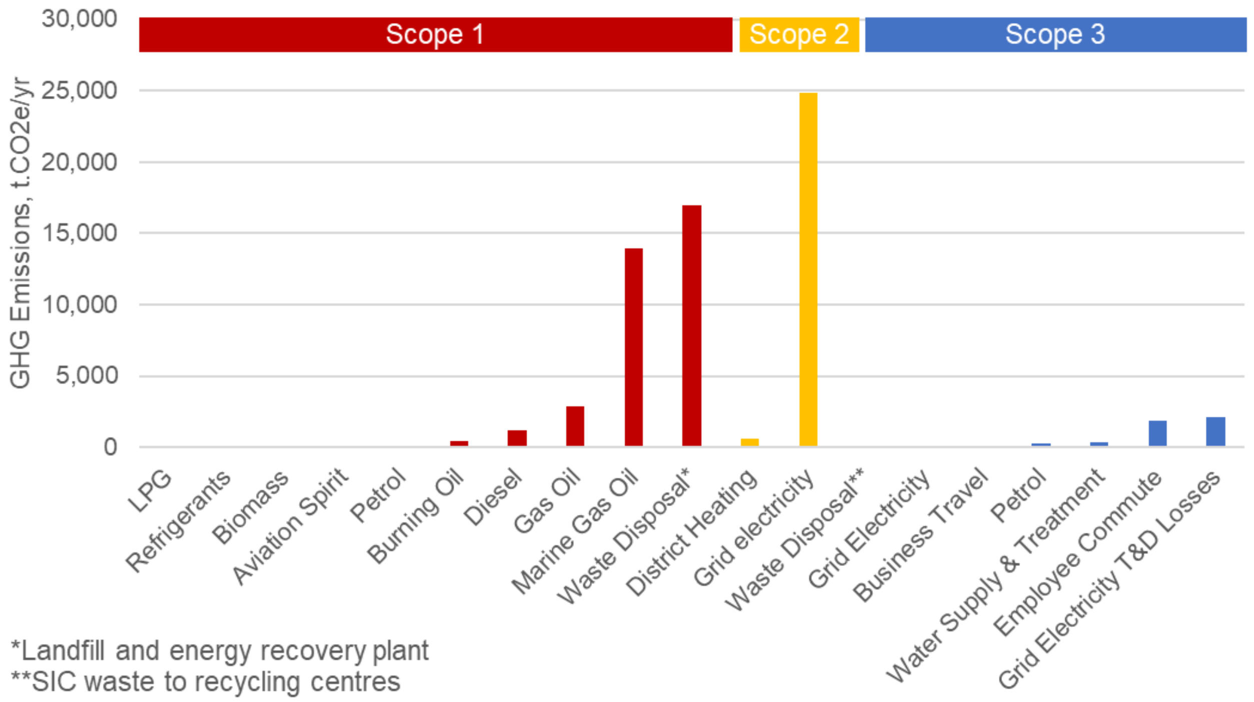


Figure 9 - Breakdown of FY 19/20 emissions by fuel type

The table below details the breakdown of emissions by fuel type and scope across the SIC estate.

Fuel type	FY 19/20 GHG Emissions, tCO_2e				% of total emissions	Notes
	Scope 1	Scope 2	Scope 3	Total		
Aviation Spirit	61	0	0	**61**	**0%**	
Biomass	27	0	0	**27**	**0%**	
Burning Oil	468	0	0	**468**	**3%**	
Business Travel	0	0	139	**139**	**0%**	
Diesel	1,222	0	0	**1,222**	**4%**	
District Heating	0	580	0	**580**	**1%**	Emissions factor calculated based on information provided by SIC & SHEAP[7]
Employee Commute	0	0	1,829	**1,829**	**2%**	
Gas Oil	2,901	0	0	**2,901**	**2%**	

[7] Shetland Heat and Power (SHEAP)

Fuel type	FY 19/20 GHG Emissions, tCO_2e				% of total emissions	Notes
	Scope 1	Scope 2	Scope 3	Total		
Grid Electricity	0	24,876	17	**24,893**	**51%**	
Grid Electricity T&D Losses	0	0	2,113	**2,113**	**4%**	
LPG	2	0	0	**2**	**0%**	
Marine Gas Oil	13,930	0	0	**13,930**	**15%**	
Petrol	127	0	290	**417**	**0%**	
Refrigerants	4	0	0	**4**	**0%**	Actual refrigerant losses not recorded. Refrigerant loss therefore estimated based on quantities of equipment
Waste Disposal	16,967	0	9	**16,976**	**18%**	
Water Supply & Treatment	0	0	312	**312**	**0%**	Water consumption at Council homes is based on Energy Savings Trust household estimations
Total	**35,709**	**25,457**	**4,709**	**65,875**		

Table 4 – Breakdown of emissions by fuel type and scope across the SIC estate

3 The Business-as-usual scenario

3.1 Definition

The Business as Usual (BAU) scenario represents a scenario for SIC where no further action is taken to decarbonise operations above what has already been committed to in capital plans.

This scenario takes account of growth and planned capital investment. The relevant projects and programmes have been determined through engagement with SIC building, energy efficiency, waste and transport managers, key staff and third-party representatives.

These factors considered as part of the BAU scenario are summarised below:

- **Known internal factors**: Known internal factors/changes that will impact on the baseline emissions, e.g. confirmed plans to redevelop sites
- **Known external factors**: Known external factors/changes that will impact on the baseline emissions, e.g. connection of the Shetland Islands grid to the mainland UK grid and subsequent decarbonisation of the national grid.
- **Confirmed pipeline projects**: Projects that impact emissions that have been signed off or are very close to being given the go-ahead, e.g. projects in the asset investment plan (AIP).

The BAU scenario provides a reference against which the potential impact of decarbonisation measures identified in the net zero pathway is measured.

3.2 Measures

As part of the BAU modelling, information has been sought for projects that are likely to affect SIC's carbon emissions under BAU conditions. It should be noted that this scenario only accounts for activities and events that are planned and are highly probable to occur.

The outcomes of the BAU meetings held with SIC, and the resulting measures and emission impacts used in the BAU projection to 2050, are detailed in the table below.

Measure	Description	Modelled BAU changes	Assumptions
Decarbonisation of the electricity grid	An interconnector to the UK mainland's electricity grid is due to be completed by 2025	A reduction in the emissions intensity of grid supplied electricity for all sectors Impacts electricity and electricity T&D losses only	Interconnector to UK mainland to complete by the end of 2024 Shetland Islands grid emissions factor is assumed to reduce at the same rate to the end of 2024 as it did between 2008 and 2018. From 2025 onwards, UK mainland grid emissions factors and projections are used. For a more detailed summary of the grid electricity emissions projections, see Appendix A2.2.
Population change	The population of the Shetland Islands is projected to decrease slightly	None.	Population change statistics from 2018 ONS projections indicate a 0.3%/year population decline to 2045.[8] It is assumed that population changes will not impact any of the Council's emissions: 1. ERP – it is assumed that SIC will continue to import waste to make up any shortfall of Shetland Islands generated waste 2. SIC domestic properties - assumed that these remain filled therefore no energy consumption change.
District heat network (DHN) decarbonisation	Two projects have been completed since FY 19/20	Project 1 - upgrade to the ERP plant has increased the efficiency of heat generation. Note that total waste incinerated does not change. Project 2 - heat recovery from the diesel power generators serving Shetland Islands electricity grid. Both projects result in a decrease in burning oil used by the DHN's peak load boilers.	The ERP upgrade results in the total heat provided by the ERP to the DHN to increase from 85% of total heat demand to 93%. Heat recovery from the diesel generators is only modelled to the end of 2024 when the interconnector to the mainland UK electricity grid is completed. At which point the diesel generators are expected to be used as backup power sources only and therefore not operated consistently. When operational, heat recovery from the diesel generators is expected to meet 3% of the total DHN heating demand For a more detailed summary of the DHN emissions projections, see Appendix A2.2.

[8] Population Projections for Scottish Areas (2018-based): Data Tables

Measure	Description	Modelled BAU changes	Assumptions
Uptake in electric vehicles (EVs)	SIC provides public charge points on the island. As the number of EVs increases, so too will the usage of these charge points SIC grey and leased fleet is also expected to electrify at a similar rate. As such, existing petrol and diesel vehicles will switch to EV.	Increase in electricity consumed at EV charge points Fuel switch from petrol to electricity for the Council's grey fleet Fuel switch from petrol to electricity for the Council's leased car fleet	For public EV charge points, total electricity supplied is assumed to be proportional to the number of charge points provided in SIC's forecasts. Projections for the uptake of EVs is aligned with the National Grid Future Energy Scenarios and adjusted for Shetland Islands vs. UK population growth rates. For grey fleet and the personal vehicles used for employee commute, this assumes that all vehicles are switched to EVs by 2045. For the Council's leased fleet, it assumes that all leased vehicles are switched to EVs by 2030, in line with Transport Scotland's targets for public fleet (plus 5 years – life of vehicle)[9].
Projects identified in the Asset Investment Plan (AIP 2021-2026)	There are several projects in the AIP that have been modelled in the BAU including: • Lerwick library • Eric Gray demolition • Housing heating replacement programme • School ICT equipment upgrade • Scord quarry plant replacement • Streetlighting upgrade • Note: Knab site redevelopment has not been included as details have not been provided though it is understood that the development aspires to be net zero	Specific improvements in energy efficiency have been estimated for each of the projects.	Assumptions specific to each project have been made including: • Number of sites impacted (e.g. number of domestic properties included in heating replacement programme) • Energy impact of project • Total impact of projects in AIP has been linearly applied between 2020 and 2026 • Site fuels do not change after site redevelopment
Projects identified in the Capital Works Programme (2020-30v5)	There are several projects in the Capital Works Programme that have been modelled in the BAU including: • Building envelope improvements • HVAC replacement (including boilers, AC and controls) • Lighting upgrade	Specific improvements in energy efficiency have been estimated for each of the projects.	Assumptions specific to each project have been made including: • Heating fuel doesn't change after boiler replacement • Specific system efficiency improvements have been identified for each measure type • Where building heating fuel is not identified, it has been assumed that heating is provided electrically. • Total impact of projects in the Capital Work Programme has been linearly applied between 2020 and 2027

[9] Mission Zero for transport | Transport Scotland

Measure	Description	Modelled BAU changes	Assumptions
Transport replacement programme	All cars and small vans in the vehicle replacement programme are to be replaced with EV alternatives. All other vehicles, ferries and tugs are to be replaced like for like.	Diesel consumption of cars and small vans to be switched to electricity. Diesel, gas oil and marine gas oil (MGO) consumption used in vehicles and vessels where replacement is like for like is reduced due to efficiency increase. All ferry replacements are accompanied by a shore power connection.	Like-for-like vehicle and vessel efficiency improvements of 7% as per improvements detailed in BEIS $kgCO_2e/km$ factors between 2019 and 2014.[10] Fossil fuel engine brake thermal efficiency is 52%. Electric vehicle efficiency (grid to shaft) is 95%. Travel distance does not change. Shore power reduces MGO consumption of ferries by 5%. Total impact of Transport Replacement Programme has been linearly applied for each vehicle type (ferries, 2021 to 2035; tugs, 2030 to 2035 and vehicles, 2020 to 2026.

Table 5 - Summary of the modelled BAU measures

[10] Government conversion factors for company reporting of greenhouse gas emissions - GOV.UK (www.gov.uk)

3.3 Results

The impact of each of the replacement and investment programmes identified in Table 5 is summarised in the table below.

Measure	Carbon impact at 2030, tCO_2e	Cumulative carbon abated by 2045, tCO_2e
Asset Investment Plan (AIP 2021-2026)	188	7,100
Capital Works Programme (2020-30v5)	153	3,660
Transport Replacement Programme (inc. electrification of grey & leased fleet)	1,386	34,910

Table 6 - Summary of the impact of the BAU replacement and investment programmes

The series of charts below show SIC's emissions and energy usage projections out to 2045 at five-year intervals based on the projects that have been committed to by the council and other regional and national level projections.

Figure 10 below demonstrates that overall, there is a decrease in total energy consumption (11% by 2045). The decreases are driven by the projects planned by the Council, and significantly exceed the forecast increase in energy usage resulting from the roll out of public EV charge points by the Council.

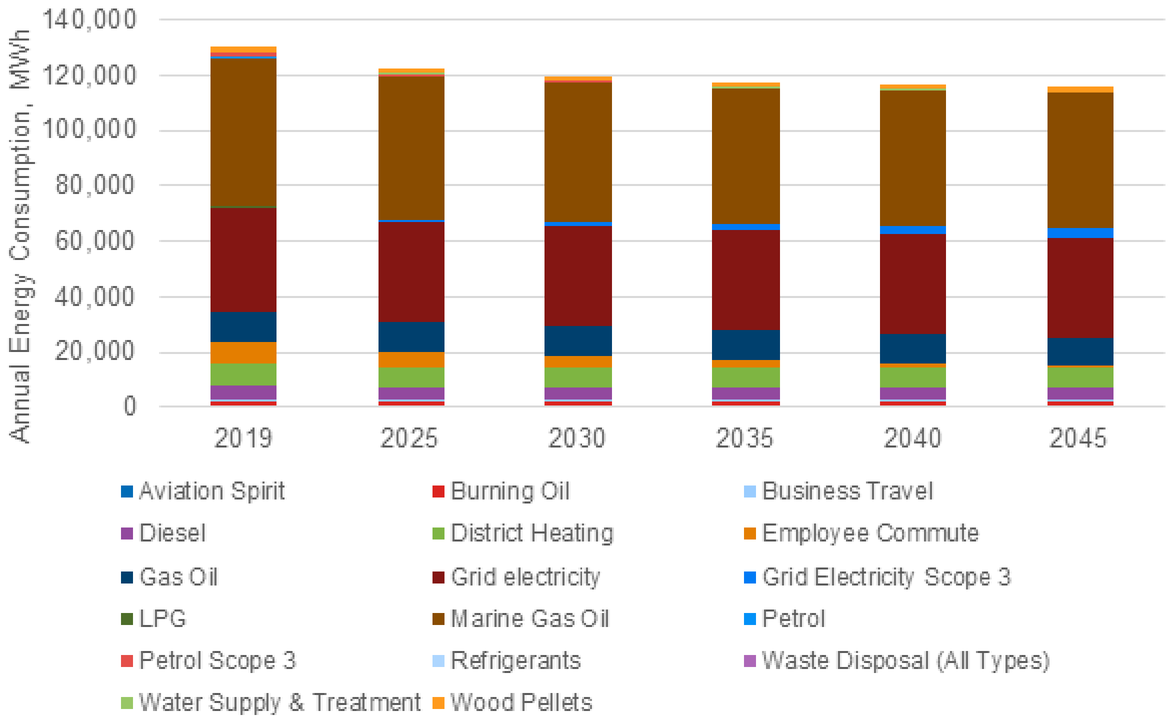


Figure 10 - BAU energy consumption projections

Whilst total energy consumption is projected to decrease by 11% by 2045, there is a greater impact to overall emissions, as highlighted in Figure 11 below. This is largely a result of the decarbonisation of grid supplied electricity as the Shetland Islands' electricity grid connects to the UK mainland's electricity grid via an interconnector in 2025. The projects identified above in Table 6 also have a significant, though smaller impact.

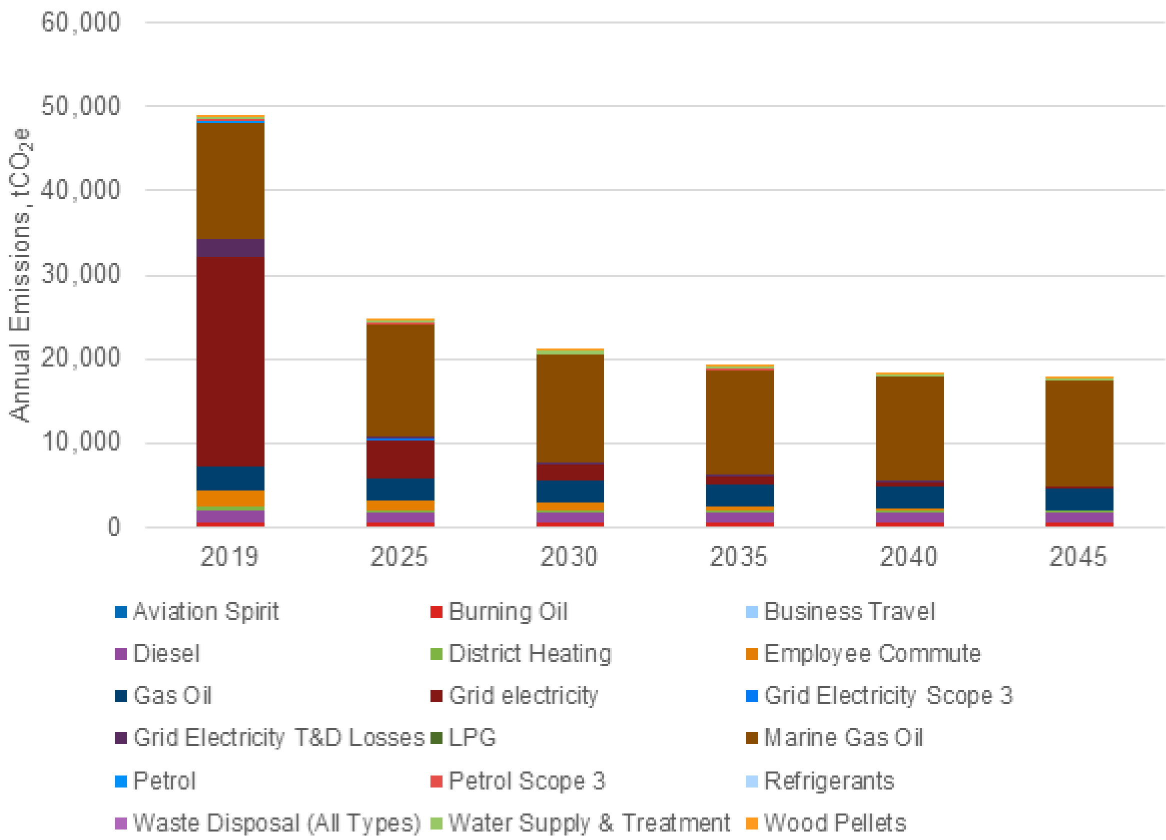


Figure 11 - BAU emissions projections by fuel type

The BAU projections indicate that the current measures and programmes committed to by the Council, coupled with the ongoing macro level trends across the region are expected to reduce the Council's emissions significantly. By 2045, total GHG emissions of the Council are forecast to reduce by 47% from the FY19/20 emissions baseline, with 34,674 tCO_2 of residual emissions.

Figure 12 below shows the breakdown of BAU emissions projections by sector in 2044/45.

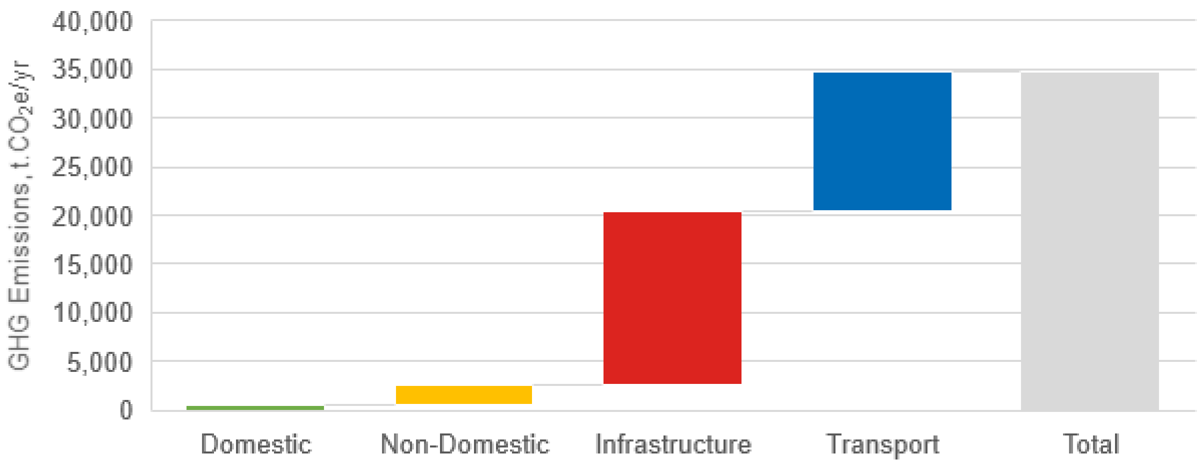


Figure 12 – Breakdown of FY 2044/45 BAU emissions projections by sector

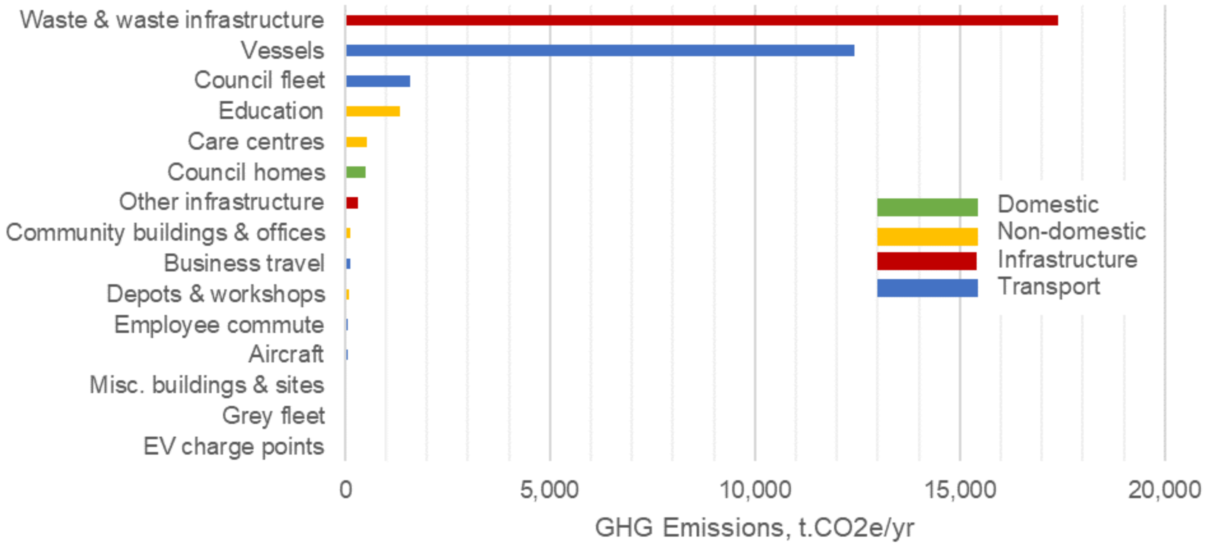


Figure 13 - Breakdown of FY 2044/45 BAU emissions projections by sub-sector

Figure 12 and Figure 13 above demonstrate that the most significant sources of emissions projected in FY 2044/45 result from the Council's infrastructure and transport operations, the majority of which are from the Council's own vessels, vehicles and the ERP. What this indicates is that the focus of the Council's decarbonisation efforts must be in these three sub-sectors.

Comparative to the baseline year, emissions resulting from domestic properties have reduced the most significantly (97%). This is almost entirely a result of the decarbonisation of grid supplied electricity when the Shetland Islands' grid connects to the UK mainland's electricity grid as the majority of SIC's Council homes (90%) are heated electrically. The breakdown of emissions by sector is detailed in Table 7 below.

Sectors	FY 2019/20 Baseline Emissions, tCO_2e	BAU Projected FY 2044/45 GHG Emissions, $t.CO_2e$	FY 2044/45 Emissions Breakdown	**Reduction against baseline**
Domestic	16,612	502	1%	**97%**
Non-domestic	8,798	2,154	6%	**76%**
Infrastructure	21,555	17,717	51%	**18%**
Transport	18,910	14,301	41%	**24%**
Total	**65,875**	**34,674**	**100%**	**47%**

Table 7 – FY2044/45 BAU projected summary of emissions by sector

4 Defining the pathways to net zero

4.1 Approach

Through discussions with SIC it was agreed that three net zero scenarios would be modelled to represent alternative pathways to net zero. Note that 2030 and 2040 have been selected as target years to allow the Council to demonstrate leadership against the Scottish Government's 2045 net zero targets. The pathways modelled are as below:

2030 ambitious pathway – assumes that significant resources and budget are made available to allow the rapid implementation of measures by 2030. This approach looks to minimise carbon emissions by 2030 with technologies available over that time frame though does not look at decarbonisation beyond 2030 other than through factors outside of the Council's control, e.g. decarbonisation of the national electricity grid. For some emissions sources therefore, the selection of decarbonisation technologies is restricted by technology maturity.

2040 pragmatic pathway – assumes a pragmatic approach to the selection of decarbonisation measures whereby assets are replaced with low carbon alternatives at their end of life, and more cost-effective technologies and approaches are preferred and therefore modelled. All assets that approach their end of life within the scenario timeframe are assumed to be replaced with low carbon alternatives.

2040 ambitious pathway – assumes that significant resources and budget are made available to minimise the Council's emissions by 2040. For several emissions sources therefore, this is likely to require significant transformation to current services and operations.

4.2 Decarbonisation interventions

Identifying decarbonisation interventions and developing emissions reduction plans is an iterative process that will evolve over time.

The feedback loops are shown in the figure below, and the following chapters reflect some of the identification, prioritisation, interactions and modelling loops that took place during the project.

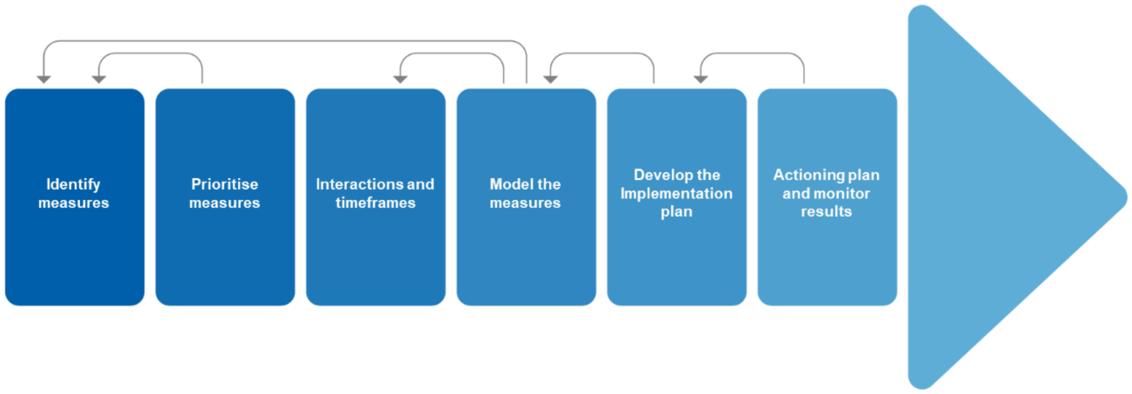


Figure 14 - Workflow to develop decarbonisation interventions

A long list of potential decarbonisation measures identified by Ricardo technical leads were discussed with the Council in sector specific workshops. The output of these workshops was a shortlist of measures to be taken forward to modelling. The measures shortlisting workshops covered the following areas.

- Non-domestic buildings including energy efficiency and heating decarbonisation
- Domestic buildings
- Transport – vehicles and aircraft
- Transport – vessels
- Waste and waste management

The measures take account of factors such as:

- Fuel type and consumption (before and after each measure is implemented).
- Investment required.
- Technology maturity
- Likely disruption
- Which year the measure is undertaken, and the number of years needed to implement.

It is important to note that costs indicated are based on a high-level desk-based assessment of potential measures, with all information on current systems and practices provided by SIC.[11]

It's also important to note that measures identified below are not a finite list and how they have been applied to the three net zero pathways is not a commitment by the Council to a certain technology.

Many low carbon technologies are currently in their infancy and as such, it is not yet clear how technologies will develop, and therefore which will be the most appropriate for the Council to adopt. The Council therefore must keep up to date with emerging technologies. As these technologies develop and begin to enter the market, the Council must engage potential suppliers to better understand practical and financial considerations and subsequently conduct feasibility studies where appropriate to inform their decision making. Only then can the Council commit to adopting technologies that are suitable and appropriate. In short, the Council is committed to reducing emissions, though is not yet committing to any specific technologies.

The Council must conduct full financial and technical feasibility studies to fully understand the practical and financial implementation considerations before measures are committed to and implemented.

A description of how each short-listed measure has been applied is provided in Appendix A6 of this report, including details of the indicative capital investment required, payback, and abatement cost for each measure. The diagram below provides an overview of the measures applied within the three different pathways. Note that although the same measure may be applied across multiple pathways, the scale, scope and timeline of implementation for each measure may vary as detailed in Appendix A6. Also note that a glossary of terms can be found in Appendix A1.

Short-listed measures	2030 ambitious pathway	2040 pragmatic pathway	2040 ambitious pathway
Non-domestic			
Estate rationalisation*	×	×	×

[11] Also note that costs are expressed in 2022 prices where available.

Short-listed measures	2030 ambitious pathway	2040 pragmatic pathway	2040 ambitious pathway
Energy efficiency measures including upgrades to BMS & controls, building fabric, lighting, HVAC systems and the implementation of an energy management programme	✓	✓	✓
Replace oil used for space heating	✓	✓	✓
Replace storage heaters with air-to-air heat pumps	✓	✓	✓
Use of hydrogen as a heating source**	✗	✗	✗
Estate rationalisation	✗	✗	✗
Installation of rooftop PV	✓	✓	✓
Domestic			
New development	✗	✗	✗
A pragmatic approach to EESH 2 compliance with a fabric first approach aimed at minimising energy consumption and fuel bills	✓	✓	✓
Installation of rooftop PV	✗	✗	✓
Infrastructure			
Biogenic waste collection in Lerwick	✓	✓	✓
Carbon capture from ERP	✓	✗	✓
Target islands wide waste reductions	✓	✓	✓
Transport			
Promote active travel and public transport for Council staff	✓	✓	✓
Target business travel and employee commute reductions	✓	✓	✓
Transition Council vehicles to BEV, FCEV and hydrogen ICE	✓	✓	✓
Transition Council vessels to low carbon fuels	✓	✓	✓
Transition Council aircraft to hydrogen/electric	✗	✗	✓

Short-listed measures	2030 ambitious pathway	2040 pragmatic pathway	2040 ambitious pathway
Replace AVGAS in Council aircraft with sustainable aviation fuel	✓	✓	×
Install fixed links serving Yell, Unst, Whalsay and Bressay***	×	×	×

*Estate rationalisation has not been included as a net zero measure, however, rationalising the Council's non-domestic estate would be expected to achieve significant energy (and therefore carbon) saving whilst also negating the requirement for potentially costly net zero measures at various sites.

**Note that hydrogen has not been included as a heating fuel at this stage however the Council should continue to investigate the potential of hydrogen (as a heating and transport fuel) as the technology develops.

***Note that fixed links have not been included at this stage as a potential means of decarbonising ferries as sufficient information is not currently available to allow modelling of carbon and cost impacts.

The Council should continue its ongoing work exploring the opportunities provided by fixed links by considering a full socio-economic assessment as the potential benefits and considerations extend far beyond carbon emissions.

4.3 Net zero pathways and measures

Each of the net-zero pathways were modelled to include the decarbonisation measures agreed with SIC. This section covers the results of this modelling and sets out a narrative and graphical explanation of what each of the pathways could look like. The following appendices provide detailed information that underpin this entire section:

- Appendix A4: A description of each measure
- Appendix A5: Indicative cost breakdown for each modelled measure
- Appendix A6: Assumptions and modelled factors for each pathway

4.3.1 The 2030 ambitious pathway

2030 ambitious pathway – assumes that significant resources and budget are made available to allow the rapid implementation of measures by 2030. This approach looks to minimise carbon emissions by 2030 with technologies available over that time frame though does not look at decarbonisation beyond 2030 other than through factors outside of the Council's control, e.g. decarbonisation of the national electricity grid. For some emissions sources therefore, the selection of decarbonisation technologies is restricted by technology maturity.

4.3.1.1 Pathway intervention measures

An overview of the modelled measures of the 2030 ambitious pathway are set out in the table below. Note that the table summarises how decarbonisation measures have been modelled and applied in this specific pathway and does not constitute a commitment to certain technologies by the Council. The Council must monitor technology developments, engage suppliers to determine financial and technical suitability, and only then adopt the appropriate technologies. This pathway is therefore indicative of how the Council could approach net zero.

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
Non-domestic	Energy efficiency improvements	Electricity, district heating, burning oil, gas oil, LPG, biomass, water supply & treatment	Energy efficiency improvements incorporates several sub-measures including the below, phased between 2022 and 2028: • Lighting upgrades – upgrade all lighting across the estate to LED including suitable occupancy and daylight controls • BMS & controls upgrades – upgrade all end-of-life and obsolete control systems and implement a BMS optimisation program to target energy efficiency improvements of mechanical systems • Metering & management – there is good metering of energy supplies across the estate though limited submetering. Install submetering at higher energy consuming buildings and build upon current monitoring systems, governance structures and energy management processes that enable a structured and targeted approach to energy management including site specific benchmarks and targets. Also provide better information to key building users to allow an improvement to site level engagement. • Water saving – replace existing tap and shower fittings with water saving (i.e. low flow/aerated and motion sensing/percussive) alternatives thus saving both water and therefore water heating. • Building fabric – upgrade building fabric (including glazing, wall and roof insulation and draft proofing) at 20% of buildings[12]. • HVAC upgrades – upgrade all mechanical ventilation systems to enable variable volume ventilation including the installation of additional environmental sensing. Re-balance all ventilation and wet heating systems. • Catering – electrify all catering equipment to remove any catering fossil fuel usage
	Heating system decarbonisation	Electricity, district heating, burning oil, gas oil	Heating system decarbonisation incorporates several sub-measures including the below, phased between 2023 and 2030: • Lerwick – bring all oil-fired heating systems onto the DHN • Mainland/inner isles – replace all oil-fired heating systems with ASHPs serving the existing wet heating distribution systems, upgrading heat emitters as required. • Storage heaters – replace 50% of buildings with existing storage heater systems with network of air-to-air heat pumps.
	Roof mounted PV	Electricity	Install roof mounted PV at 15% of Council buildings, phased between 2023 and 2030. Note installations have been limited to 12kW.

[12] Note that based on analysis and extrapolation of condition survey reports, it is estimated that 47% of the Council non-domestic building stock would benefit from building fabric upgrades.

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
Domestic	EESSH 2 compliance	Electricity, district heating, burning oil, biomass, water supply & treatment	Target EPC B or higher for 60% of the domestic building stock, requiring refurbishment to slightly over 70 properties per year. A pragmatic approach to EESSH 2 compliance whereby a fabric first approach is taken to improve energy efficiency and storage heaters are upgraded.
Infrastructure	Waste reduction and recycling	Landfill, ERP, waste sent to recycling centers	Waste reduction and recycling incorporates several targets including the below, phased between 2022 and 2030: • Islands level – support island wide targets for both a reduction in total waste generated (15%) and overall recycling rates (15%) • Council level – set Council specific waste reduction targets (30%) and increase in recycling rates (30%)
	Waste management	Landfill, ERP	Waste management incorporates two key measures including the below, phased between 2022 and 2030: • Lerwick biogenic waste collection – set up a biogenic waste collection scheme in Lerwick to reduce incineration of organic waste. Biogenic waste to be sent to a micro-anaerobic digestion plant to provide electricity to the waste management center • Increase rate of waste import – waste reduction measures will reduce the total waste available for incineration at the ERP. SIC must therefore increase the amount of waste imported from the Scottish mainland to make up the shortfall. Note that no costs or emissions have been modelled associated with getting waste to the Shetland Islands.
	Carbon capture and storage	ERP	Install carbon capture technology at the ERP to reduce CO_2e emissions from the incinerator by roughly 85%. Carbon capture at the scale required for the ERP is not a mature technology though there are pilot sites at this scale. CO_2 captured can be used for multiple purposes including conversion to low carbon fuels or as a medical gas, or alternatively CO_2 can be sent to long term storage. Carbon capture to be installed in 2029.
Transport	Low carbon vessels	Marine gas oil (MGO), biodiesel, hydrogen, electricity	Decarbonise Council vessels using low carbon fuels as they reach their end of life. Vessels identified below are those that approach their end of life by 2030. • Inter-island ferries – replace MV Hendra, MV Snolda, MV Fivla and MV Geira with low carbon alternatives modelled here using battery electric, or hydrogen fuel cell propulsion systems based on route demands, including suitable port charging and hydrogen storage and refueling infrastructure (approximately 25% of current MGO consumption) Replaced ferries to also include a shore power connection. • Tugs – replace Tystie and Dunter with low carbon alternatives, modelled here as dual fuel vessels (75% hydrogen and 25% biofuel), including suitable hydrogen storage and refueling infrastructure at Sullom Voe port.
	Low carbon vehicles	Diesel, gas oil, hydrogen, electricity	Decarbonise Council vehicles using low carbon fuels/power systems as they reach their end of life by 2030. • Heavy-duty vehicles – replace with low carbon alternatives utilising dual-fuel (diesel-hydrogen) power systems including sufficient hydrogen storage and refueling infrastructure

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
			• Medium-duty vehicles – replace with low carbon alternatives utilising dual-fuel (diesel-hydrogen) power systems including sufficient hydrogen storage and refueling infrastructure • Light-duty vehicles – replace with BEV alternatives with suitable charging infrastructure. All new light vehicles purchased after 2025 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2030 to allow for 5 year vehicle life.
	Low carbon aircraft	Aviation spirit, electricity	Replace AVGAS used in both Council aircraft with sustainable aviation fuel between 2025 and 2030
	Home working	Employee commute	Target 20% increase in homeworking as appropriate by 2030 to minimise employee commute emissions.
	Business travel reductions	Business travel	Target 20% reductions in business travel as appropriate by 2030.

Table 8 - 2030 ambitious pathway net zero measures

4.3.1.2 Pathway mitigation potential

The following charts illustrate the mitigation potential of the of 2030 ambitious pathway.

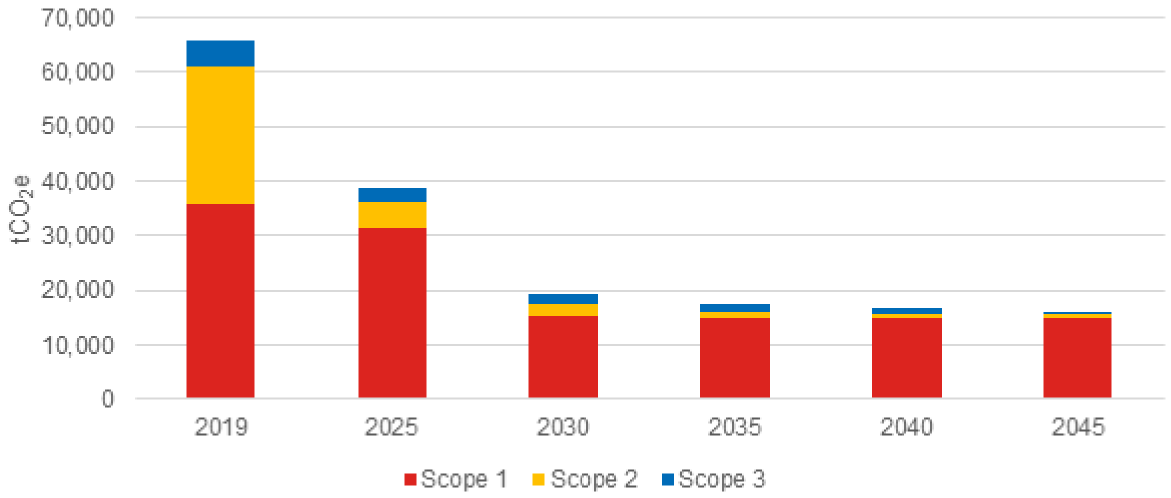


Figure 15 - Impact of the 2030 ambitious pathway by emissions scope

Emissions could be reduced by 71% by 2030 under the 2030 ambitious scenario and are projected to continue to decrease to an 76% reduction by 2045 due to ongoing electricity grid decarbonisation.

	2019	2025	2030	2035	2040	2045
Scope 1, tCO_2e	35,709	31,490	15,125	14,785	14,785	14,785
Scope 2, tCO_2e	25,457	4,662	2,140	1,129	766	541
Scope 3, tCO_2e	4,709	2,461	1,785	1,282	840	487
Total, tCO_2e	**65,875**	**38,612**	**19,049**	**17,197**	**16,391**	**15,813**
% change	**0%**	**41%**	**71%**	**74%**	**75%**	**76%**

Table 9 – Impact of the 2030 ambitious pathway by emissions scope

As under the BAU scenario, the single most significant impact to SIC's emissions is the decarbonisation of the electricity grid as the interconnector is completed in 2024. By 2045, scope 1 emissions dominate the Council's footprint, accounting for 93% of total emissions.

Figure 16 and Figure 17 highlight that under this scenario, the sector responsible for the greatest emissions in 2030 is projected to be transport, responsible for 48% of total emissions. This is specifically due to the limited roll out of low carbon fuels to the Council's vessels as several of the vessels do not approach their end of life by 2030, and as such are not pragmatic to decarbonise over that timeframe. The second largest emissions source in 2030 under this scenario is the landfill as a significant proportion of the islands waste continues to be sent to landfill under this scenario.

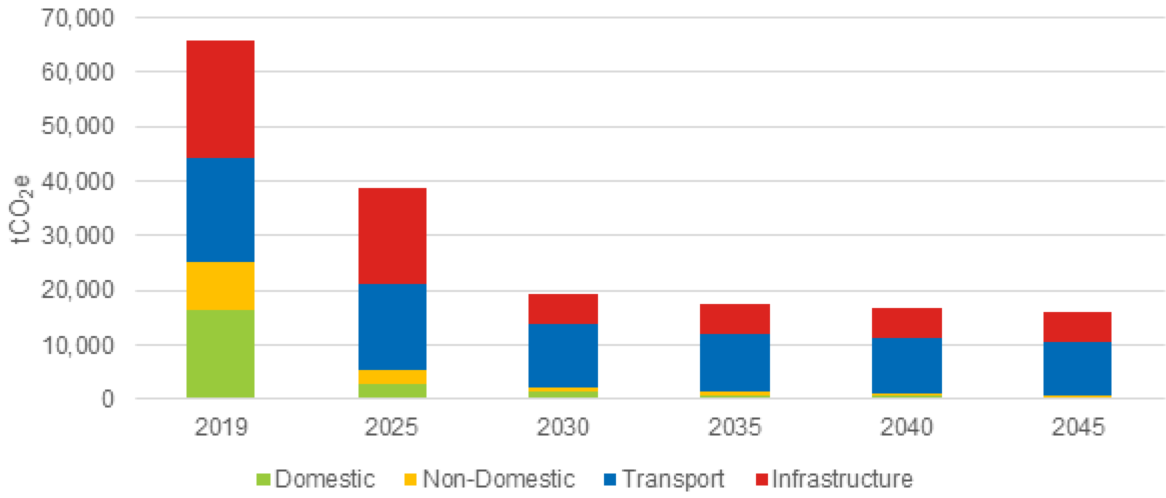


Figure 16 – Emissions projection by sector

	2019	2025	2030	2035	2040	2045	% change at 2030
Domestic, tCO_2e	16,612	3,047	1,350	775	570	444	**-97%**
Non-domestic, tCO_2e	8,798	2,367	782	527	437	381	**-96%**
Transport, tCO_2e	18,910	15,864	11,639	10,734	10,264	9,896	**-48%**
Infrastructure, tCO_2e	21,555	17,334	5,278	5,161	5,119	5,093	**-76%**

Table 10 - Breakdown of emissions by sector under pathway

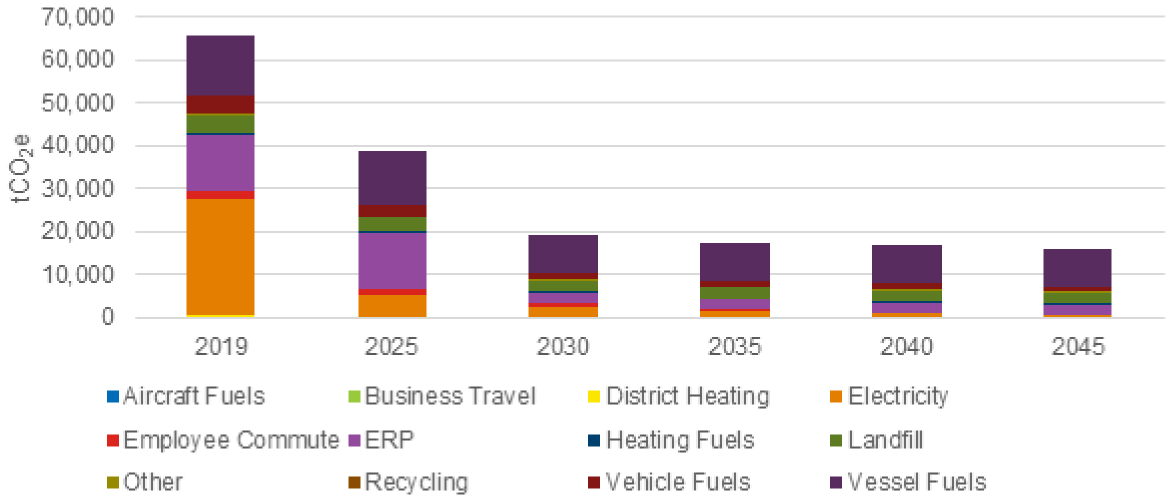


Figure 17 - Emissions projection by fuel type

The chart above also demonstrates the impact that carbon capture has to the emissions from the ERP. In 2019, the ERP was responsible for 12,875 tCO_2e however by 2030, this is reduced by 84% to 2,097 tCO_2e despite importing waste to enable the ERP to continue operating at full capacity. The chart below summarises how each of the net zero measures contribute to the net zero pathway.

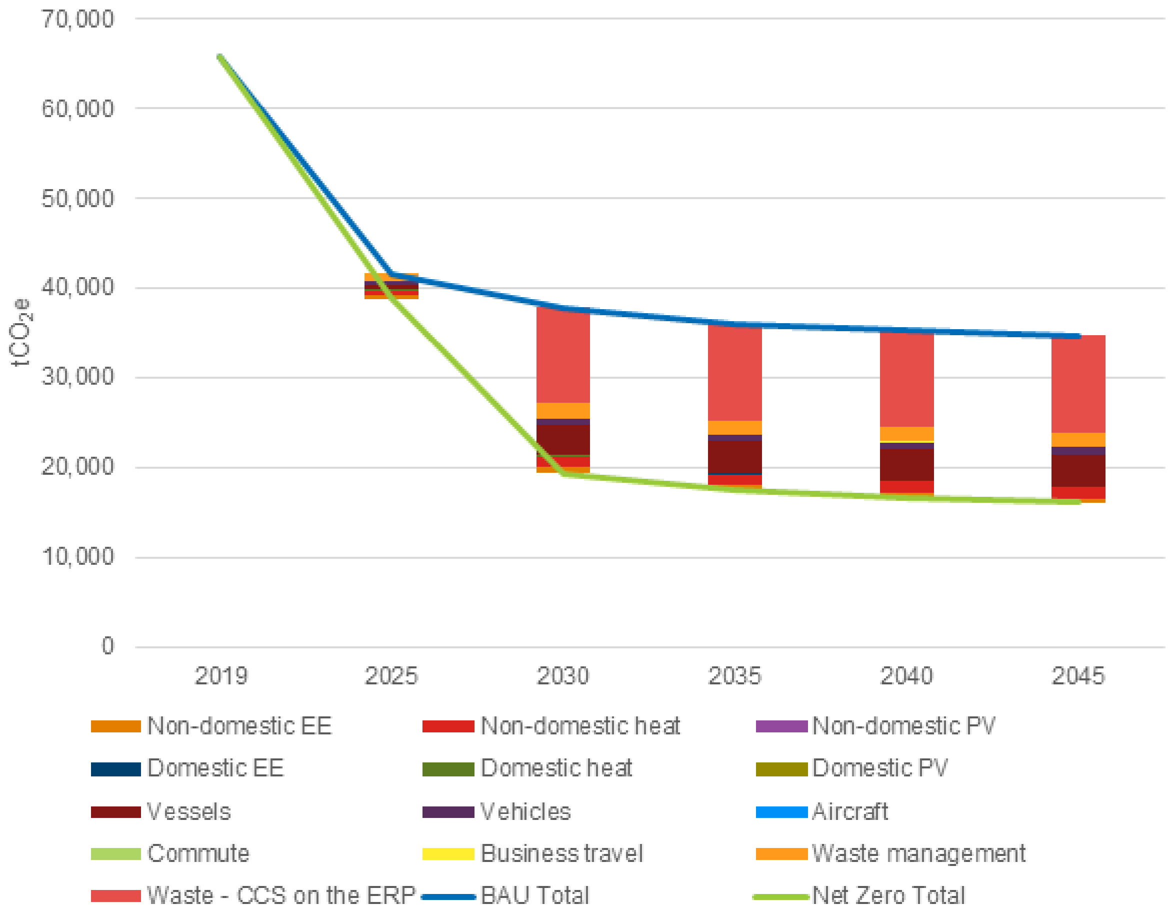


Figure 18 - Contribution of measures to the net zero pathway

The figure above demonstrates that the 2030 ambitious pathway reduces emissions by 49% against the BAU at 2030, taking total emissions reductions to 71% by 2030, and 76% by 2045. This scenario illustrates that there is more that can be achieved between 2030 and 2040 that is not possible between now and 2030, such as further decarbonisation of heavy and medium-duty vehicles. In practice, decarbonisation efforts would not be expected to stop at 2030, despite that being the scenario target.

4.3.1.3 Indicative investment costs and potential cost savings

Figure 19 shows the estimated 2030 ambitious pathway costs including capital investment (CAPEX), ongoing maintenance (OPEX) and impacts to fuel costs over five year intervals.

> The 2030 ambitious scenario is expected to require a capital investment of £56m, with a total operational cost increase of £7.9m by 2045 due to the balance between fuel cost savings and the required additional operational expenditure. The pathway achieves carbon saving against the BAU scenario at an overall rate of £150/tCO_2e by 2045.

Capital expenditure is expected to peak in 2029 at £9.2m, though averages £7.0m between 2022 and 2029. The measures achieve net operational cost increase of approximately £0.6m per year at 2030, though by 2045, this is expected to have decreased to £0.3m as fossil fuel prices are expected to rise faster than electricity prices in long range government forecasts.

The breakdown of capital investment is explored further in Appendix A5, however, the most significant costs are projected to be those required to provide energy efficiency improvement to the council's non-domestic estate, estimated to cost a total of £16m (largely driven building fabric improvement costs), and for the vessel decarbonisation, also estimated to cost a total of £16m (additional to fossil fuel ICE alternatives).

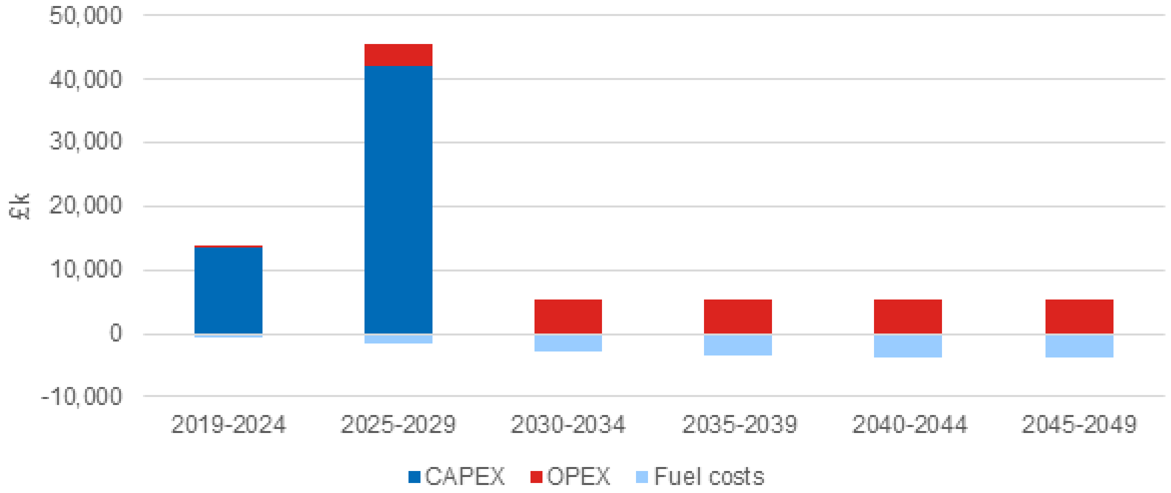


Figure 19 - 2030 ambitious pathway costs

In summary, the 2030 ambitious demonstrates the fastest pathway to reducing emissions for SIC, achieving a total carbon reduction of 71% by 2030, and 76% by 2045. In this scenario, beyond 2030, the Council would need to focus on decarbonising the remaining fossil fuel powered vessels and vehicles.

4.3.2 The 2040 pragmatic pathway

2040 pragmatic pathway – assumes a pragmatic approach to the selection of decarbonisation measures whereby assets are replaced with low carbon alternatives at their end of life, and more cost-effective technologies and approaches are preferred and therefore modelled. All assets that approach their end of life within the scenario timeframe are assumed to be replaced with low carbon alternatives.

4.3.2.1 Pathway intervention measures

An overview of the modelled measures of the 2040 pragmatic pathway are set out in the table below. Note that the table summarises how decarbonisation measures have been modelled and applied in this specific pathway and does not constitute a commitment to certain technologies by the Council. The Council must monitor technology developments, engage suppliers to determine financial and technical suitability, and only then adopt the appropriate technologies. This pathway is therefore indicative of how the Council could approach net zero.

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
Non-domestic	Energy efficiency improvements	Electricity, district heating, burning oil, LPG, biomass, water supply & treatment	Energy efficiency improvements incorporates several sub-measures including the below, phased between 2022 and 2030: • Lighting upgrades – upgrade all lighting across the estate to LED including suitable occupancy and daylight controls • BMS & controls upgrades – upgrade all end-of-life and obsolete control systems and implement a BMS optimisation program to target energy efficiency improvements of mechanical systems • Metering & management – there is good metering of energy supplies across the estate though limited submetering. Install submetering at higher energy consuming buildings and set-up governance structures and energy management processes that enable a structured and targeted approach to energy management including site specific benchmarks and targets. • Water saving – replace existing tap and shower fittings with water saving (i.e. low flow/aerated and motion sensing/percussive) alternatives thus saving both water and therefore water heating. • Building fabric – upgrade building fabric (including glazing, wall and roof insulation and draft proofing) at 20% of buildings. • HVAC upgrades – upgrade all mechanical ventilation systems to enable variable volume ventilation including the installation of additional environmental sensing. Re-balance all ventilation and wet heating systems. • Catering – electrify all catering equipment to remove any catering fossil fuel usage
	Heating system decarbonisation	Electricity, district heating, burning oil	Heating system decarbonisation incorporates several sub-measures including the below, phased between 2025 and 2033: • Lerwick – bring all oil-fired heating systems onto the DHN • Mainland/inner isles – replace all oil-fired heating systems with ASHPs serving the existing wet heating distribution systems, upgrading heat emitters as required. • Storage heaters – replace 50% of buildings with existing storage heater systems with network of air-to-air heat pumps.
	Roof mounted PV	Electricity	Install roof mounted PV at 15% of Council buildings, phased between 2022 and 2030. Note installations have been limited to 12kW.
Domestic	EESSH 2 compliance	Electricity, district heating, burning oil, biomass, water supply & treatment	Target EPC B or higher for 100% of the domestic building stock, requiring refurbishment to slightly under 70 properties per year. A pragmatic approach to EESSH 2 compliance whereby a fabric first approach is taken to improve energy efficiency and storage heaters are upgraded.

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
Infrastructure	Waste reduction and recycling	Landfill, ERP, waste sent to recycling centers	Waste reduction and recycling incorporates several targets including the below, phased between 2022 and 2040: • Islands level – support island wide targets for both a reduction in total waste generated (15%) and an increase in recycling rates (15%) • Council level – set Council specific waste reduction targets (30%) and increase in recycling rates (30%)
	Waste management	Landfill, ERP	Waste management incorporates two key measures including the below, phased between 2022 and 2040: • Lerwick biogenic waste collection – set up a biogenic waste collection scheme in Lerwick to reduce incineration of organic waste. Biogenic waste to be sent to a micro-anaerobic digestion plant to provide electricity to the waste management center • Increase rate of waste import – waste reduction measures will reduce the total waste available for incineration at the ERP. This pathway models an increase in waste imported from the Scottish mainland to make up the shortfall. Note that no costs or emissions have been modelled associated with getting waste to the Shetland Islands.
Transport	Low carbon vessels	Marine gas oil (MGO), biodiesel, hydrogen, electricity	Decarbonise Council vessels using low carbon fuels as they reach their end of life. Vessels identified below are those that approach their end of life by 2040. • Inter-island ferries – replace all ferries with low carbon alternatives, modelled here using battery electric, or hydrogen fuel cell propulsions systems based on route demands, including suitable port charging and hydrogen storage and refueling infrastructure • Tugs – replace all Council tugs with low carbon alternatives, modelled here to use dual fuel vessels (hydrogen and biofuel), including suitable hydrogen storage and refueling infrastructure at Sullom Voe port.
	Low carbon vehicles	Diesel, gas oil, hydrogen, electricity	Decarbonise Council vehicles using low carbon fuels/power systems as they reach their end of life. • Heavy-duty vehicles – replace with low carbon alternatives utilising hydrogen internal combustion engines (ICE) systems including sufficient hydrogen storage and refueling infrastructure. All new heavy-duty vehicles purchased after 2030 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2040 to allow for 10 year heavy-duty vehicle life. • Medium-duty vehicles – replace with low carbon alternatives utilising either hydrogen ICE (50% of MDVs) or fuel cell (50% of MDVs) powertrains including sufficient hydrogen storage and refueling infrastructure. All new medium-duty vehicles purchased after 2030 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2040 to allow for 10 year medium-duty vehicle life.

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
			• Light-duty vehicles – replace with BEV alternatives with charging infrastructure. All new light vehicles purchased after 2025 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2030 to allow for 5 year vehicle life.
	Low carbon aircraft	Aviation spirit, electricity	Replace AVGAS in both Council aircraft with sustainable aviation fuel between 2025 and 2030.
	Home working	Employee commute	Target 30% increase in homeworking as appropriate by 2040 to minimise employee commute emissions.
	Business travel reductions	Business travel	Target 30% reductions in business travel as appropriate by 2040.

Table 11 - 2040 pragmatic pathway net zero measures

4.3.2.2 Pathway mitigation potential

The following charts illustrate the mitigation potential of the of 2040 pragmatic pathway.

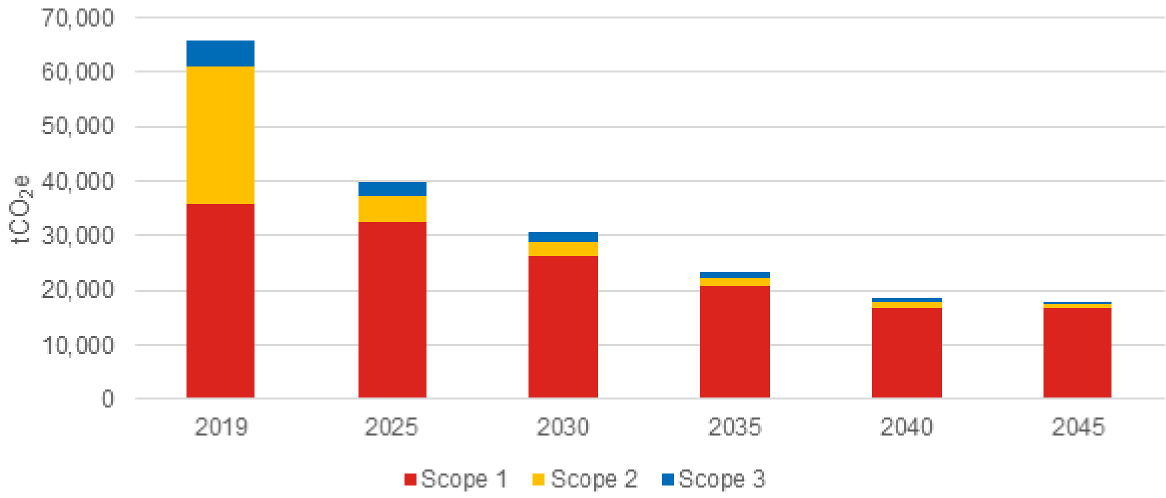


Figure 20 - Impact of the 2040 pragmatic pathway by emissions scope

Emissions could be reduced by 72% by 2040 under the 2040 pragmatic scenario and are projected to continue to decrease to an 73% reduction by 2045 due to ongoing electricity grid decarbonisation.

	2019	2025	2030	2035	2040	2045
Scope 1, tCO_2e	35,709	32,488	26,333	20,643	16,557	16,557
Scope 2, tCO_2e	25,457	4,687	2,237	1,260	883	612
Scope 3, tCO_2e	4,709	2,480	1,809	1,274	808	453
Total, tCO_2e	**65,875**	**39,655**	**30,379**	**23,178**	**18,248**	**17,622**
% change	**0%**	**40%**	**54%**	**65%**	**72%**	**73%**

Table 12 - Impact of the 2040 pragmatic pathway by emissions scope

As under the BAU scenario, the single most significant impact to SIC's emissions is the decarbonisation of the electricity grid as the interconnector is completed in 2024. As with the 2030 scenario, by 2045, scope 1 emissions dominate the Council's footprint, accounting for 94% of total emissions.

Figure 21 and Figure 22 highlight that under this scenario, the sector responsible for the greatest emissions in 2040 is projected to be infrastructure, responsible for 87% of total emissions. This is specifically due to no mitigation measures being applied to the ERP. In this scenario, the targeted reduction of total waste generated on the islands is offset at the ERP by importing waste to allow the ERP to continue provide the majority of Lerwick DHN's heat, thus ensuring that DHN heat continues to be provided at low cost. All other sectors reduce by at least 95% under this scenario.

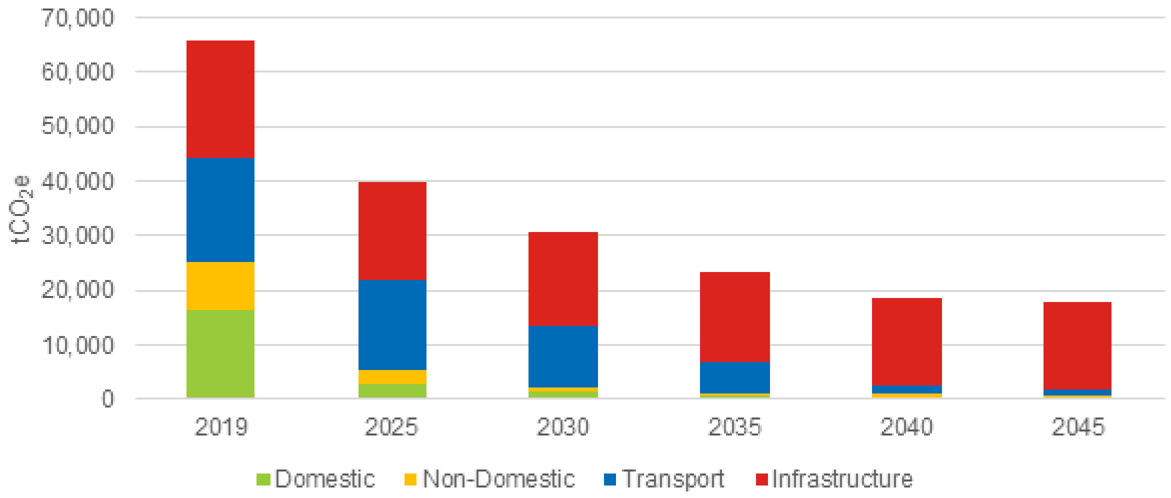


Figure 21 – Emissions projection sector

	2019	2025	2030	2035	2040	2045	% change at 2040
Domestic, tCO_2e	16,612	3,064	1,359	737	516	403	**-98%**
Non-domestic, tCO_2e	8,798	2,512	997	527	437	381	**-96%**
Transport, tCO_2e	18,910	16,206	11,026	5,561	1,398	967	**-95%**
Infrastructure, tCO_2e	21,555	17,873	16,997	16,352	15,897	15,871	**-26%**

Table 13 - Breakdown of emissions by sector under pathway

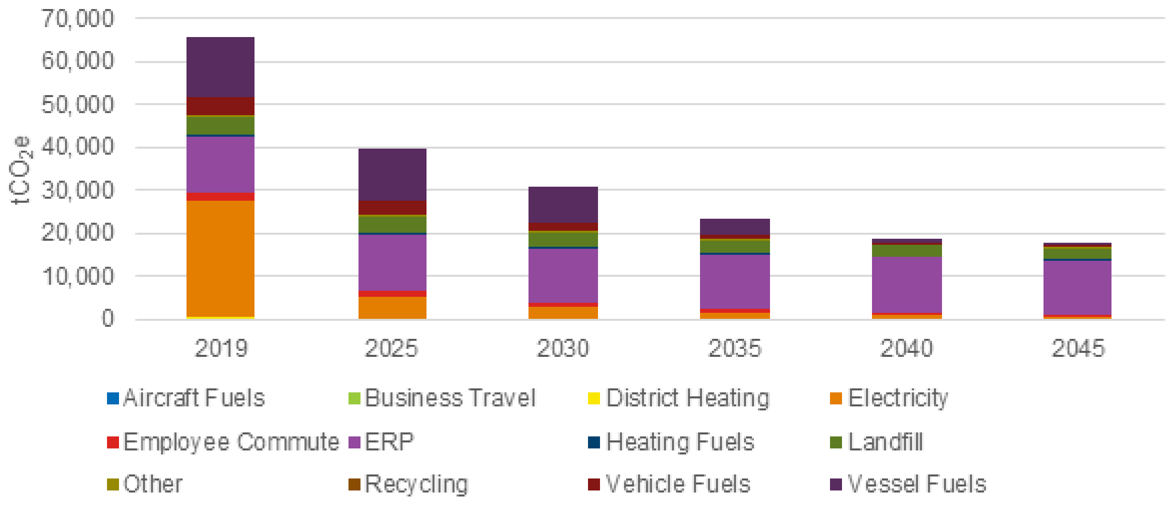


Figure 22 - Emissions projection by fuel type

The chart above demonstrates that by 2045, emissions from the ERP are projected to dominate the Council's footprint, contributing 73% to the breakdown of emissions. The chart below summarises how each of the net zero measures contribute to the net zero pathway. The chart highlights that the decarbonisation of vessels, vehicles & waste management contribute most significantly to the net zero pathway (68%, 9% & 11% of total decarbonisation respectively).

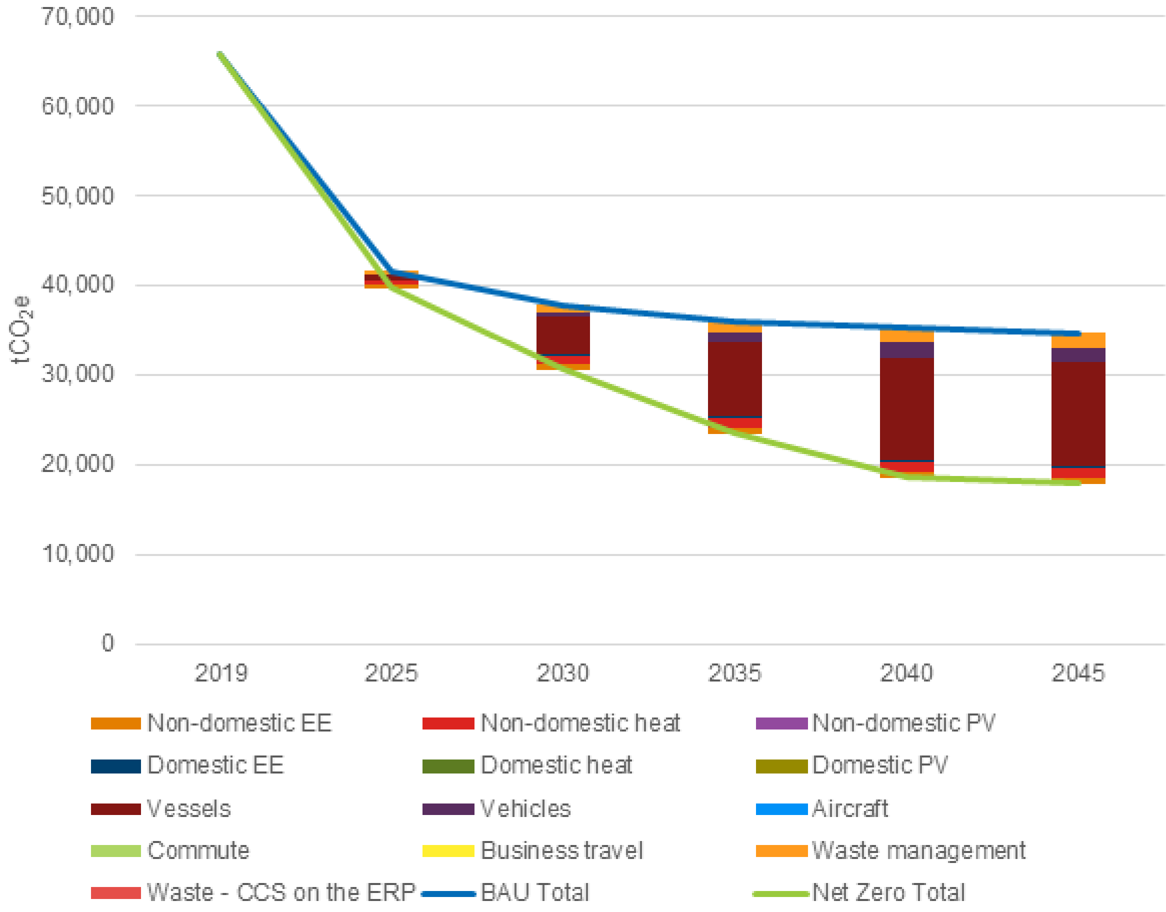


Figure 23 - Contribution of measure to the net zero pathway

The figure above demonstrates that the 2040 pragmatic pathway reduces emissions by 48% against the BAU by 2040, taking total emissions reductions to 72% by 2040, and 73% by 2045. This scenario illustrates that there is more decarbonisation that can be achieved, specifically by incorporating carbon capture onto the exhaust of the ERP.

4.3.2.3 Indicative investment costs and potential cost savings

Figure 24 shows the estimated 2040 pragmatic pathway cost including capital investment (CAPEX), ongoing maintenance (OPEX) and impacts to fuel costs over five year intervals.

> The 2040 pragmatic scenario is expected to require a capital investment of £96m, with a total operational cost increase of £16m by 2045 due to slight fuel savings outweighed by additional operational expenditure. The pathway achieves carbon saving against the BAU scenario at an overall rate of £318/tCO_2e by 2045.

Capital expenditure is expected to peak between 2028 and 2029 at £7.4m, though averages £5.3m per year between 2022 and 2039. The measures result in a net operational cost increase of approximately £1.1m per year in 2040, reducing to £1.0m by 2045 as fossil fuel prices are expected to rise faster than electricity prices in long range government forecasts.

The breakdown of capital investment is explored further in Appendix A5, however, the most significant costs are expected to be for the vessels and the investments required to bring the remaining 75% of the domestic housing stock up to EESSH 2 compliance, estimated to cost a total of £43m (additional to fossil fuel ICE ferries) and £24m respectively.

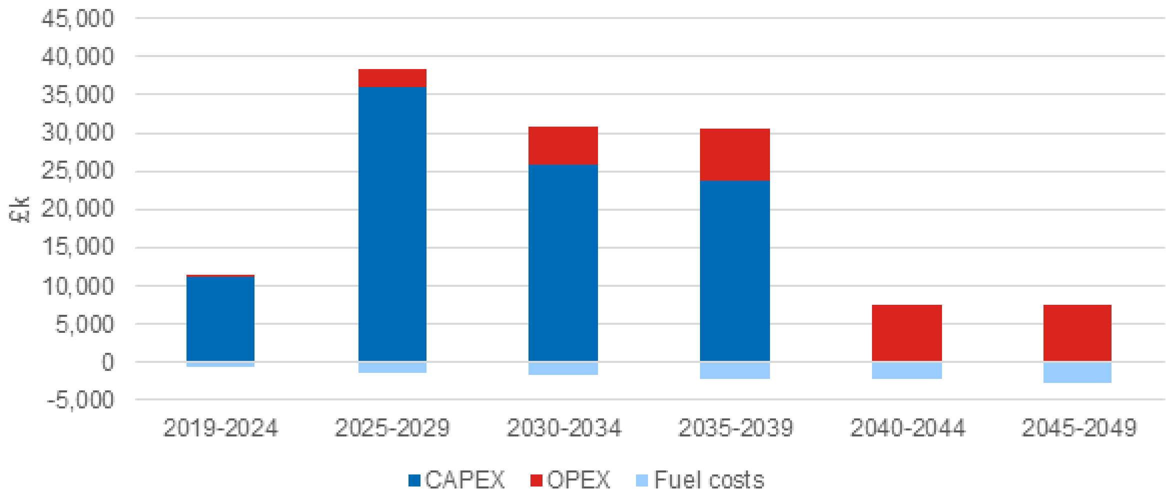


Figure 24 – 2040 pragmatic pathway costs

In summary, the 2040 pragmatic pathway demonstrates a pathway which is reducing emissions for SIC, achieving a total carbon reduction of 72% by 2040, and 73% by 2045.

4.3.3 The 2040 ambitious pathway

2040 ambitious pathway – assumes that significant resources and budget are made available to minimise the Council's emissions by 2040. For several emissions sources therefore, this is likely to require significant transformation to current services and operations.

4.3.3.1 Pathway intervention measures

An overview of the modelled measures of the 2040 ambitious pathway are set out in the table below. Note that the table summarises how decarbonisation measures have been modelled and applied in this specific pathway and does not constitute a commitment to certain technologies by the Council. The Council must monitor technology developments, engage suppliers to determine financial and technical suitability, and only then adopt the appropriate technologies. This pathway is therefore indicative of how the Council could approach net zero.

<table>
<tr><th>Sector/sub-sector</th><th>Measure</th><th>Emissions sources impacted</th><th>Modelled measures</th></tr>
<tr><td rowspan="3">Non-domestic</td><td>Energy efficiency improvements</td><td>Electricity, district heating, burning oil, LPG, biomass, water supply & treatment</td><td>Energy efficiency improvements incorporates several sub-measures including the below, phased between 2022 and 2030:
• Lighting upgrades – upgrade all lighting across the estate to LED including suitable occupancy and daylight controls
• BMS & controls upgrades – upgrade all end-of-life and obsolete control systems and implement a BMS optimisation program to target energy efficiency improvements of mechanical systems
• Metering & management – there is good metering of energy supplies across the estate though limited submetering. Install submetering at higher energy consuming buildings and set-up governance structures and energy management processes that enable a structured and targeted approach to energy management including site specific benchmarks and targets.
• Water saving – replace existing tap and shower fittings with water saving (i.e. low flow/aerated and motion sensing/percussive) alternatives thus saving both water and therefore water heating.
• Building fabric – upgrade building fabric (including glazing, wall and roof insulation and draft proofing) at 20% of buildings
• HVAC upgrades – upgrade all mechanical ventilation systems to enable variable volume ventilation including the installation of additional environmental sensing. Re-balance all ventilation and wet heating systems.
• Catering – electrify all catering equipment to remove any catering fossil fuel usage</td></tr>
<tr><td>Heating system decarbonisation</td><td>Electricity, district heating, burning oil</td><td>Heating system decarbonisation incorporates several sub-measures including the below, phased between 2025 and 2033:
• Lerwick – bring all oil-fired heating systems onto the DHN
• Mainland/inner isles – replace all oil-fired heating systems with ASHPs serving the existing wet heating distribution systems, upgrading heat emitters as required.
• Outer isles – replace all oil-fired heating systems with ASHPs serving the existing wet heating distribution systems, upgrading heat emitters as required.
• Storage heaters – replace 50% of building with existing storage heater systems with network of air-to-air heat pumps.</td></tr>
<tr><td>Roof mounted PV</td><td>Electricity</td><td>Install roof mounted PV at 25% of Council buildings, phased between 2023 and 2030. Note installations have been limited to 12kW.</td></tr>
<tr><td>Domestic</td><td>EESSH 2 compliance</td><td>Electricity, district heating, burning oil,</td><td>Target EPC B or higher for 100% of the domestic building stock, requiring refurbishment to slightly under 70 properties per year.</td></tr>
</table>

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
		biomass, water supply & treatment	A more ambitious approach to EESSH 2 compliance whereby a fabric first approach is taken to improve energy efficiency, however in addition to storage heat upgrades, heat pumps are also installed at 50% of suitable properties on the mainland and inner isles, and 100% of suitable properties on the outer isles. Properties in Lerwick have not been modelled as connecting to the DHN. It is noted that this would result in an emissions increase, however it is recognised that this would likely offer a fuel cost saving for Lerwick residents. .
Infrastructure	Waste reduction and recycling	Landfill, ERP, waste sent to recycling centers	Waste reduction and recycling incorporates several targets including the below, phased between 2022 and 2040: • Islands level – support island wide targets for both a reduction in total waste generated (20%) and an increase in recycling rates (20%) • Council level – set Council specific waste reduction targets (50%) and increase in recycling rates (50%)
	Waste management	Landfill, ERP	Waste management incorporates two key measures including the below, phased between 2022 and 2040: • Lerwick biogenic waste collection – set up a biogenic waste collection scheme in Lerwick to reduce incineration of organic waste. Biogenic waste to be sent to a micro-anaerobic digestion plant to provide electricity to the waste management center • No increase of waste import – waste reduction measures will reduce the total waste available for incineration at the ERP, therefore high temperature heat pumps have been modelled to make up the shortfall in heat generation. Note that the costs of operating these heat pumps has been modelled to be borne by the council.
	Carbon capture and storage	ERP	Install carbon capture technology at the ERP to reduce CO_2e emissions from the incinerator by roughly 85%. Carbon capture at the scale required for the ERP is not a mature technology though there are pilot sites at this scale. CO_2 captured can be used for multiple purposes including conversion to low carbon fuels or as a medical gas, or alternatively CO_2 can be sent to long term storage. Carbon capture to be installed around 2030.
Transport	Low carbon vessels	Marine gas oil (MGO), biodiesel, hydrogen, electricity	Decarbonise Council vessels using low carbon fuels as they reach their end of life. Vessels identified below are those that approach their end of life by 2040. • Inter-island ferries – replace all ferries with alternatives that have battery electric, or hydrogen fuel cell propulsions systems based on route demands, including suitable port charging and hydrogen storage and refueling infrastructure • Tugs – all Council tugs with dual fuel vessels (Hydrogen and biofuel), including suitable hydrogen storage and refueling infrastructure at Sullom Voe port .
	Low carbon vehicles	Diesel, gas oil, hydrogen, electricity	Decarbonise Council vehicles using low carbon fuels/power systems as they reach their end of life. • Heavy-duty vehicles – replace with low carbon alternatives utilising fuel cell systems including sufficient hydrogen storage and refueling infrastructure. All new heavy-duty vehicles purchased after 2030 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2040 to allow for 10

Sector/sub-sector	Measure	Emissions sources impacted	Modelled measures
			year heavy-duty vehicle life. Some vehicles reaching end of life between 2030 and 2033 may need to be replaced with hydrogen ICE alternatives as an alternative solution as fuel cell technology matures and becomes more cost competitive. • Medium-duty vehicles – replace with low carbon alternatives utilising either hydrogen fuel cell (75% of MDVs) or battery electric (25% of MDVs) powertrains including sufficient hydrogen storage and refueling and charging infrastructure All new vehicles purchased after 2030 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2040 to allow for 10 year medium-duty vehicle life. Some vehicles reaching end of life between 2030 and 2033 may need to be replaced with hydrogen ICE alternatives as an alternative solution as fuel cell technology matures and becomes more cost competitive. • Light-duty vehicles – replace with BEV alternatives with charging infrastructure. All new light commercial vehicles purchased after 2025 must be low carbon in line with Transport Scotland targets. Therefore transition phased to 2030 to allow for 5 year vehicle life.
	Low carbon aircraft	Aviation spirit, electricity	Replace both aircraft serving Foula and Fair Isle with zero carbon alternatives between 2030 and 2035. It is recommended that both aircraft adopt the same zero carbon technology to facilitate fleet management and maintenance. Zero carbon aircraft here have been modelled with battery electric propulsion systems though it is recognised that hydrogen fuel cell powered aircraft may provide a viable alternative. Provide required charging or refueling infrastructure at Tingwall and island airports.
	Home working	Employee commute	Target 30% increase in homeworking as appropriate by 2040 to minimise employee commute emissions.
	Business travel reductions	Business travel	Target 30% reductions in business travel as appropriate by 2040.

Table 14 - 2040 ambitious pathway net zero measures

4.3.3.2 Pathway mitigation potential

The following charts illustrate the mitigation potential of the of 2040 ambitious pathway.

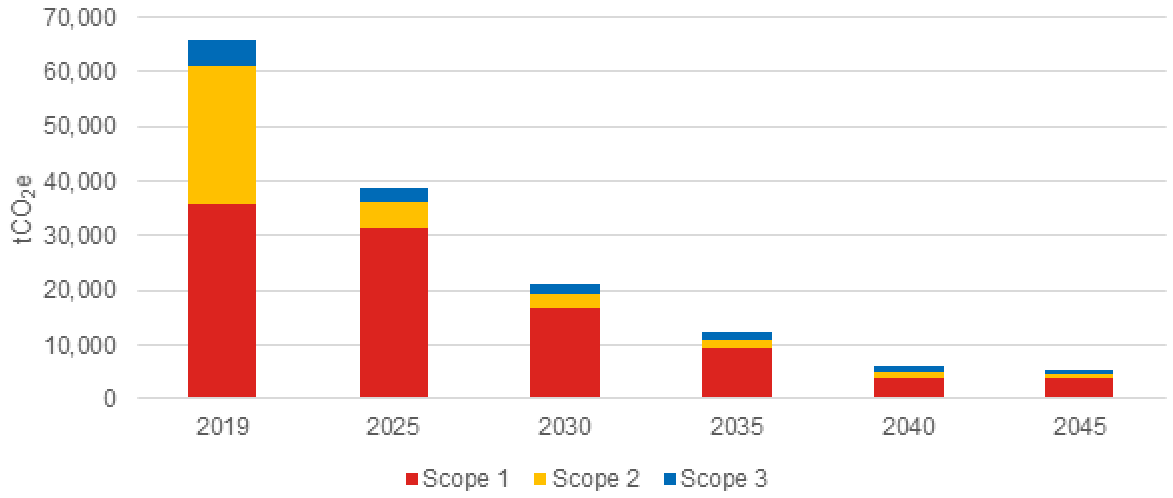


Figure 25 - Impact of the 2040 ambitious pathway by emissions scope

Emissions could be reduced by 91% by 2040 under the 2040 ambitious scenario increasing to 92% by 2045 due to the ongoing decarbonisation of the UK electricity grid.

	2019	2025	2030	2035	2040	2045
Scope 1, tCO_2e	35,709	31,327	16,837	9,538	4,177	4,177
Scope 2, tCO_2e	25,457	4,892	2,429	1,406	999	684
Scope 3, tCO_2e	4,709	2,498	1,825	1,287	818	459
Total, tCO_2e	**65,875**	**38,717**	**21,091**	**12,231**	**5,994**	**5,319**
% change	**0%**	**41%**	**68%**	**81%**	**91%**	**92%**

Table 15 - Impact of the 2040 ambitious pathway by emissions scope

As under the BAU scenario, the single most significant impact to SIC's emissions is the decarbonisation of the electricity grid as the interconnector is completed in 2024. By 2045, scope 1 emissions remain the majority of the Council's footprint, accounting for 78% of total emissions.

Figure 26 and Figure 27 highlight that under this scenario, the sector responsible for the greatest emissions in 2040 is projected to be infrastructure, responsible for 71% of total emissions. This is specifically due to the difficulty of decarbonising emissions from landfill and the residual emissions from the ERP, which account for 33% and 23% of Council emissions in 2040.

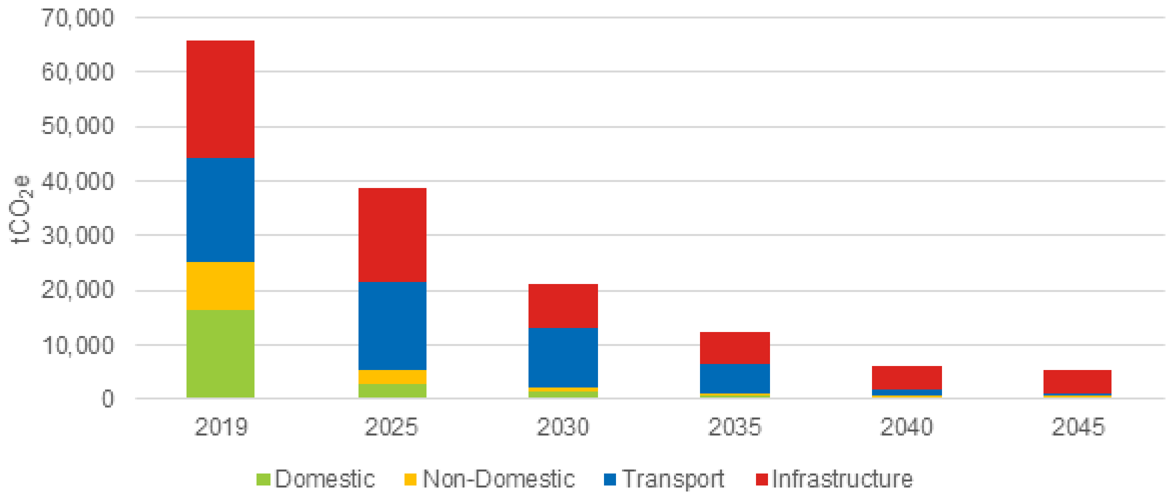


Figure 26 – Emissions projection by sector

	2019	2025	2030	2035	2040	2045	% change at 2040
Domestic, tCO_2e	16,612	3,026	1,315	700	484	381	**-98%**
Non-domestic, tCO_2e	8,798	2,496	973	505	416	361	**-96%**
Transport, tCO_2e	18,910	16,163	10,767	5,084	756	323	**-98%**
Infrastructure, tCO_2e	21,555	17,032	8,036	5,941	4,338	4,254	**-80%**

Table 16 - Breakdown of emissions by sector under pathway

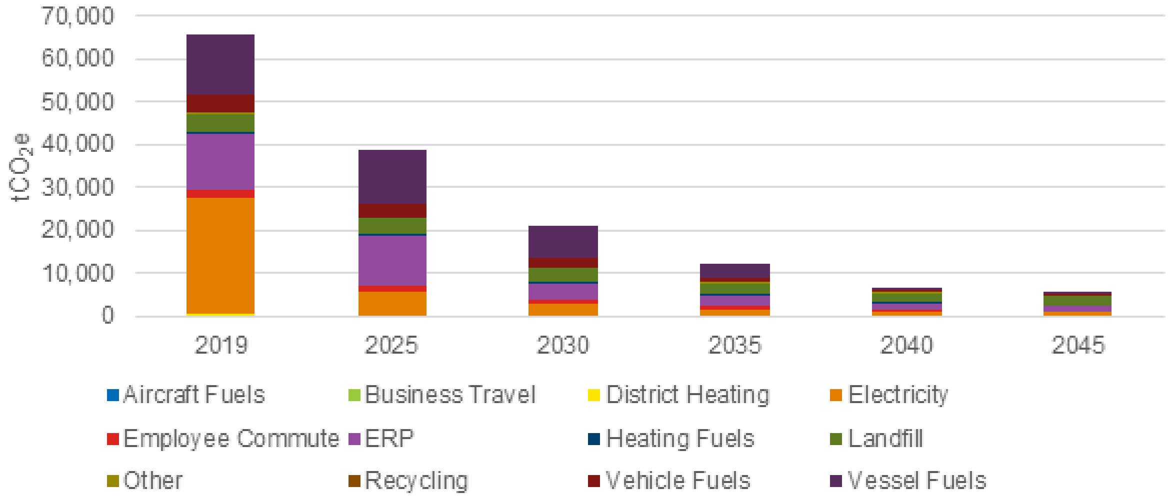


Figure 27 - Emissions projection by fuel type

The chart above demonstrates that by 2045, there is no single emission source that dominates the Council's footprint though the ERP and landfill contribute the most significantly, accounting for approximately 63% of the total footprint. The chart below summarises how each of the net zero measures contribute to the net zero pathway. The chart highlights that the decarbonisation of vessels, the ERP and other waste management actions contribute most significantly to the net zero pathway (42%, 23% and 23% of total decarbonisation respectively).

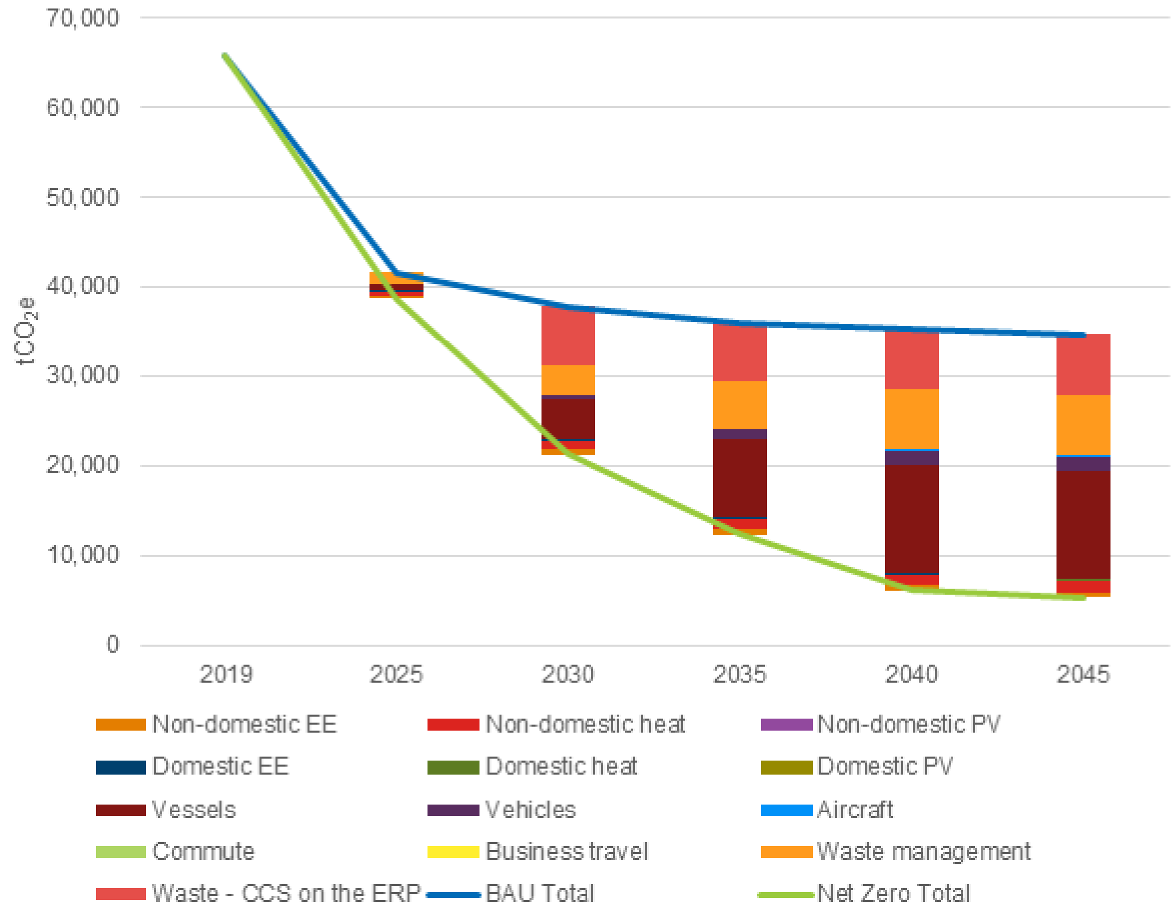


Figure 28 - Contribution of measures to the net zero pathway

The figure above demonstrates that the 2040 ambitious pathway reduces emissions by 83% against the BAU in 2040, taking total emissions reductions to 91% by 2040, and 92% by 2045. This scenario illustrates that there is limited additional decarbonisation that can be achieved.

4.3.3.3 Indicative investment costs and potential cost savings

Figure 29 shows the estimated 2040 ambitious pathway cost including capital investment (CAPEX), ongoing maintenance (OPEX) and impacts to fuel costs over five year intervals.

The 2040 ambitious scenario is expected to require a capital investment of £109m, with a total operational cost increase of £46m by 2045 due to additional costs for low carbon fuels and additional operational expenditure. The pathway achieves carbon saving against the BAU scenario at an overall rate of £240/tCO_2e by 2045.

Capital expenditure is expected to peak between 2028 and 2029 at £8.3m, though averages £6.0m per year between 2022 and 2039. The measures achieve a net operational cost increase of approximately £3.1m per year in 2040, reducing to £3.0m by 2045 as fossil fuel prices are expected to rise faster than electricity prices in long range government forecasts.

The breakdown of capital investment is explored further in Appendix A5, however, the most significant costs are expected to be for the ferries and the investment required to bring 75% of the domestic housing stock up to EESSH 2 compliance, estimated to cost a total of £47m (additional to fossil fuel ICE ferries) and £25m respectively.

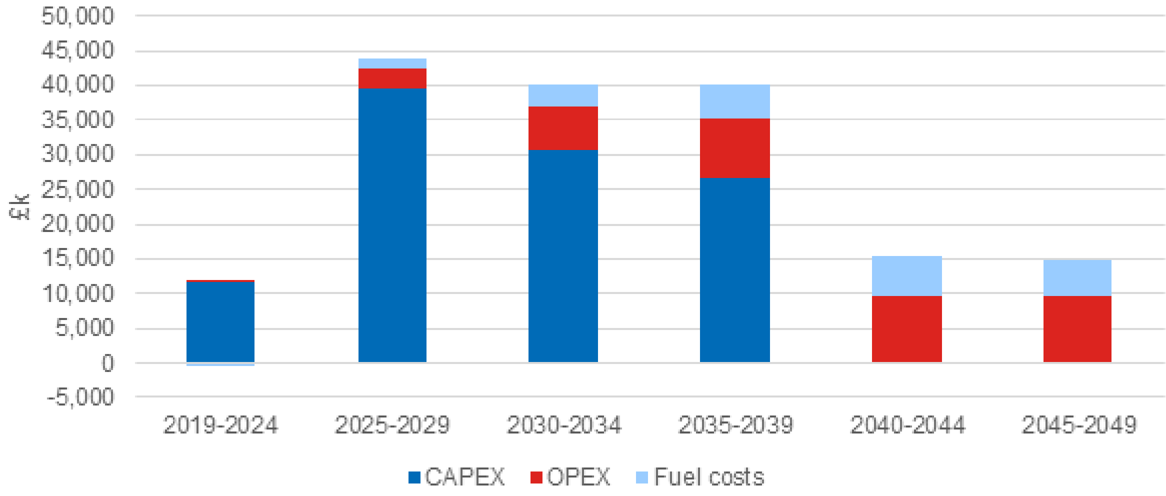


Figure 29 - 2040 ambitious pathway costs

In summary, the 2040 ambitious pathway demonstrates the most ambitious net zero pathway, decarbonising Council emissions, achieving a total carbon reduction of 91% by 2040, and 92% by 2045.

4.3.4 Residual emissions

Regardless of the measures that the Shetland Islands Council implement, there will be residual emissions remaining in 2045. A breakdown of the scope of residual emissions is provided in the chart and supporting table below. This has been calculated as a percentage of the 2019/20 baseline for each pathway, and, consistently across all pathways, is dominated by scope 1 emissions, though the largest residual emission source varies by pathway.

As expected, the 2040 ambitious pathway contains the lowest residual emissions of the modelled pathways.

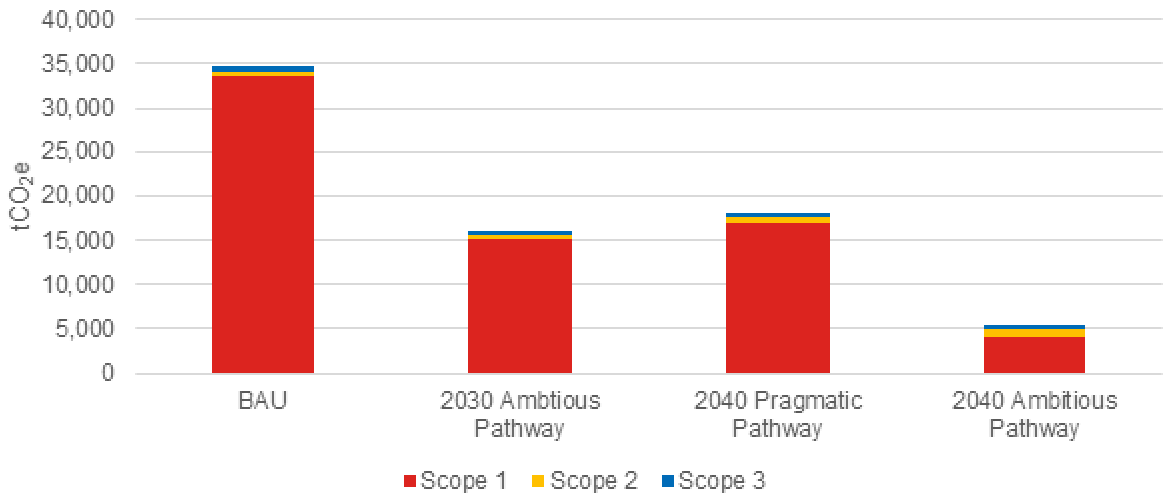


Figure 30 - Residual emissions in 2045 for each pathway

Emissions scope	BAU, tCO_2e	2030 ambitious, tCO_2e	2040 pragmatic, tCO_2e	2040 ambitious, tCO_2e
Scope 1	33,540	14,785	16,557	4,177
Scope 2	570	541	612	684
Scope 3	564	487	453	459
Total	**34,674**	**15,813**	**17,622**	**5,319**
Emissions reduction against 19/20 baseline	**47%**	**76%**	**73%**	**92%**

Table 17 - Residual emissions in 2045 for each pathway

4.3.4.1 Offsetting and carbon sequestration

The "net" in the term net zero is an important aspect of decarbonisation and represents the inherent challenges in reducing emissions to absolute zero. For example, there could be technical, financial or practical barriers that preclude reaching absolute zero emissions.

In order to reach net zero emissions and be able to credibly claim net zero status, SIC will need to offset its residual emissions by 2040, projected to be 5,300 – 17,700 tCO_2e dependent on the net zero measures adopted. Offsetting is a term which has a wide definition but can be broadly categorised into the following two subsets:

- Offsets that neutralise or remove carbon emissions from the atmosphere – these are compatible with net zero as they remove any residual emissions generated.
- Offsets that reduce or avoid emissions into the atmosphere – these are not compatible with net zero as they do not remove residual emissions generated. They are, however, compatible with carbon neutrality, as long as the offsets are outside of the Council's own value chain

The Assessment of the Shetland Islands Council Land Carbon Sequestration project has investigated the carbon sequestration potential of both SIC owned land, and land across the wider Shetland Islands area. The project has identified that from the Council's landholdings, there is an opportunity to reduce emissions through the restoration of land, however there is no opportunity to sequester carbon. As such there is not an opportunity for the Council to become net zero using solely its own land.

Whilst emissions from the Council's landholdings are currently excluded from the Council's emissions baseline and therefore excluded from the net zero pathways, emissions from Council owned land should be considered a part of the Council's operations. It is strongly recommended that the Council targets offsets outside of its value chain in order for any carbon neutrality claims to be credible. Therefore, it is suggested that there is not an opportunity for the Council to achieve carbon neutrality from its own landholdings. None-the-less, the Council should still target restoration of peat and grass land to achieve emissions reduction from its own operational land.

Looking outside of the Council's operational land on the Shetland Islands, again there is an opportunity to reduce cumulative emissions from land use (reduction of over 600ktCO_2e per year, significantly greater than Council residual emissions), however overall there is not an opportunity for the Shetland Islands to sequester carbon emissions. This is because in general terms, there is not an opportunity for restored peat land to become a net sequester of carbon emissions, and peat land makes up the majority of land on the Shetland Islands. There are, however, smaller pockets of land where sequestration is possible, specifically from restoring grass land. Investing in grass land restoration projects in areas of the Shetland Islands outside of their own operations may therefore provide an opportunity for the Council to achieve net zero.

However, there is far more opportunity for the Council to invest in peat land restoration, therefore supporting the reduction of emissions from the Shetland Islands as a whole. Providing that the projects and the associated emission reduction is verified through a scheme such as the Peatland Code, this would provide a credible and robust opportunity for the Council to achieve carbon neutrality within the boundary of the Shetland Islands.

For a detailed assessment of the carbon sequestration potential of Shetland Islands land, see the Assessment of Shetland Islands Council Land Carbon Sequestration project report.

5 Summary of outcomes

The figure and supporting table below show the emissions trajectory for all pathways.

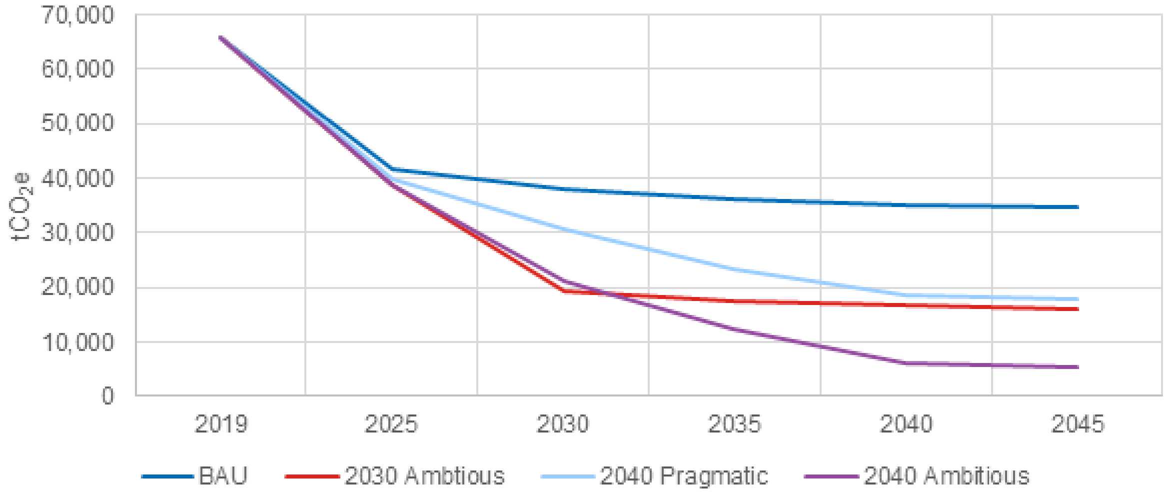


Figure 31 - Pathway comparison

	Residual emissions, in 2045 tCO_2e	Emissions reduction in 2045 vs. baseline		Cumulative carbon saving vs. BAU in 2045, ktCO2e	Capital Investment, £m	Pathway NPV, £m	Abatement cost, £/tCO2e
		tCO2e	%				
BAU	34,674	31,201	47%	-	-	-	-
2030 Ambitious	15,813	50,062	76%	344	56	-51	150
2040 Pragmatic	17,622	48,254	73%	249	96	-79	318
2040 Ambitious	5,319	60,556	92%	438	109	-105	240

Table 18 - Pathway comparison

The figure above demonstrates that all pathways ultimately lead to a reduction in Council emissions by 2045 that is significantly greater than the projected 47% under the Business As Usual scenario. The key messages are as below:

Key messages

The 2030 ambitious pathway achieves the most cost-effective rate of decarbonisation, costing approximately 50% less per tonne of carbon saved when compared to the two 2040 pathways. The 2030 pathway is able to achieve for this for four main reasons:

1. Pathway includes carbon capture at the ERP which is more cost-effective than most other decarbonisation measure
2. Pathway only includes a limited roll out low carbon fuels to ferries and tugs, which require high capital investment
3. Pathway sets a target of 60% of domestic properties to achieve EPC B or higher. Domestic properties decarbonise significantly under the BAU scenario and as such, are not cost effective to decarbonise further
4. Measures are rolled out sooner, therefore where there is an operational cost saving, this is achieved over a longer time period

- The 2040 ambitious pathway has more than 10,000 tCO_2e fewer residual emissions in 2045 which is expected to be significantly easier, and more cost effective to offset
- The 2040 ambitious pathway achieves 27% more cumulative carbon savings by 2045 than the 2030 ambitious pathway, and 76% more than the 2040 pragmatic pathway.
- The difference in cumulative savings between the 2030 ambitious pathway and the 2040 pragmatic pathway (+40%) demonstrate the benefit of taking early action, despite the two scenarios achieving similar levels of total annual carbon reduction in 2045.
- In each pathway, different measures contribute differently to total carbon reduction however there some key themes:
    - Vessels are a significant source of emissions in the baseline and continue to be under the BAU scenario. Decarbonisation of vessels is one of the biggest contributors to emissions reduction in each pathway and is therefore fundamental to achieving net zero for the Council.
    - The ERP is also a significant source of emissions. There are some key decisions that the Council needs to make around the future of the ERP, and subsequently the future of low-cost heat in Lerwick. Carbon capture, however, appears to be a relatively low cost emissions reduction measure and therefore does indicate one potential cost-effective decarbonisation pathway.
    - Decarbonisation of the Council's domestic building stock is largely achieved through decarbonisation of the electricity grid and therefore further decarbonisation achieves diminishing returns, despite requiring high levels of capital investment. As such, the focus for the Council's domestic building stock should be on achieving EESSH 2 compliance in a pragmatic manner, with a focus on minimising energy costs (whilst simultaneously not driving up rent costs).

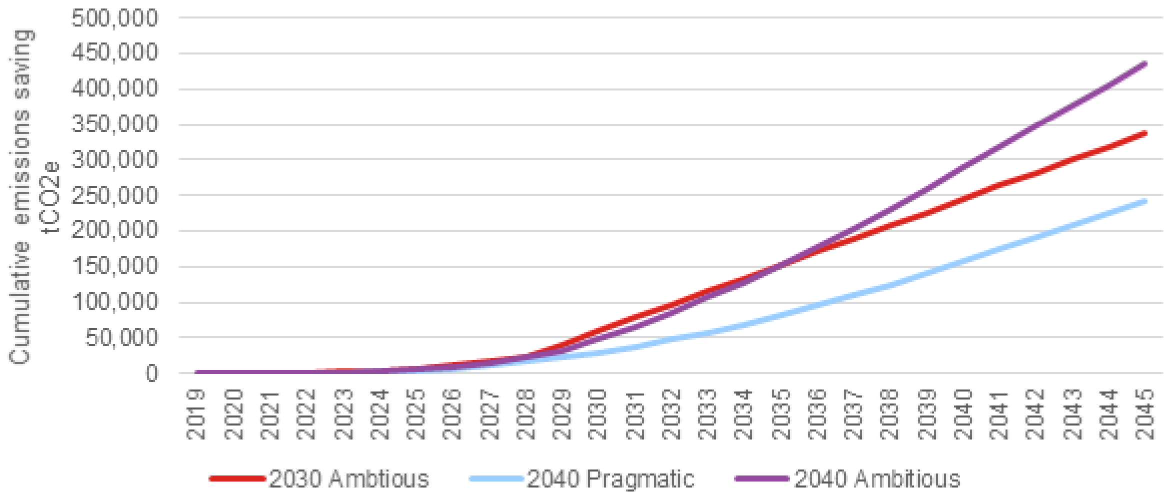


Figure 32 - Cumulative emissions savings against the BAU per pathway

6 Implementation

Whilst a detailed action plan is outside the scope of this routemap, it is important to identify how the Council can begin driving towards net zero by outlining the key aspects of an implementation plan and highlighting some of the key next steps. The measures and pathways detailed in this report are indicative of how the Council might achieve net zero though, in reality, there are multiple variations to these pathways that would allow the Council to achieve net zero by 2045.

It must also be reiterated that the Council cannot at this stage commit to the decarbonisation measures and technologies modelled and applied in the three net zero pathways as further detailed feasibility work and technology development is required. The Council must monitor technology developments, engage suppliers to determine financial and technical suitability, and only then adopt the appropriate technologies.

The Council's net zero implementation plan, therefore, should be an evolving document that identifies where the key technology and decarbonisation measure decision points are, and what information, further feasibility work and enabling measures need to be implemented ahead of those decisions points in order for the Council to make informed decarbonisation decisions.

Consideration	Impact to emissions sources	Comment
Progress monitoring	All emissions sources	Achieving net zero requires immediate, well-planned action to ensure that there is a balanced capital investment profile. It is recommended that interim net zero targets are set to enable the Council to monitor progress on a regular basis. Interim targets should include both decarbonisation targets and KPIs for number of sites addressed and key dates for any further feasibility work to be conducted by. Progress monitoring should also be used for identifying both successful and unsuccessful decarbonisation projects to enable the Council to continually feed lessons learned back into their net zero implementation process. In addition to this, the Council could consider mandating climate impact assessments at key project milestones to ensure that projects are in line with the Council's suitability objectives.

Consideration	Impact to emissions sources	Comment
		Targets and milestones will also help to provide transparency around progress and capital investment required. Setting a carbon budget would provide a robust framework for the Council to regularly report progress against.
Technology readiness	All emissions sources	The Council's net zero pathways plot decarbonisation trajectories over 20 years into the future. Over that 20-year period, there are expected to be significant advances in low carbon technologies in all sectors. It is crucial that the Council remains abreast of technology developments and how these are applicable to their operational estate, particularly around key emissions areas such as waste management, vessels and vehicles. The Council's role must be to monitor technology developments, engage suppliers to determine financial and technical suitability, and only then adopt the appropriate technologies. Key platforms/forums that the Council should maintain engagement with to further deepen their relationship with local low and zero carbon developments are: • The ORION project • The Sustainable Aviation Test Environment • The Scottish Hydrogen and Fuel Cell Association. • The North Sea Hydrogen Ports and Maritime Community • Islands Centre for Net Zero • Shetland Marine Working Group
Pilot projects	All emissions sources	As more low-carbon technologies become commercially available, it is important that these technologies are trialled to demonstrate that they are compatible with the Council's requirements within the geographical constraints of the Shetland Islands. As well as helping to demonstrate technology compatibility, pilot projects will help to de-risk capital investment and identify considerations for full scale roll out. SIC should also remain engaged with pilot programmes being run by other Councils to share lessons learned and best practice.
Feasibility studies	All emissions sources	The measures outlined in this report require further technical and financial feasibility studies to fully scope and cost measures into projects. Feasibility studies must also focus on other non-technical considerations, such as disruption to service and decanting of building occupants as an example.
Funding	All emissions sources	Significant capital investment is required by the Council to achieve net zero under all scenarios. As such, the Council should seek to capitalise on sources of central government decarbonisation funding. Some funding examples include: • Low Carbon Infrastructure Transition Programme (LCITP) – currently closed (with the exception of the Social Housing Net

Consideration	Impact to emissions sources	Comment
		Zero Heat Fund – see below) though SIC should remain aware of opportunity in case of re-opening • Green Growth Accelerator Programme – currently in pilot trials though aims to unlock up to £200m in additional investment in infrastructure projects to support Scotland's transition to an inclusive, net-zero emissions economy. • Scottish Green Public Sector Estate Decarbonisation Scheme (GPSEDS) • Scottish Public Sector Energy Efficiency Loan Scheme (SEELS) – zero interest loan for energy efficiency projects that payback in less than 10 years and achieve carbon saving at a cost of less than £278/tCO_2e • Non-Domestic Energy Efficiency (NDEE) – framework for energy industry funding of energy efficiency projects over £1m and achieve carbon saving at a cost of less than £400/tCO_2e • Social Housing Net Zero Heat Fund (SHNZHF) – £200 million has been made available over the next five years to support social landlords across Scotland to install zero emissions heating systems and energy efficiency measures across their existing stock. There is a focus on a "fabric first" approach" • Energy Efficiency Scotland (EES) Area Based Scheme (ABS) – funding for energy efficiency programmes (mainly insulation upgrades) in areas with high fuel poverty. It understood that the Council has been administering this funding locally on behalf of the Scottish Government since its inception. It is also understood that there is currently an ongoing piece of work reviewing options for the delivery of EES: ABS in Shetland. • Low Carbon Travel and Transport (LCTT) Challenge Fund – now closed, the LCTT provided £9.5m of funding to 10 active travel and low carbon projects across Scotland. Similar schemes are expected to be available in the coming years and as such, SIC should remain aware of announcements. Public funding is expected to become increasingly competitive, as such it is extremely important that SIC remain aware of fund application deadlines and opening dates to ensure that applications are ready for submission. Funds are generally administered on a first come first served basis and it is not uncommon for all available funding to be allocated within a few days.
Engagement with other Councils	All emissions sources	For a Scotland wide transition to net zero, it is crucial that local authorities engage and share any lessons learned. The Shetland Islands have some unique challenges with respect to service delivery due the geographical constraints of the islands, however there will be valuable lessons for the Council to learn from projects that other local authorities are running.

Consideration	Impact to emissions sources	Comment
Offsetting & carbon sequestration	All emissions sources	There is an opportunity to reduce Shetland Islands wide emissions by approximately 90 ktCO_2e per year through the restoration of degraded peat bog on SIC operational land, or 6,000 ktCO_2e per year through the equivalent on non-Council land. The Council should begin exploring opportunities to restore this land and to subsequently develop a dedicated carbon offsetting strategy and implementation plan. It is not expected that SIC will need to begin to restore peatland immediately, however a strategy should be developed by the end of 2023 to enable the Council sufficient time to plan the restoration works. For a detailed review of next steps, see the Assessment of Shetland Islands Council Land Carbon Sequestration project report. As discussed in section 4.3.4, restoring peat land is expected to reduce land use emissions though is not expected to sequester carbon. Peat land restoration is therefore not expected to be a viable long term offsetting strategy for the council. The Council must therefore also explore alternative offsetting opportunities either locally or outside the boundary of the Shetland Islands.

Table 19 - Summary of key considerations for Council net zero implementation plan

6.1 Key emissions areas

In addition to Table 19, there are some more specific implementation considerations for each emissions source. The table below outlines some of those considerations.

Emissions area	Key considerations
Waste management	Waste is perhaps the most challenging emissions source to decarbonise in the Council's operations because it is fundamentally linked to the provision of low-cost heat from the ERP to Lerwick's DHN. Some of the key challenges are: • Cost of heat – the ERP is currently able to provide very low-cost heat to the DHN. If the ERP is to be replaced, alternative low carbon heating systems (such as high temperature heat pumps) would be expected to increase the cost per unit of heat • Landfill / transport of waste – if the ERP were to be decommissioned, the current waste that is incinerated would need to be either sent to landfill or exported to the Scottish mainland for treatment. It is understood that there is limited cargo space available on outgoing ferries from the Shetland Islands therefore exporting waste may not be possible. • Waste reduction targets – reducing total waste generated on the islands will reduce emissions, however, it will also reduce heat generated by the ERP. Therefore, waste will either need to be imported to make up this shortfall, or alternative low carbon heating systems will need to be sought to make up the DHN heating demand.

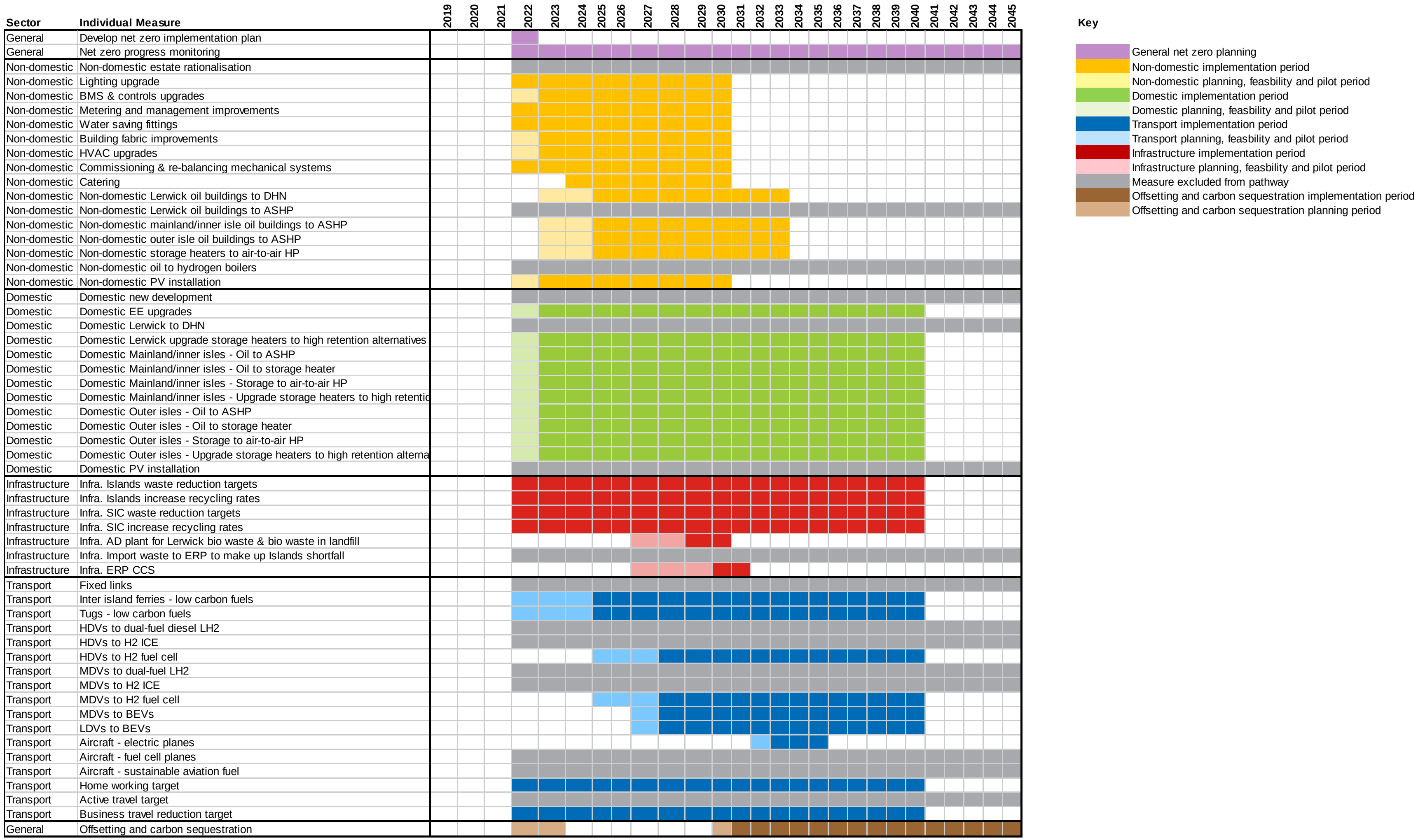
Emissions area	Key considerations
	• Carbon capture – carbon capture at the scale required for the ERP is not a mature technology though there are pilot sites at this scale. CO_2 captured can be used for multiple purposes including conversion to low carbon fuels or as a medical gas, or alternatively CO_2 can be sent to long term storage. Current CO_2 emissions from the ERP are estimated. The Council should seek to get CO_2 monitoring on the ERP exhaust to improve the accuracy of emissions reporting and to inform discussions with carbon capture technology providers. Due to the complexity of waste management on the Shetland Islands, and the fundamental role waste has in reducing fuel poverty through the provision of low-cost heat, it is highly recommended that the Council develop a net zero aligned waste management strategy.
Vessels	The decarbonisation trajectory for the Council's vessels has been aligned with the ongoing Project Neptune work that is specifically focussed on decarbonising the Shetland Islands maritime industries. The outcomes of this piece of work detail which vessels are likely to be compatible with which low carbon propulsion systems, as well as fuel storage, refuelling and charging infrastructure requirements. Building on this piece of work, vessel costs have been estimated based on a combination of Ricardo and SIC project experience. There is significant uncertainty in costing low carbon vessels as this is an emerging market and the regulatory requirements of low carbon vessels is not yet clear. SIC should continue to engage suppliers to better understand this regulatory landscape and low carbon vessel costs more broadly. As the existing vessels approach their end of life, there is a possibility that the low carbon alternatives available to the Council are not as projected in Project Neptune. As such, the Council must monitor technology developments, engage suppliers as vessels approach end of life to determine financial and technical suitability of low carbon propulsion systems for specific routes including the shore infrastructure costs, and only then adopt the appropriate technologies. Project Neptune, alongside the Council's ongoing assessment of fixed links, should form the basis of the Council's implementation plan for decarbonising inter island transportation though further work is required to establish more robust vessel costs, including the associated charging/refuelling and other shore infrastructure costs.
Domestic buildings	Decarbonisation of the Council's domestic building stock is largely achieved through decarbonisation of the electricity grid and therefore further decarbonisation achieves diminishing returns, despite requiring high levels of capital investment. There are also only a limited number of available properties for decanting tenants into to allow works to be carried out. Works therefore need to be carefully managed and planned to minimise disruption. The focus for the Council's domestic building stock should be on achieving EESSH 2 compliance in a pragmatic manner, with a focus on minimising energy costs and disruption (whilst simultaneously not driving up rent costs). It is recognised that the current social housing business model may not be able to enable fuel cost savings whilst minimising changes to rent and therefore may need

Emissions area	Key considerations
	review. It is recommended that public funding for decarbonisation is targeted through the SHNZHF as a priority.
Vehicles	Under Transport Scotland targets, there must be no new petrol or diesel light commercial vehicles by 2025, and no new petrol or diesel vehicles of any kind by 2030. Decarbonising some of the Council's social care buses, school buses and heavy-duty vehicles is expected to be challenging and as such, this is expected to be an area that would greatly benefit from pilot trials. As the Council must not purchase any new petrol or diesel heavy-duty vehicles by 2030, it is critical that the Council begins trialling vehicles with different low carbon powertrains no later than 2025, to ensure that an informed investment decision for each vehicle type can be made.
Aircraft	There is currently little certainty of which technologies will be available to decarbonise the Council's existing aircraft as they approach their end of life. As such, the Council must monitor technology developments, engage suppliers as aircraft approach end of life to determine financial and technical suitability of low carbon alternatives for specific routes, and only then adopt the appropriate technologies.
Non-domestic buildings	Key to the roll out of decarbonisation projects at the Council's non-domestic buildings is feasibility studies. Each building is expected to need a dedicated feasibility study that identifies fabric improvement requirements, control and monitoring system upgrades, and compatibility with low carbon heating systems. A fabric first approach is recommended though at some buildings is expected to be cost prohibitive. As such, a more pragmatic approach might be for feasibility studies to identify whether low carbon heating systems would be able to satisfy building heating demand without the need for fabric improvements, and where fabric improvements are a necessity for low carbon heating system installation. This assessment should then be used to drive the investment decision. Estate rationalisation has not been included in any pathway; however, the Council should begin considering how to utilise its space as effectively as possible and achieve some straightforward decarbonisation through the release of poorly performing assets.
Power infrastructure	Electrification plays a key roll in the decarbonisation of the Council's operations. It is understood that there is limited available electrical infrastructure on the Shetland Islands, an issue that is particularly pertinent at the outer isles. SIC must engage with Scottish & Southern Electricity Networks (SSEN) to identify and ultimately work to improve capacity issues. The NZSR provides a more in depth assessment of electrical capacity constraints on the islands.

Table 20 - Implementation considerations for key emissions sources

6.2 Indicative implementation plan

The figure below provides an indicative timeline for implementing measures identified in the 2040 ambitious net zero pathway. The darker bars indicate the ongoing implementation of a measure, and the lighter bars indicate periods for enabling works and further feasibility studies to be conducted. The figure demonstrates that there is a significant amount of early engagement required and as such, it is crucial that SIC set out their net zero implementation plans by the end of 2022.



7 Conclusions and next steps

This net zero routemap details achievable pathways for which the Shetland Islands Council can achieve net zero greenhouse gas emissions by 2040.

The mitigation measures identified are estimated to reduce greenhouse gas emissions by up to 92% from 2019 to 2045 and achieve a cumulative saving of up to 438 $ktCO_2e$, when compared to Business as Usual.

This report provides the context and evidence to enable SIC to achieve net zero emissions by 2040, ahead of Scottish Government targets, therefore provide an opportunity to demonstrate leadership within the Shetland Islands.

Aligned with this opportunity, a proactive approach as modelled by both the 2030 and 2040 ambitious pathways could avoid a situation where SIC finds itself approaching the 2045 Scottish Government decarbonisation deadline with significant major projects left to implement. In this situation, the Council may have to pay a premium for low-carbon solutions because demand exceeds availability. This could be exacerbated by a late rush to adapt to net zero by the private sector, which ultimately could lead to SIC missing the 2045 deadline. This could be further exacerbated in the Shetland Islands as there is a significant risk that UK-based installers may be less willing to work in the Shetland Islands when there is significant local work available. Delaying actions will also lead to higher carbon emissions over the period which will exacerbate climate change globally.

As modelled in the three pathways, there are significant differences in the capital investment profile that come about through the mixture of measures selected, their year of installation and the corresponding cost savings from, primarily, fuel switching but also efficiencies in energy use overall. The pathways with the highest investment demonstrate a faster route to net zero, and a higher level of overall long-term savings.

The recommended pathway for the Shetland Islands Council to strive for is the 2040 ambitious pathway, which addresses all major emissions sources, achieving a 92% reduction in emissions from the 2019/20 baseline by 2045.

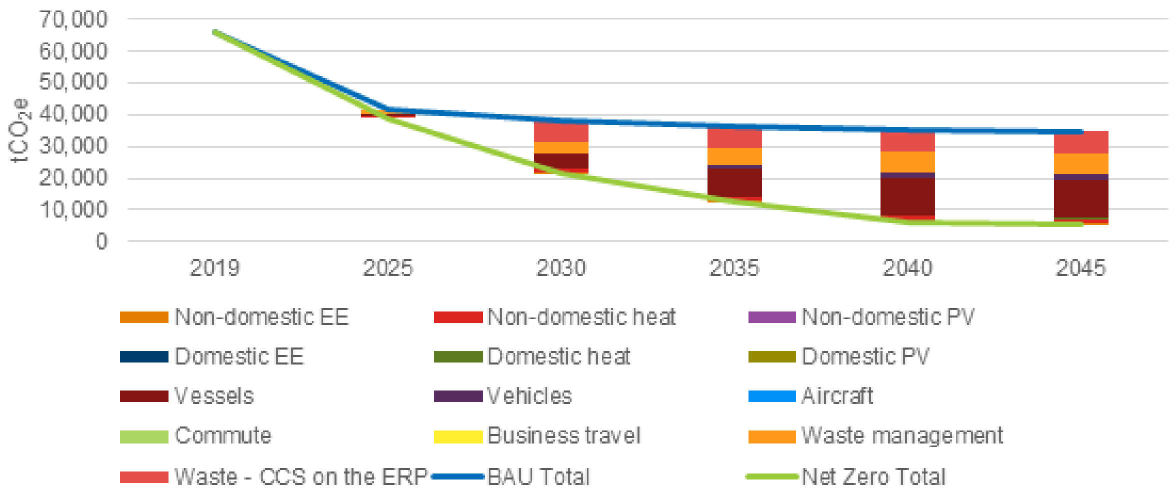


Figure 33 - Contribution of measures to the 2040 ambitious pathway

In spite of the risks and indicative costs outlined, Shetland Islands Council recognises that the public sector has a duty to lead the way on investing in low and zero-carbon, provided that it is given the appropriate funding. SIC also recognise the role they play in driving climate action with the local area and leading by example. Strong policy direction and clear requirements for future low carbon technologies will give the market confidence to develop solutions and generate efficiencies of scale, paving the way for the rest of society to follow.

Most importantly, early adoption of low and zero-carbon solutions will lead to early cuts in carbon emissions and fuel costs which will have long term global environments benefits, and immediate expenditure savings for the Council to use to either fund further decarbonisation or provide to services.

The Shetland Islands Council must now set out a clear implementation plan that identifies the key actions milestones and decarbonisation targets that will enable the Council to deliver on their net zero commitments.

Wider conclusions

Ricardo completed a study of local energy systems on small islands across Scotland in 2019, which highlighted that island resilience was reliant on key anchor services, such as those provided by the Council and that SIC infrastructure can form a hub for the decarbonisation of local island energy systems[13] identifying options for the decarbonisation of heat, power and transport as an interconnected system. We recommend that the Shetland Islands Council seeks to share learning and experience with other island local authorities as a collaborative approach is fundamental to streamlining the roll out of decarbonisation measures in an informed and de-risked way.

Emerging technologies such as hydrogen are expected to be crucial to SIC's net zero transition, however the technology is not yet at a point where it can be widely deployed. We recommend that the Council, seeks to identify opportunities for demonstrator projects which could inform future revisions of this net zero strategy. The Council's continued engagement with the Orion Clean Energy Project is expected to be pivotal in the successful development of hydrogen infrastructure on the Shetland Islands.

Finally, from a funding perspective, the Scottish Government has committed to significant investment to decarbonise the public estate, through schemes such as the Scottish Green Public Sector Estate Decarbonisation Scheme, Social Housing Net Zero Heat Fund and the Green Growth Accelerator Programmes. These schemes draw together capital grants, loans, and other revenue funding mechanisms - as the main government-led capital funding mechanisms to support leadership for heat decarbonisation right across the public sector. It is vitally important that SIC continues to develop the business case for some or all of the eligible recommended measures.

The Shetland Islands Council has a strong opportunity to achieve net-zero by 2040, with significant options to implement measures to reduce the need for expensive off-setting requirements beyond 2040.

To achieve net zero through divestment from all fossil fuels, it is recommended that the Shetland Islands Council implements/reviews the following measures at a minimum whilst continuing to investigate other technologies & emissions reduction opportunities where full information is not currently available.

General

- Develop an action plan for the implementation of measures outlined in the 2040 ambitious pathway, and set up strong internal governance by:
  - Setting up a Net Zero taskforce within the Council that has responsibility for driving the implementation of the measures outlined in the pathway, as well as monitoring the outcomes of these measures to continually provide lessons learned.

[13] https://www.hie.co.uk/research-and-reports/our-reports/2020/april/06/small-islands-energy-system-overview/

- Mandating climate impact assessments at key project milestones to ensure that projects are in line with the Council's broader suitability objectives.
- Maintain the routemap and action plans as live documents, with regular reviews of the measures recommended within the report, in particular at major investment decision points that would have a significant impact on emissions and ahead of reaching major milestones.
- Setting a carbon budget for the Council to regularly reports progress against

Non-domestic buildings

- Replace fossil fuel heating systems with low carbon alternatives. The 2040 ambitious pathway models the impact of electric heating systems such as heat pumps, electric storage heaters or a district heat network connection. However, over the next 20 years, emerging technologies such as hydrogen boilers are likely to become more competitive therefore the SIC must continue to monitor developments in low carbon heating systems
- Strategically upgrade building fabric to minimise heat loss. This is particularly important where potential low carbon heating systems would not perform effectively without fabric upgrades
- Replace all fossil fuels used for catering, likely with electric systems

Domestic buildings

- Replace fossil fuel heating systems with low carbon alternatives. The 2040 ambitious pathway models the impact of electric heating systems such as high retention storage heaters, heat pumps or a district heat network connection. However, over the next 20 years, emerging technologies such as hydrogen boilers are likely to become more competitive. The SIC must continue to monitor developments in low carbon heating systems
- Strategically upgrade building fabric to minimise heat loss.

Transport

- Replace all fleet vehicles with low carbon models such as EVs or hydrogen fuel cell vehicles aligned with Scottish Government public sector fleet decarbonisation targets
- Replace ferries and tugs with low carbon alternatives. The market for low carbon vessels is emerging, however it is likely that alternatives utilising either hydrogen fuel cell, battery electric or dual fuel propulsion systems will be developed
- Either replace aircraft with battery electric or hydrogen fuel cell alternatives or begin using a sustainable aviation fuel blend.
- Ensure there is sufficient charging and hydrogen storage and refuelling infrastructure to enable the above.

Infrastructure

- Target significant levels of waste reduction both within the Council and across the Shetland Islands to minimise emissions from landfill
- Continue investigating the opportunity to install carbon capture on the exhaust from the ERP

Other identified measures across all three potential pathways are aimed at reducing absolute emissions through efficiency improvements, better operating practices through implementation of policies, generating electricity from renewable sources, or replacement of existing equipment with high-efficiency models.

Appendices

A.1 Glossary

Abbreviation	Full description
ASHP	Air-Source Heat Pump
BEV	Battery Electric Vehicle
BMS	Building Management System
BAU	Business As Usual
CCC	Committee on Climate Change
NZCR	Council Net Zero Routemap
BEIS	Department for Business Energy & Industrial Strategy
DHN	District Heating Network
EESSH	Energy Efficiency Standard for Social Housing
EPC	Energy Performance Certificate
ERP	Energy Recovery Plant
ESTHA	Energy Savings Trust Housing Analytics
GHG	Greenhouse Gas
GSHP	Ground-Source Heat Pump
HVAC	Heating, Ventilation and Air Conditioning
HDV	Heavy Duty Vehicle
H2FC	Hydrogen Fuel Cell
H2ICE	Hydrogen Internal Combustion Engine
ICE	Internal Combustion Engine
LDV	Light Duty Vehicles
LTHW	Low Temperature Hot Water
MGO	Marine Gas Oil
MCV	Medium Commercial Vehicle

Abbreviation	Full description
MDV	Medium Duty Vehicle
MW	Mega-Watt
MSW	Municipal Solid Waste
NPV	Net Present Value
SSEN	Scottish & Southern Electricity Network
SCOP	Seasonal Coefficient of Performance
SHEAP	Shetland Heat and Power
NZSR	Shetlands Net Zero Routemap
SAP	Standard Assessment Procedure
SAF	Sustainable Aviation Fuel
TRV	Thermostatic Radiator Valve
T&D	Transmission and Distribution
ASHP	Air-Source Heat Pump

A.2 Modelling assumptions

The technoeconomic modelling is based on the following parameters

A.2.1 Costs

SIC specific energy prices have been used for the FY19/20 baseline where available. Where unavailable, Average 2019 prices from the Digest of UK Energy Statistics (DUKES)[14] have been used. Electricity & fuel price time profiles are based on HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions Tables 4-8, Central, Public & Commercial.[15]

Capital and operational costs and based on a mixture of Ricardo project experience, literature review / rules of thumb and SIC project experience.The costs are high level and developed from desk based research and as such, all measures require detailed techno-economic assessment by the council to inform the Council's decision making.

A.2.2 Emissions Factors

Where appropriate, all emissions factors used are from the UK Government GHG Conversion Factors for Company Reporting 2019.[16] Electricity & fuel emissions time profiles are based on HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions Tables 1 (Long range Generation based) & 2b. There are two exceptions, as detailed below.

Electricity

For the Shetland Islands' electricity grid, there is no official emissions factor, as such an emissions factor for electricity has been sourced and developed from analysis conducted by Pure Energy Centre[17].Pure Energy Centre's analysis suggests the following emissions factors:

	$kgCO_2/kWh$
2008	0.7746
2018	0.6668

Four assumptions have been made based on the above:

- Shetland Islands grid emissions factor is assumed to reduce at the same rate to the end of 2024 as it did between 2008 and 2018
- The ratio of kgCO2e/kWh to kgCO2/kWh for the Shetland Islands electricity grid is the same as for the UK National Grid
- An interconnector to the UK mainland's electricity grid is due to be completed by 2025, at which point, UK mainland grid emissions factors and projections are used
- The ratio between electricity supply and T&D loss emissions factors for the Shetland Islands electricity grid is the same as for the UK National Grid

Therefore the following grid supplied electricity emissions factors have been used:

	Electricity Supply, $kgCO_2e/kWh$	Electricity T&D Losses, $kgCO_2e/kWh$
2008	0.781	0.066
2018	0.672	0.057
2019	0.661	0.056
2020	0.650	0.055
2021	0.640	0.054

[14] Digest of UK Energy Statistics (DUKES) - GOV.UK (www.gov.uk)

[15] The Green Book: appraisal and evaluation in central government - GOV.UK (www.gov.uk)

[16] Greenhouse gas reporting: conversion factors 2019 - GOV.UK (www.gov.uk)

[17] Pure Energy Centre's "Shetland Energy Source Analysis 2020 Refresh – Summary of key findings"

	Electricity Supply, $kgCO_2e/kWh$	Electricity T&D Losses, $kgCO_2e/kWh$
2022	0.629	0.053
2023	0.618	0.052
2024	0.607	0.052
2025	0.124	0.010

District Heat Network

There is no calculated or measured carbon emissions from the ERP. As such, the following assumptions have been made to estimate emissions associated with DHN supplied heat and the ERP in FY 2019/20.:

	Value	Unit	Source
Annual ERP heat generation	47,981	MWh	Service Stats Annual
ERP heat as fraction of DHN	85%		Anecdotal, SHEAP
Total DHN demand	56,448	MWh	Estimated based on above
Total peak oil boiler demand	9,961	MWh	Estimated based on above
ERP annual incineration	20,880	Tonnes	Service Stats Annual
MSW emissions factors	0.022 0.0003 0.00004	$kt.CO_2$/TJ MSW (net) $kt.CH_4$/TJ MSW (net) $kt.N_2O$/TJ MSW (net)	National Atmospheric Emissions Inventory, 2019[18]
MSW energy per tonne	6.9	GJ (net)/tonne	DUKES 2020, Table A.1 – Estimated average calorific values of fuels 2019[19]
MSW emissions factor	**616.57**	**$kgCO_2e$/tonne MSW**	**Calculated based on above**
Parasitic electrical loads	1%	Of DHN heat demand	Southwark Council SELCHP District Heat Network[20]
DHN heat losses	30%		Anecdotal, SHEAP
DHN delivered heat emissions factor	**0.398**	**$kgCO_2e/kWh$**	**Calculated based on above**
DHN delivered heat to Council sources	0.072	$kgCO_2e/kWh$	Includes peak oil boiler consumption only to prevent double counting of ERP emissions..

Two projects completed in 2021 impact DHN emissions factors as below:

[18] Emission factors detailed by source and fuel - NAEI, UK (beis.gov.uk)

[19] DUKES_2020_dataset.xls (live.com)

[20] **Southwark Council SELCHP District Heat Network**

- **ERP water cooled wear zones** – increase ERP efficiency, subsequently increasing ERP contribution of heat to DHN from 85% to 93%. Measure is active from 2022.
- **Power station heat recovery** – heat recovered from diesel power generators is used to provide heating to DHN. Measure is only active between 2022 and 2024 as there is modelled to be no heat recovered from diesel generators when UK mainland interconnector is complete. Provides 3% of overall DHN heat demand

A.2.3 Net zero modelling tool assumptions extract

Net Zero Modelling Assumptions

The following assumptions have been agreed to support the net zero modelling process

(yellow)	User adjustable assumptions
(grey)	Non-user adjustable assumptions

General

Cost uplift for Shetland Islands projects

	Mainland and inner isles	30%
	Outer isles	50%

Cost premiums

Where asset is replaced at end of life (e.g. vehicle) with a low carbon alternative, cost premiums have been modelled (i.e. the additional cost associated with a low carbon alternative vs. current asset type)

Where a new asset is identified as a measure (e.g. metering), absolute costs have modelled

Non-domestic

Estate rationalisation

No capital or operational costs have been identified with asset rationalisation (other than costs associated with fuel savings)

Lighting

	Percentage of estate by energy consumption not yet upgraded to LED	27%
	LED energy consumption vs. fluorescent tube	45%
	Percentage of floor areas suitable for lighting controls (presence detection, daylight dimming etc.)	50%
	Increased energy savings resulting from controls	17%

Current lighting consumption per building type based on ECUK statistics for 2019

Lighting capital and operational costs based on Energy Systems Catapult guidance

BMS and controls upgrades

	Percentage of low energy users by energy consumption (<20,000kWh/yr) with programmable thermostats	45%
	Percentage of mid energy users by energy consumption (20,000 - 150,000kWh/yr) with BMS	38%
	Of which require upgrade (controllers, connectivity etc.)	50%
	Percentage of high energy users by energy consumption (>150,000kWh/yr) with BMS	72%
	Of which require upgrade (controllers, connectivity etc.)	50%

	Assumed current BACS class	D
	Targeted BACS class	C
	BMS capital and operational costs based on Energy Systems Catapult guidance	
Metering and management improvements		
	Targeted energy management at all buildings with total energy consumption greater than 10,000 kWh/yr	
	Energy saving from targeted energy management (if no control system on site)	5%
	Energy saving from targeted energy management (if there is a BMS on site)	3%
	In "High" scenario, electrical submeter per 100,000kWh and thermal energy meter on all wet heating systems with thermal demand greater than 20,000kWh	
	In the "Mid" and "Low" scenarios, 75% and 50% of total meters recommended in the "High" scenario are rolled out respectively	
	Energy metering and management, capital and operational costs based on Energy Systems Catapult guidance	
Water saving fittings		
	DHW consumption per building type estimated based on ECUK statistics for 2019	
	Number of fittings for each building type estimated based on extrapolation of condition surveys	
	Typical water saving	25%
Building fabric improvements		
	Based on condition surveys, percentage of buildings by energy consumption that would benefit from wall and roof insultation upgrades	47%
	Based on condition surveys, all buildings are already double glazed	
	Fraction of buildings that would benefit from draft proofing (note no details contained in condition surveys)	50%
	Building fabric upgrades only considered at buildings with a heat demand greater than 20,000kWh/yr	
	Estimated thermal performance (i.e. current U-values) and potential for improvement (i.e. proposed U-values) estimated based on condition surveys	
	Average thermal performance improvement per building	33%
	Building fabric upgrade costs based on Ministry of Housing Communities and Local Government Energy Performance of Buildings Directive	
HVAC upgrades		
	Ventilation rates estimated based on floor area serviced by system	
	Ventilation systems are currently fixed speed though are proposed to vary between 70% and 100% fan speed	
	All AHUs to be upgraded	
	Average system energy saving per upgrade	35%
	Capital costs estimated based on Spon's industry standard cost estimating guide	
Commissioning and re-balancing		
	Impacts wet heating systems only	

	Pump electrical consumption estimated based on ECUK statistics for 2019	
	Pumping energy saving potential	5%
	Cost estimates based on labour only	
Catering systems		
	Increase in electrical consumption is equal to catering fuel consumption saving	
	Costs estimated based on Ricardo project experience	
Heating systems		
	Air to water heat pump efficiency	2.4
	Air to air heat pump efficiency	2.2
	DHW heat pump efficiency	1.3
	Existing fossil fuel boiler efficiency	84%
	Hydrogen boiler efficiency	80%
	Storage heater efficiency	100%
	High retention storage heater energy saving vs. standard storage heater	5%
	DHN efficiency (assumed that metering is secondary side of heat exchanger)	100%
	Capital costs estimated based on Spon's industry standard cost estimating guide and Ricardo project experience	
	Capital costs include heat emitter upgrades as required	
	Average kWh/year generated per W of installed heating capacity	2.04
Solar PV		
	Percentage of commercial roof space suitable for PV	40%
	Energy generation (kWh/yr) per installed kW (specific to Shetland Islands)	**759**
	Maximum size of array in kW	**12**
	Capital costs based on industry rules of thumb and Ricardo project experience, £/kW	**1,274**
	Operating costs based on industry rules of thumb and Ricardo project experience, £/kW/yr	**32**
Domestic		
Energy efficiency		
	Fraction of buildings at EPC B or higher by 2022	26%
	Typical heating demand per property	11,838
	Typical non-heating electrical demand per property	3,157
	Average energy saving potential of bringing properties up to EPC B	**17%**
	Typical water consumption per day (litres)	**349**

	Capital costs estimated based on Spon's industry standard cost estimating guide and Ricardo project experience	
Heating systems		
	Air to water heat pump efficiency	2.4
	Air to air heat pump efficiency	2.2
	DHW heat pump efficiency	1.3
	Existing fossil fuel boiler efficiency	84%
	Hydrogen boiler efficiency	80%
	Storage heater efficiency	100%
	High retention storage heater energy saving vs. standard storage heater	5%
	DHN efficiency (assumed that metering is secondary side of heat exchanger)	100%
	Capital costs estimated based on Spon's industry standard cost estimating guide and Ricardo project experience	
	Capital costs include heat emitter upgrades as required	
	Average kWh/year generated per W of installed heating capacity	2.04
Solar PV		
	Percentage of domestic roof space suitable for PV	25%
	Energy generation (kWh/yr) per installed kW (specific to Shetland Islands)	**759**
	Typical size of domestic PV array (kW)	**2**
	Capital costs based on industry rules of thumb and Ricardo project experience, £/kW	**1,274**
	Operating costs based on industry rules of thumb and Ricardo project experience, £/kW/yr	**32**
New development		
	Heating demand per new dwelling	**9,575**
	Non-heating electrical demand per new dwelling	**2,798**
Infrastructure		
Waste management		
	Current area wide recycling rates	6%
	Current council recycling rates	22%
AD plant		
	Lerwick population as a fraction of total Shetland Islands population	**29%**
	Food waste as a fraction of total MSW	**23%**
	Electrical energy generation per tonne of food waste	**300**
	Capital costs based on Ricardo project experience, £/tonne	**910**

	Operating costs based on Ricardo project experience, £/tonne	**70**
DHN & ERP		
	Thermal energy generation (MWh) per tonne of MSW	**2.3**
	High temperature heat pump COP	**2.0**
	High temperature heat pump capital cost, £/kW	**1,370**
	CO2 absorption by CCS	**95%**
	CCS capital costs, £/tCO2	**92**
	CCS operational costs (as a fraction of CAPEX)	**10%**
Transport		
Fixed Links		
	Mainland to Bressay capital cost, £m	**29.1**
	Mainland to Whalsay capital cost, £m	**226.3**
	Mainland to Yell capital cost, £m	**200.2**
	Yell to Unst capital cost, £m	**149.1**
	Average fixed link operational cost (exc. energy consumption) as a fraction of capital cost	**0.6%**
	Fixed link electricity consumption, kWh/m/yr	**200**
	Assumed that where ferries serve multiple islands, 50% of fuel consumption is saved when fixed link is installed	
Vessels		
	Vessel decarbonisation (i..e low carbon fuel type and volumes) aligned with Project Neptune	
	Brake thermal efficiencies	
	MGO	52%
	Biofuel	52%
	Electricity	95%
	Hydrogen	49%
	Biofuel fraction for hydrogen-biofuel dual fuel vessel	25%
	Hydrogen fuel cell electrical efficiency	**60%**
	Hydrogen ferries use fuel cells whereas hydrogen tugs use ICE	
	Cost premiums for low carbon vessels based on Ricardo project experience	
Vehicles		
	Fossil fuel to electricity relative efficiencies - from BEIS Greenhouse gas reporting conversion factors 2019	
	Average car - diesel	3.3

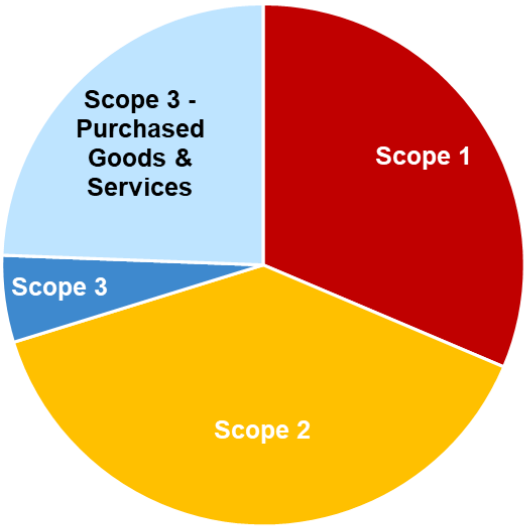
	Average car - petrol	3.6
	Average van - diesel	4.5
	Average van - petrol	4.5
	Trucks (including large vans)	3.3
	Buses (including minibuses)	4.7
	Large specialist	3.3
	Hydrogen fuel cell electrical efficiency	**60%**
	Hydrogen content of hydrogen-diesel dual fuel vehicle	**40%**
	Number of vehicles by type - Pure Energy Centre for SIC, Review of decarbonising existing vehicle fleet using hydrogen fuel alternatives, 2021	
	Cars	**6**
	Small vans	**78**
	MPVs	**11**
	Medium size vans	**69**
	Large vans	**2**
	4wd / pick ups	**32**
	Mini-buses	**8**
	Liftec	**1**
	Tractor	**1**
	Road sweeper	**1**
	Trucks	**9**
	Refuse collection vehicles	**8**
	Cost premiums for low carbon vehicle types vs. ICE vehicles - Low Carbon Vehicle Partnership, Influences on the Low Carbon Car Market from 2020 - 2030	
	BEV	**44%**
	Hydrogen fuel cell	**53%**
	Hydrogen ICE	**14%**
	Low carbon vehicle vs. ICE vehicle maintenance costs - Low Carbon Vehicle Partnership, Influences on the Low Carbon Car Market from 2020 - 2030	**81%**
Aircraft		
	Average flight hours per year	297
	Maximum scheduled flight time, mins - Shetland Summer Timetable (LWK - FIE and return)	70

	Flight time contingency (i.e. extra fuel requirements), mins - Based on EASA regulations	70
	Aviation spirit to electricity relative efficiency for aircraft - from BEIS Greenhouse gas reporting conversion factors 2019	2.7
	Hydrogen fuel cell electrical efficiency	**60%**
	Typical emissions savings associated with SAF/aviation spirit blend	**50%**
	Cost premiums for low carbon aircraft based on Ricardo project experience	
Hydrogen refuelling		
	Hydrogen fuelling station costs, £/kg/day	4,770
EV charge points		
	Capital costs per standard charge point	£10,000
	Capital costs per ultra fast charge point (150kW)	£167,000

A.3 Emissions baseline including purchased goods

Emissions associated with the procurement of goods and services have not been included within the net zero pathway analysis. Primarily, this is because the majority of Council emissions related data is, physical data (i.e. energy, consumption, distance travelled) and of good quality. However for the emissions associated with the purchase of goods and services, only expenditure data is available. As such, the accuracy and reliability of this data is not in line with other data sources. Expenditure based data also offers little insight into why emissions are what they are, and therefore does not provide the level of information detail required to develop decarbonisation measures.

For context, however, the emissions associated with the purchase of goods and services have been estimated based on the Council's procurement data using the GHG Scope 3 Evaluator Tool.[21]



	FY 19/20 GHG Emissions, tCO_2e	
Scope 1	35,709	37%
Scope 2	25,457	27%
Scope 3	4,709	5%
Scope 3 - Purchased Goods & Services	29,944	31%
Total	**95,820**	

Figure 34 - FY 2019/20 emissions baseline breakdown including purchased goods and services

The figure above demonstrates that the inclusion of purchased goods and services is estimated to increase the Council's reported emissions by 45%. Purchased goods and services would also become the second largest emissions source, after grid supplied electricity.

Figure 35 below provides a breakdown of emissions by spend category. As is clear, the spend categories are often vague (e.g. Business Activities), therefore it is not clear what action ought to be taken in order to reduce emissions from these categories, other than to reduce spend. The Council should set out an action plan that defines the process they intend to take to improve data quality and begin driving emissions reductions. Below are some key considerations / elements for the Council's action plan:

- Identify emissions hotspots:
  - Spend categories with high emissions
  - High emissions associated with specific suppliers
- Data gap analysis
  - Engage procurement teams to determine what data is available on SIC systems that can be substituted for spend data, e.g. for textiles, tonnes of fabric instead of GBP spent
- Engage key suppliers
  - Suppliers are likely to have physical information that can be substituted for spend data
  - Identify if key suppliers have any product LCAs
  - Work with suppliers to identify data requirements and opportunities for improvement

[21] Scope 3 Evaluator (quantis-suite.com)

- Set targets for:
  - Data quality improvement
  - Supplier engagement
  - Emissions reduction
- Set procurement standards for example:
  - All new buildings to be designed and constructed to a standard aligned with net zero (e.g. Passivhaus, Net Zero Public Sector Buildings Standard)
  - Embodied and operational carbon emissions of all new buildings to be considered vs retrofitting existing buildings
  - Key potential suppliers to have carbon management plans with clean decarbonisation targets
  - Key suppliers of goods (e.g. IT equipment, clothing, machinery) to have product LCAs demonstrating minimised environmental impact
- Data quality is expected to need to improve before credible and robust decarbonisation measures can be identified and quantified

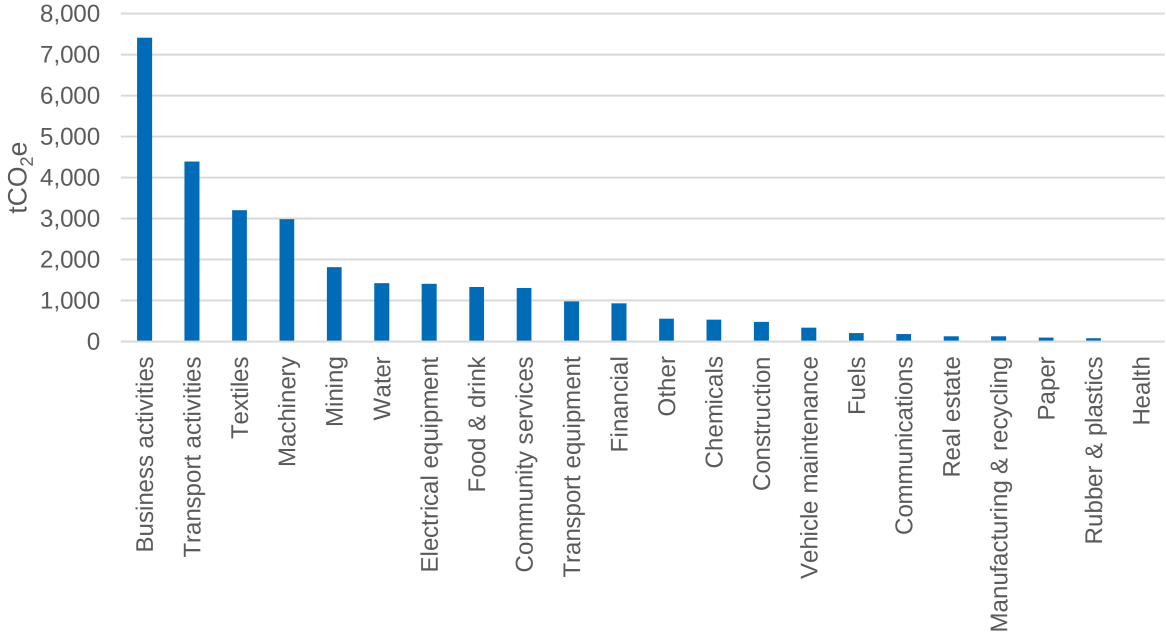


Figure 35 - Breakdown of emissions from purchased good and services, including capital goods

A.4 Description of shortlisted measures

1 Heat

1.1 Air to air heat pumps

Multi-split air to air heat pump systems connect one or more outdoor units to multiple indoor units using refrigerant. These units can provide heating and cooling and many units can recover heat between areas of heating and cooling making them ideal for buildings with cooling and heating demands. Most air source heat pumps can continue to operate effectively down to around –20°C outside temperature though are expected to need a housing to ensure protection from harsh weather conditions. Key design considerations and savings include:

- Runs on grid electricity, hence low carbon emissions compared to conventional fossil fuel boilers. Especially when grid mix has a high share of renewables such as wind.
- Coefficient of Performance is highly variable as heat recovery from heated areas to areas being cooled significantly increases SCOP. In heating only SCOP is assumed to be 2.2 in Shetland Islands context.[22]
- Requires refrigerant pipework to distribute heat.
- Does not require underfloor heating or large radiators.
- Different types of internal units can be used in combination depending on room being served – such as ceiling cassettes, wall mounted units in place of radiators or curtain heaters over doors.
- These systems can supply heating and cooling by way of air handling units. This may require existing air handling units to be replaced.
- Suited to offices due to high internal gains due to people and equipment can lead to cooling loads for much of the year.
- Suited to buildings which may otherwise be hard to treat.

1.2 Air to water heat pumps

Ait to water heat pumps have one of the most well-developed supply chains of all low carbon heat sources. They extract heat from outside air and upgrade it using a refrigeration cycle to the temperature required by the building. Most air source heat pumps can continue to operate effectively down to around –20°C outside temperature though are expected to need a housing to ensure protection from harsh weather conditions.

The efficiency of air to water heat pumps is primarily dependent upon the temperature of the water required by the heating systems and they are therefore well suited to wet underfloor heating systems. Where a building has an existing hydronic heating circuit it is likely that upgrades to that system will be required such as replacing radiators with models which have a higher surface area or replacing water to air heat exchangers in air handling units. In practice air handling unit replacement is often required.

- Runs on grid electricity, hence low carbon emissions compared to traditional fossil fuel boilers. Especially when grid mix has a high share of renewables such as wind.
- Lower capital cost than ground or water source heat pumps
- SCOP is assumed to be 2.4 in Shetland Islands context.[23]
- High space requirement and high installation costs for Ground-Source Heat Pumps.
- For water source heat pumps, building must be located near to a sustainable source of water.
- Suitable for sites requiring up to around 500kWth

1.3 Increase utilisation of heat network

[22] http://norden.diva-portal.org/smash/get/diva2:1313699/FULLTEXT01.pdf

[23] https://norden.diva-portal.org/smash/get/diva2:1312951/FULLTEXT01.pdf

There are several domestic and non-domestic sites that could potentially be served by the heat network therefore increased utilisation of the heat network would have a cost and carbon benefit. Key design considerations and savings include:

- Site specific measures would need to be identified to determine if LTHW from the DHN can meet the load.
- May require updated equipment.
- Heat medium used by air handling units and calorifiers would need to be assessed to determine if replacement units would be required.
- Site assessment would need to be carried out therefore not possible to include specific recommendations.
- DHN pipework runs need to be assessed to determine

1.4 Storage heaters

Shetland islands have a lot of experience with storage heaters in both domestic and non-domestic properties. As the Shetland Islands electricity grid decarbonise, these storage heaters become a lower carbon form of heating though. In the Council's domestic building stock High retention storage heaters are being rolled out as a more energy efficient alternative. Key design considerations and savings include:

- Ability to store heat overnight could lead to low operational costs though systems need to be properly set up.
- Shetland has significant renewable electricity generation and periods when supply exceeds demand leading to curtailment.
- Minimised disruption and minimised refrigerant usage
- Would be an innovative project as part of the Shetland smart grid – speculative at this stage.
- Would need more detailed analysis as part of a feasibility study to determine potential business case and outline technical specification.

1.5 Hydrogen boilers

Hydrogen boilers do not currently have an established supply chain, largely because there is not currently a widely established market for hydrogen as a heating fuel. Hydrogen boilers on the Shetland Islands would be expected to operate with very similar conditions to current oil-fired boilers, therefore making them an effective drop in solution. Key considerations include:

- Expected to be most suitable at non-domestic properties where building fabric upgrades are cost prohibitive, therefore ASHP is not a viable option
- Requires a more established market for green hydrogen to bring down fuel cost prices and ensure that there is a guarantee of supply
- Hydrogen will require external storage, more similar to LPG storage thank than oil storage tanks
- It is assumed that building fabric, pipework and radiators do not need to be upgraded to accommodate hydrogen boilers. Fuel supply pipelines, however, will need to be upgraded.
- Hydrogen boilers are most suited to assets with an existing wet distribution system, i.e. have an existing oil-fired or LPG-fired boiler
- Likely to require more frequent deliveries of fuel as hydrogen has a low density compared to oil, therefore a similarly sized storage tank will store less energy
- Green hydrogen is currently a relatively expensive fuel as electrolysis is powered by zero carbon electricity. For each unit of hydrogen, approximately 1.3 units of electricity are required. Hydrogen then also has to be delivered to site
- The efficiency of a hydrogen boiler is assumed to be 80% as per the Climate Change Committee's 6^{th} Carbon Budget . Therefore, heat pumps potentially use electricity up to 3.2 times more efficiently.

1.6 Localised/small scale district heat networks

There is an opportunity to create small scale district heat networks whereby a central energy centre is used to provide heat to several nearby assets. Small scale heat networks could be solely used to connect council assets, but the benefit would be maximised where there is an opportunity to connect other, non-council buildings. One potential example is at Brae, one of the most densely populated areas outside of

Lerwick. Here, there are approximately 20 non-domestic buildings along a 2km stretch of road that could potentially be connected, plus dozens of potential domestic properties. A detailed feasibility study should be carried out to determine the technical and economic viability of such a project. Key considerations include:

- Central energy centre and heat distribution network would need to be cost competitive with heating systems local to each building considering CAPEX, fuel costs and maintenance costs
- District heat networks generally become viable as a result of economies of scale, this is particularly pertinent with low carbon heating systems that potentially require reasonably high CAPEX
- Heat demand of each asset to be established to determine heat density of area
- Current heating system of each asset to be established to determine viability of heat network connection. For example, a property with storage heaters is likely to be costly to upgrade for compatibility with heat network compared to upgrading storage heaters.
- Opportunities for central government funding including LHEES
- Heat network could potentially operate with either hydrogen boilers or ASHPs. To minimise disruption in each asset (i.e. radiator/pipework upgrades), heat pumps are likely to need to operate at high temperatures.

2 Energy efficiency

The energy efficiency of a building is essential to maintaining a low carbon performance in its operations. This is often achieved through a mixture of retrofitting and energy management processes including:

<u>2.1 Energy management</u>

The implementation and enhancement of energy management processes in order to ensure a systematic approach to energy use and achieve reductions across the portfolio can be helpful for improving the energy efficiency of a location. This includes the implementation of suitable management processes plus the installation and use of metering / sub metering with energy data analysis, performance reporting, and working toward agreed reduction targets.

Energy management becomes increasingly important as low hanging opportunities are completed and further improvements become more difficult to identify, implement and sustain. This will include aspects such as formal site policies with senior management engagement, the setting of objectives and targets, and systematic programmes and mechanisms to report and account for energy performance at a local level (e.g. by key plant or activity, for example how much energy used per department per week). Typically, savings of between 5% - 10% can be anticipated from effective management systems.

Energy management can generally be applied to all operational sites. The level of metering infrastructure will depend on the amount of energy used at each site and their complexity. For example:

- A large college is likely to require extensive sub metering by area / department.
- At smaller facilities usually the main electricity supply and fuel supply are all that need to be metered, and this can be carried out with smart meters (SMETS2 or similar).

<u>2.2 Controls</u>

Improvements to controllers and control systems for buildings can reduce energy consumption through ensuring equipment only operates when required, and that it does not work harder than necessary. This may for example include controls to automatically switch equipment off, adjusting control programmes including timers, changing setpoints and increased use of sensors.

It is commonplace to find equipment operating unnecessarily in buildings and it is not uncommon to realise 10%-15% energy savings through improved control of service plant and equipment. Standard measures may be classed as:

- Amend control settings to optimise energy performance.
- Upgrade controls to facilitate ability to optimise energy performance.

A variety of potential measures exist, examples include:

Upgrades to building management systems (BMS) to increase control capability, plus optimising control algorithms.

- Use of sensors such as occupancy sensors for lighting, or CO2 sensors for air handling plant.
- Rationalisation of boiler controls settings.
- Simply reprogramming existing control units/BMS to optimise energy performance.

Improvements to controls can be applied to all operational sites, and measures will vary according to building type, size, use and installed infrastructure. However, it may be possible to group buildings by size and age in order to come up with common groups of measures. Large facilities are likely to have a BMS whereas smaller facilities are likely to have simple standalone controllers on different plant, e.g. central heating controller, or air conditioning controller.

Simpler measures will be easy to implement at low cost and will only require a competent person to carry out. These are likely to focus on optimising control settings on existing equipment. Changes to BMS will require specialist persons and potentially have modest to high costs. Some measures may require the installation of additional equipment to enable better control, e.g. occupancy sensors for lighting, more advance heating controllers for heating systems in smaller buildings, whereas BMS may require additional functionality, weather sensors, control valves and other hardware.

2.3 Building Envelope

The implementation of improvements to the building envelope can be a useful instrument in order to reduce heat loss / gain and improve insulation. This in turn will save energy through reducing the demand for heating and cooling.

Measures may include:

- Replacing windows and doors to reduce heat loss, and / or fitting better seals around doors and windows.
- Fitting air curtains and air locks to doors with high traffic to reduce heat loss.
- Fitting solar films and shades to large windows reduce heat gain.
- External / internal wall insulation, and loft / roof insulation.

Saving potential varies by measure and are likely to be in the range 3% - 10% of associated energy.

The improvement and implementation of building envelope can be applied to all sites, and measures will vary according to building type, size, use and installed infrastructure. However, it may be possible to group buildings by size and age in order to come up with common groups of measures. Older buildings are likely to have lower levels of insulation and so are likely to be better suited to these measures. For example, buildings over 30 years old are more likely to have low levels of wall / roof insulation and windows and doors older than 20 years are more likely to need replacing. Buildings with low occupancy rates or requiring low levels of heating are less suited to these measures. If major Council buildings are due to be replaced in the near future, then only measures with significant carbon saving / short paybacks are advisable.

Some investigation will be required on a building by building basis to determine which measures are best suited and cost effective. For example, cavity wall insulation is relatively low cost whereas external/internal insulation on solid walls may not be economic to implement. Moreover, some insulation measures may be costly to implement, and this should be weighed against the long-term operating cost of the building factoring in the impact on energy costs to determine viability.

2.3 Plant

It is possible to reduce energy consumption through implementing improvements to building services equipment – heating, ventilation, air conditioning (HEVAC) and related equipment.

This method can be applied to all sites. However, there are a large range of efficiency measures that could be applied, and so will vary according to building type, size, use and the existing infrastructure. It may be possible to group buildings by size and age in order to come up with common groups of measures.

Larger sites will have AHUs and extensive infrastructure that could be addressed. Smaller sites are less likely to have AHUs etc, and more likely to have simpler heating systems, e.g. boiler with radiators. Here the focus will likely be on boiler replacement, better heating controller with zones control, TRVs and circulation pumps. Savings potential will vary by measure, typical range is between 5% - 20% of related energy use.

Types of measure include:

- Change technology – migrate from steam to hot water, fit PoU (point of use) hot water supplies.
- Reduce losses – improve insulation, restrict use, fit higher efficiency equipment (upgrade boilers, fans, pumps, electric motors etc.)
- Rationalise plant – consolidate multiple plant in centralised system
- Recover wasted energy – heat recovery on AHUs, boilers and compressors
- Improve controls – enable more efficient operating modes

Measures will be specific to existing infrastructure in each building and should take account of wider decarbonisation plans, e.g. if there are plans to migrate from gas fired boilers to alternative heat sources then there could be a significant impact on the way the heat is delivered, e.g. heat pumps may require larger radiators. Life of existing plant should also be taken into account, and it may be more cost effective to wait to upgrade / change plant when it reaches end of life and implement a larger more wide-ranging improvement.

3 Power

There are a range of methods that the Council could undertake to decarbonise power supply across their sites. Only roof mounted PV has been modelled in the net zero pathways.

<u>3.1 New roof-mounted solar photovoltaics (PV)</u>

Typically, this would consist of rooftop solar PV and/or carpark-mounted solar PV modules directly on site. Key design considerations and savings include:

- Assumes roof mounted PV is appropriate at up to 40% of Council properties.[24]
- Circa. 1MW of cumulative rooftop capacity across all SIC non-domestic estate based on 12kW PV array limit.
- Year 1 generation of 754MWh
- Important to note PV modules degrade at approximately 0.3-0.5% annually.
- Assumes an average domestic PV array size of 2kW[25]. Note that no roll out of PV to council domestic properties has been assumed, therefore no PV generation has been assumed.

This measure is assumed to be applicable at up to 40% of non-domestic sites, and 25% of all domestic assets. Note that Rooftop PV is easily scalable and provides a renewable generation source for even the smallest of buildings.

[24] Microsoft Word - Renewable and Low-carbon Energy Capacity Methodology - Final 04032010c.doc (publishing.service.gov.uk)

[25] Microsoft Word - Renewable and Low-carbon Energy Capacity Methodology - Final 04032010c.doc (publishing.service.gov.uk)

4 Waste

4.1 Waste reduction

Waste is a significant component of the Council's emissions under both the BAU and net zero trajectories. Waste arisings from both the Council's operations and the wider islands community impact the Council's footprint as a result of the Council's landfill site and ERP. Significant waste reduction must therefore be targeted in order to achieve decarbonisation.

- It is expected that Council can target more significant levels of waste reduction than the wider islands, therefore leading by example
- Scottish government is targeting a 15% waste reduction target by 2025, longer term targets do not exist though minimum waste targets by 2030 and 2040 should therefore be 15%.[26]

4.2 Increase recycling rates

It is possible to achieve a reduction in waste sent to landfill and ERP through an improved segregation of waste. Improved waste segregation should be targeted at all sites and also across the islands as a whole. Where possible, install dry mixed recycling bins in every ward and department.

- Install dry mixed recycling bins in areas with higher portions of packaging waste (e.g. depots, public areas).
- Install dry mixed recycling bins in areas with higher portions of plastic waste (e.g. restaurant, public areas, and offices).
- Install dry mixed recycling bins in areas with higher proportion of non-confidential paper (e.g. offices).
- Provide clear bin labels on all waste bins (e.g. general and recycling).
- Review the positioning of waste bins in each department.
- Deliver waste segregation campaign to minimise recycling waste in non-recycling bins.
- Reduce the use of single-use items and consumables (e.g. appliances and cleaning supplies).

4.3 Biogenic waste segregation

There is an opportunity for a biogenic waste collection in more densely populated areas (e.g. Lerwick). Removing biogenic waste from MSW incinerated in the ERP will improve the quality of heat from the ERP and could be used to generated electricity via anaerobic digestion and subsequent combustion. Some key considerations are as follows:

- Assumes biogenic waste is 23% of total MSW27
- Assumes Lerwick accounts for 29% of population and therefore 29% of waste
- Assumes 300 kWhel per tonne of MSW28
- Assumes all electricity is used at the waste management centre
- Does not account for increased fuel usage for refuse collection as assumes biogenic waste can be collected in same trip as MSW

4.4 Rate of waste import

Waste reduction measures will reduce the total waste available for incineration at the ERP, therefore reducing the total heat generating capacity. The Council and SHEAP must decide whether an increased rate of waste is imported from elsewhere (e.g. Scottish mainland) or whether alternative low carbon heating sources are added to network. Some key considerations are as follows:

- ERP is a currently a low-cost form of heat therefore inclusion of low carbon heat source would be expected to increase cost of heat

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[26] Managing waste - gov.scot (www.gov.scot)

[27] https://www.zerowastescotland.org.uk/sites/default/files/The composition of household waste at the kerbside in 2014-15.pdf

[28] Biogas from source separated organic waste within a circular and life cycle perspective. A case study in Ontario, Canada - ScienceDirect

- High temperature ASHPs are expected to be viable heat sources at the heat loads required though SCOPs would be reduced to circa 2.
- For the purposes of the net zero pathways, it is assumed that the Council will provide the investment and ongoing maintenance of any low carbon heating system to preserve the revenue stream
- If the Council wishes for the ERP to continue providing the vast majority of heat to the DHN, waste will need to be imported from elsewhere. The Council must decide and begin making arrangements for waste contracts with other local authorities if required
- It is expected that there is only capacity to import waste and note export to/from the Shetland Islands due to cargo capacities on ferries.

4.5 Carbon capture

There are several carbon capture techniques that could be considered to extract CO_2, these include pre-combustion, combustion and post combustion options. Given that the proposal focuses on capturing CO_2 from an existing facility, the technology focus is on post-combustion capture from post-combustion flue gases.

The most well proven technology is the absorption process based on the use of a chemical solvent, such as various amines e.g. Monoethanolamine (MEA) or Tetraethylenepentamine (TEPA)[29], alkali (e.g. potassium carbonate) or physical solutions This study will therefore focus on the application of absorption (and use of a solvent) as the preferred method for post-combustion CO_2 removal. This process is estimated to be able to capture at least 90% of the CO_2 in the flue gas

For a detailed assessment of carbon capture potential at the ERP, see the Project Neptune WP3 Final Report, Appendix A2.

8 Transport and travel

8.1 Vehicles

Shetland Islands Council has a fleet of just under 300 vehicles under its management with a majority of the vehicles being 4x4s and pick-ups. A breakdown of the fleet composition and the current fuel of operation has been presented in the table below:

Vehicle category	Vehicle examples	No. vehicles
Light-duty	Cars & small vans	125
Medium-duty	Medium to large vans, pick-ups, MCVs etc.	137
Heavy-duty	Refuse collection, gritters, machinery etc.	32

A selection of low-carbon and zero-emissions powertrains have been identified as alternatives for the conventional ICE powertrains of the various vehicle types considered in this study. The technology selections have been based on key criteria including

- Spatial characteristics (i.e., dispersed nature of the locale)
- Current energy mix and ongoing developments in the on/offshore renewables sector
- Prospects for energy security and resilience

Evaluating the current trajectory for low-carbon transition and these planned developments for future energy security, two sustainable, low/ zero carbon, 'end-point' energy carriers have been identified:

[29] Solvent selection for carbon dioxide absorption - ScienceDirect

renewable electricity and green hydrogen. Based on the identification of these energy carriers and the nature of trips and purposes the prospective technologies would need to replace, the following selection of powertrains have been identified.

1. Diesel and Hydrogen – Dual fuel Tech. – Conventional ICE powertrains operating in
2. Battery Electric Vehicle (BEV)
3. Hydrogen Internal Combustion Engine (H2ICE)
4. Hydrogen Fuel Cells (H2FC)

The table below presents which specific powertrain will be applied to the existing diesel-run ICE as low-carbon replacements, under the three scenarios which are driven by two variables: tech. availability and cost-competitiveness.

Vehicle type	Vehicle category	Current fuel type	2030-Ambitious	2040-Pragmatic	2040-Ambitious
Refuse Collector	HDV	Diesel	Diesel-LH2	H2ICE	H2FC
Trucks	HDV	Diesel	Diesel-LH2	H2ICE	H2FC
Road sweeper	HDV	Diesel	Diesel-LH2	H2ICE	H2FC
Mini-buses	Medium-LDV	Diesel	Diesel-LH2	H2ICE	BEVs
Buses	Medium-LDV	Diesel	Diesel-LH2	H2ICE	BEVs
Liftec	Medium-LDV	Diesel	Diesel-LH2	H2FC	H2FC
Medium Vans	Medium-LDV	Diesel	Diesel-LH2	H2FC	H2FC
Large Vans	Medium-LDV	Diesel	Diesel-LH2	H2FC	H2FC
4WD/Pickups	Medium-LDV	Diesel	Diesel-LH2	H2ICE	H2FC
MCV	LDV	Diesel	BEVs	BEVs	BEVs
Small Vans	LDV	Diesel	BEVs	BEVs	BEVs
Cars	LDV	Diesel	BEVs	BEVs	BEVs

Note:

Diesel-LH2: Hydrogen Dual-fuel Tech. – Adaptation based on fleet analysis report by PURE Energy Ltd, 2021

BEVs: Battery Electric Vehicles – Assumed transition

H2ICE: Hydrogen Internal Combustion Vehicles - Assumed transition

H2FC: Hydrogen Fuel Cell - Assumed transition

A BEV needs to be charged, which is ideally done overnight while the vehicle is not being used. Provision of sufficient 7 kW AC chargers at SIC sites will be required for BEVs. Where longer trips are necessary the growing network of public chargers at destinations and along the road network can be used to "top up" charge, with high-power rapid chargers able to add between 100 and 300 miles of range in 30 minutes of charging[30].

The higher energy storage requires higher power chargers, especially as it may be necessary to have vehicles ready for redeployment as soon as possible, so a minimum of 150 kW DC chargers[31] can be expected with most heavy duty vehicles having a dedicated charger. It would also be possible to use

[30] Depending on charger and vehicle specification.

[31] DAF state the 252 kWh battery in their LF electric can be charged from 20% to 80% in just one hour using a 150 kW charger: https://www.daf.com/en/About-DAF/Sustainability/Alternative-fuels-and-drivelines/Battery-Electric-Vehicles/DAF-LF-Electric

these chargers to rapid-charge light-duty vehicles. This level of power demand is likely to require grid reinforcement.

Where vehicles are fuelled using hydrogen, suitable on-site storage and refuelling infrastructure will be required. It has been assumed that hydrogen will be imported and stored at vehicle depots and not electrolysed on site.

8.2 Vessels

Ferries

There are 12 ferries connecting the populations of the Shetland Islands together. All are owned by the Council and only one is operated by an external operator. The route between Foula island and Walls on Shetland is operated by a private company. The ferry vessels regularly sail the specific route they are assigned to and occasionally sail additional routes if required. MV Fivla is a relief vessel that will temporarily replace vessels being serviced.

The distance and frequency of routes vary significantly. MV Leirna saisl the shortest route between Lerwick and Bressay across circa. 0.5 nautical miles and taking approximately 10 minutes.

In comparison, MV Good Shephard sails the longest route between Lerwick and Fair isle across 40 nautical miles and taking approximately 5 hours. The route sails just once a week and carries up to 12 passengers.

Some of the routes are being considered for a fixed crossing that would see the islands connected by bridges or tunnels. This outcome would eliminate the fuel requirement for the crossing it replaces.

All inter-island ferry vessels are currently refuelled by fuel delivery trucks.

Inter-island ferries are generally suited for battery-electrification. Depending on the route, the inter-island ferries may require a combination of "opportunity" fast charging at suitable ports and overnight slow charging. Where battery vessels need to make longer trips, for example to dry dock on the mainland, it is envisaged that the batteries could be supplemented by a temporary containerised generator carried on-deck. However, battery electrification may not be possible for all ferries due to range or lack of recharging opportunities during the working day. In which case, hydrogen will generally be the preferred fuel, due to the relatively high fuel volume used precluding use of biofuels

Where vessels are fuelled using hydrogen, suitable on-site storage and refuelling infrastructure will be required. It has been assumed that hydrogen will be imported and stored at vehicle depots and not electrolysed on site.

Vessel low carbon premiums have been estimated based on the following:

- Propulsion systems – based on Ricardo project experience
- Additional uplift for vessel architecture design & development – based on quotes provided to SIC

The low carbon premiums do not include any of the potential shore infrastructure costs required to support the transition to low carbon vessels, other than the charging and refuelling infrastructure. As such, the Council should consider all potential costs when reviewing the opportunity of low carbon vessels.

Tugs

There are six tugs operating on the islands. Two tugs operate in Lerwick port and are owned and managed by Lerwick Port Authority. The remaining four tugs operate in Sullum Voe oil terminal are owned and operated by Shetland Islands Council. The Sullom Voe tugs are significantly larger than Lerwick tugs as they regularly support large oil transport vessels visiting the island.

The tugs' core use is to assist less manoeuvrable vessels by pulling them with a tow line or pushing them with direct contact. Tugs are required to have high power engines to provide the force necessary to move much larger and heavier vessels. This requirement means that tugs have periods of intense operation that consume significant quantities of fuel relative to other vessels of similar size. Tugs are relatively small, to maximise manoeuvrability.

Tugs are an interesting use-case, as their total energy demand is not large, and on many days, their routine would be suitable for battery-electrification or hydrogen. However, the tugs have to occasionally either travel long distance to support ships at sea, or remain on-station pushing up ships in high winds, both of which will require more energy than can be stored by hydrogen or batteries in the small tugs. Therefore, a suitable powertrain choice could be dual-fuel hydrogen/biodiesel.

Where vessels are fuelled using hydrogen, suitable on-site storage and refuelling infrastructure will be required. It has been assumed that hydrogen will be imported and stored at vehicle depots and not electrolysed on site.

8.3 Aircraft

Aviation is considered one of the most challenging transport sectors to decarbonise. Due to constant development of the current aviation policy and evolution of technological solutions, there is an inherited uncertainty associated with predicting uptake of specific decarbonisation measures at specific airports.

As such, the opportunities for implementation of aviation measures described below have been based on the net zero pathways published by CCC, the Sustainable Aviation Coalition and the Jet Zero Strategy Policy (consultation document). Measures developed as part of the net zero pathway reflect the uniqueness of the operation, aircraft fleet, the scale and locations of SIC aircraft, specifically the short haul nature of Council flights patterns.

Hydrogen planes

Improvements in aircraft and engine technology and subsequent fleet replacement hold the largest promise for decarbonising SIC's aircraft emissions. This includes the introduction of hydrogen-powered aircrafts that could operate inter island routes. SIC's aircraft are the correct size to be replaced with hydrogen aircraft and this is expected to be achievable 2035 which will require technology and infrastructure readiness by 2035.

Hydrogen for aircraft needs to be in a liquified state. Given the volumes of hydrogen SIC are likely to require, it is expected to be extremely cost prohibitive to have on site electrolysis and liquification plant. Instead, it is far more feasible for SIC to take deliveries of liquified hydrogen and have storage and refuelling infrastructure at Tingwall airport. This is the assumption that has been costed and included in the net zero modelling.

Electric planes

SIC aircraft are also of suitable size and flight range for electrification. Currently, the low specific energy of batteries is a major constraint of this technology, however with future improvements, it is expected that this technology could infiltrate into the fleet from 2030 onwards. This technology will likely be suitable for small aircraft (<10 passengers, generally piston engines).

Sustainable aviation fuel

SAFs are “drop-in” replacements for fossil jet fuel. Being chemically almost identical to their fossil derived counterparts, they emit CO_2 upon combustion, however, the origin of the carbon is via extraction from the atmosphere upon production of these fuels, making them more sustainable. Carbon accounting therefore considers these fuels as having zero emissions upon combustion. However, emissions will be generated in the production of these fuels (often referred to as the upstream emissions), therefore when considering the sustainability of these fuels on a lifecycle basis (upstream and combustion), they are not considered zero emission. As such, it is therefore assumed that SAF results in 50% emissions reductions, compared to current aviation fuel.

With an increase availability of SAFs, it is expected the proportion of SAF in fuel blend increase to 35% by 2040, starting in 2025.

8.4 Fixed Links

The following routes are being considered for a fixed crossing that would see the islands connected by tunnels:

- • Lerwick to Bressay
- • Laxo to Symbister (Whalsay)
- • Toft to Ulsta (Yell)
- • Gutcher (Yell) to Belmont (Unst)

It is recommended that any consideration of fixed links should include a more detailed assessment of the potential embodied carbon impacts, along with the anticipated impacts on the transport network.

In parallel with this assessment of carbon emissions, the Council should also continue its work exploring the opportunities provided by fixed links by considering a full socio-economic assessment.

A.5 Measures savings and cost details

This appendix summarises the cost and carbon impacts of each of the measures, or groups of measures, modelled in each of the pathways.

Note:

- Cashflow – positive is a saving, negative is an outgoing
- NPV – negative indicates projected savings exceed the anticipated cost, positive indicates the opposite. i.e. the greater the NPV, the greater the cost to SIC
- Abatement cost – negative indicates cost and carbon saving, positive indicates carbon saving but overall cost for measure

2030 ambitious pathway

	Carbon saving in 2045, tCO2e	Total carbon abated by 2045	CAPEX, £m	Cashflow at 2045, £k	NPV, £m	Abatement cost, £/tCO2e
Non-domestic estate rationalisation	0	0	0.0	0	0.0	0
Non-domestic EE	521	14,324	15.6	347	11.6	809
Non-domestic heat	1,249	30,392	7.8	-192	10.4	342
Non-domestic PV	3	291	0.5	47	-0.1	-314
Domestic new development	40	2,300	8.2	352	4.0	1,723
Domestic EE	0	0	0.0	0	0.0	0
Domestic heat	19	534	3.0	25	2.6	4,950
Domestic PV	0	0	0.0	0	0.0	0
Fixed links	0	0	0.0	0	0.0	0
Vessels	3,608	85,156	15.8	-948	27.5	323
Vehicles	724	18,268	2.5	121	1.6	88
Aircraft	30	730	0.0	-7	0.1	99
Commute	15	832	0.0	0	0.0	0
Business Travel	27	700	0.0	0	0.0	0
Waste management	1,846	47,853	1.3	64	0.5	10
Waste - CCS on the ERP	10,778	240,694	1.1	-105	2.0	8

2040 pragmatic pathway

	Carbon saving in 2045, tCO2e	Total carbon abated by 2045	CAPEX, £m	Cashflow at 2045, £k	NPV, £m	Abatement cost, £/tCO2e
Non-domestic estate rationalisation	0	0	0.0	0	0.0	0
Non-domestic EE	521	14,324	15.6	347	11.6	809
Non-domestic heat	1,249	28,847	7.8	-192	10.0	345
Non-domestic PV	3	291	0.5	47	-0.1	-314
Domestic EE	87	3,099	17.9	767	10.3	3,334
Domestic new development	0	0	0.0	0	0.0	0
Domestic heat	12	333	5.8	52	5.0	14,999
Domestic PV	0	0	0.0	0	0.0	0
Fixed links	0	0	0.0	0	0.0	0
Vessels	11,655	218,746	42.5	-2,371	59.1	270
Vehicles	1,584	27,702	5.1	264	3.2	114

	Carbon saving in 2045, tCO2e	Total carbon abated by 2045	CAPEX, £m	Cashflow at 2045, £k	NPV, £m	Abatement cost, £/tCO2e
Aircraft	30	654	0.0	-7	0.1	93
Commute	22	792	0.0	0	0.0	0
Business Travel	41	845	0.0	0	0.0	0
Waste management	1,846	38,230	1.3	64	0.6	17
Waste - CCS on the ERP	0	0	0.0	0	0.0	0

2040 ambitious pathway

	Carbon saving in 2045, tCO2e	Total carbon abated by 2045	CAPEX, £m	Cashflow at 2045, £k	NPV, £m	Abatement cost, £/tCO2e
Non-domestic estate rationalisation	0	0	0.0	0	0.0	0
Non-domestic EE	521	14,324	15.6	347	11.6	809
Non-domestic heat	1,267	29,248	7.9	-195	10.1	346
Non-domestic PV	5	485	0.8	78	-0.2	-314
Domestic EE	87	3,099	17.9	767	10.3	3,334
Domestic new development	0	0	0.0	0	0.0	0
Domestic heat	34	1,338	7.3	321	4.1	3,074
Domestic PV	0	0	0.0	0	0.0	0
Fixed links	0	0	0.0	0	0.0	0
Vessels	12,272	230,470	47.1	-2,687	66.1	287
Vehicles	1,582	27,644	6.5	317	4.0	146
Aircraft	60	1,261	1.3	1	1.2	967
Commute	22	792	0.0	0	0.0	0
Business Travel	41	845	0.0	0	0.0	0
Waste management	6,745	134,258	3.2	-1,840	19.4	144
Waste - CCS on the ERP	6,718	143,303	1.1	-105	2.0	14

A.6 Supporting pathway modelling information

A.6.1 2030 ambitious pathway

	Measure description	Modelled value	Implementation year	Implementation period
Non-domestic				
Care center rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Community, services & office buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Depot & workshop buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Education buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Misc. buildings & site rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Lighting upgrade	Enter fraction of buildings (by energy consumption) to undergo lighting upgrade	27%	2022	8
BMS & controls upgrades	Enter fraction of buildings (by energy consumption) to undergo control system upgrade (inc. both new systems and upgrades)	67%	2023	7
Metering and management improvements	Enter extent of metering and management improvements	High	2022	8
Water saving fittings	Enter fraction of tap and shower fittings to be replaced with water saving alternatives	100%	2022	8
Building fabric improvements	Enter fraction of buildings (by floor area) to undergo fabric upgrades	20%	2023	7
HVAC upgrades	Enter fraction of ventilation systems to be upgraded	100%	2023	7
Commissioning & re-balancing mechanical systems	Enter fraction of mechanical systems to be re-balanced	100%	2022	8
Catering	Enter fraction of catering systems to be electrified	100%	2024	6
Non-domestic Lerwick oil buildings to DHN	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be brought onto the DHN	100%	2023	7
Non-domestic Lerwick oil buildings to ASHP	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be converted to ASHP	0%	2022	8
Non-domestic mainland/inner isle oil buildings to ASHP	Enter fraction of mainland/inner isle oil heated buildings (exc. Lerwick & by energy consumption) to be converted to ASHP	100%	2023	7
Non-domestic outer isle oil buildings to ASHP	Enter fraction of outer isle oil heated buildings (by energy consumption) to be converted to ASHP	0%	2023	7
Non-domestic storage heaters to air-to-air HP	Enter fraction of storage heaters to be replaced with air-to-air heat pumps	50%	2023	7
Non-domestic oil to hydrogen boilers	Enter fraction of oil heated buildings (by energy consumption) to be converted to hydrogen	0%	2023	7
Non-domestic PV installation	Enter fraction of buildings to undergo PV installation	15%	2023	7
Domestic				
Domestic new development	Enter total number of new dwellings	0	2025	5

	Measure description	Modelled value	Implementation year	Implementation period
Domestic new development	Enter fraction of dwellings heated by heat pump	0%		
Domestic new development	Enter fraction of dwellings heated with storage heaters	0%		
Domestic new development	Enter fraction of dwellings heated by the Lerwick district heat network	0%		
Domestic new development	Enter fraction of dwellings heated with oil	0%		
Domestic new development	Enter fraction of dwellings heated with biomass	0%		
Domestic EE upgrades	Enter target fraction of properties for EPC B or higher. Assumes 26% are already at EPC B.	60%	2023	7
Domestic Lerwick to DHN	Enter fraction of non-heat pump heated properties in Lerwick to be brought onto the DHN	0%	2023	7
Domestic Lerwick upgrade storage heaters to high retention alternatives	Enter fraction of storage heaters in Lerwick to upgrade to high retention storage heaters	50%	2023	7
Domestic Mainland/inner isles - Oil to ASHP	Enter fraction of mainland/inner isle oil heated properties to be converted to ASHP	0%	2023	7
Domestic Mainland/inner isles - Oil to storage heater	Enter fraction of mainland/inner isle oil heated properties to be upgraded to high retention storage heaters	100%	2023	7
Domestic Mainland/inner isles - Storage to air-to-air HP	Enter fraction of suitable mainland/inner isle storage heaters to be replaced with air-to-air heat pumps	0%	2023	7
Domestic Mainland/inner isles - Upgrade storage heaters to high retention alternatives	Enter fraction of mainland/inner isle storage heaters to be upgraded to high retention storage heaters	50%	2023	7
Domestic Outer isles - Oil to ASHP	Enter fraction of suitable outer isle oil heated properties to be converted to ASHP	0%	2023	7
Domestic Outer isles - Oil to storage heater	Enter fraction of outer isle oil heated properties to be upgraded to high retention storage heaters	100%	2023	7
Domestic Outer isles - Storage to air-to-air HP	Enter fraction of suitable outer isle storage heaters to be replaced with air-to-air heat pumps	0%	2023	7
Domestic Outer isles - Upgrade storage heaters to high retention alternatives	Enter fraction of outer isle storage heaters to be upgraded to high retention storage heaters	50%	2023	7
Domestic PV installation	Enter fraction of properties to undergo PV installation	0%	2023	7
Infrastructure				
Infra. Islands waste reduction targets	Enter Shetland Islands wide waste reduction target	15%	2022	8
Infra. Islands increase recycling rates	Enter Shetland Islands wide target for recycling rates	15%	2022	8
Infra. SIC waste reduction targets	Enter council waste reduction target	30%	2022	8
Infra. SIC increase recycling rates	Enter council target for recycling rates	30%	2022	8
Infra. AD plant for Lerwick bio waste & bio waste in landfill	Install anaerobic digestion plant for all Lerwick biogenic waste?	Yes	2025	1
Infra. Import waste to ERP to make up Islands shortfall	Import waste to ERP to makeup the shortfall in Shetlands Islands wide waste generation?	Yes	2022	8
Infra. ERP CCS	Install carbon capture technology at the ERP?	Yes	2029	1
Transport				
Fixed links to replace ferries to Whalsay	Include fixed link?	No	2022	18
Fixed links to replace ferries to Unst	Include fixed link?	No	2022	18
Fixed links to replace ferries to Yell	Include fixed link?	No	2022	18

	Measure description	Modelled value	Implementation year	Implementation period
Fixed links to replace ferries to Bressay	Include fixed link?	No	2022	18
Inter island ferries - low carbon fuels	Enter fraction of retained ferries (by energy consumption) to be replaced with low carbon alternatives	25%	2025	5
Tugs - low carbon fuels	Enter fraction of tugs (by energy consumption) to be replaced/retrofitted with low carbon alternatives	60%	2025	5
HDVs to dual-fuel diesel LH2	Enter fraction of HDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	100%	2022	8
HDVs to H2 ICE	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	0%	2022	8
HDVs to H2 fuel cell	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	0%	2022	8
MDVs to dual-fuel LH2	Enter fraction of MDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	100%	2022	8
MDVs to H2 ICE	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	0%	2022	8
MDVs to H2 fuel cell	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	0%	2022	8
MDVs to BEVs	Enter fraction of MDVs (by energy consumption) to be replaced with battery electric alternatives	0%	2022	8
LDVs to BEVs	Enter fraction of LDVs (by energy consumption) to be replaced with battery electric alternatives	100%	2022	8
Aircraft - electric planes	Enter number of aircraft to be replaced with electric alternatives	0	2028	2
Aircraft - fuel cell planes	Enter number of aircraft to be replaced with hydrogen fuel cell alternatives	0	2028	2
Aircraft - sustainable aviation fuel	Enter number of aircraft to utilise a jet fuel/SAF blend	2	2025	5
Vehicles per charge point	Enter number of vehicles per charge point	2		
Home working target	Enter council wide homeworking target (fraction of working days)	20%	2022	8
Active travel target	Enter council wide active travel target (fraction of distance travelled)	0%	2022	8
Business travel reduction target	Enter council wide business travel reduction target (i.e. video conferencing instead of in person meetings)	20%	2022	8

A.6.2 2040 pragmatic pathway

	Measure description	Modelled value	Implementation year	Implementation period
Non-domestic				
Care center rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Community, services & office buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Depot & workshop buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Education buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Misc. buildings & site rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Lighting upgrade	Enter fraction of buildings (by energy consumption) to undergo lighting upgrade	27%	2022	8
BMS & controls upgrades	Enter fraction of buildings (by energy consumption) to undergo control system upgrade (inc. both new systems and upgrades)	67%	2023	7
Metering and management improvements	Enter extent of metering and management improvements	High	2022	8
Water saving fittings	Enter fraction of tap and shower fittings to be replaced with water saving alternatives	100%	2022	8
Building fabric improvements	Enter fraction of buildings (by floor area) to undergo fabric upgrades	20%	2023	7
HVAC upgrades	Enter fraction of ventilation systems to be upgraded	100%	2023	7
Commissioning & re-balancing mechanical systems	Enter fraction of mechanical systems to be re-balanced	100%	2022	8
Catering	Enter fraction of catering systems to be electrified	100%	2024	6
Non-domestic Lerwick oil buildings to DHN	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be brought onto the DHN	100%	2025	8
Non-domestic Lerwick oil buildings to ASHP	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be converted to ASHP	0%	2022	8
Non-domestic mainland/inner isle oil buildings to ASHP	Enter fraction of mainland/inner isle oil heated buildings (exc. Lerwick & by energy consumption) to be converted to ASHP	100%	2025	8
Non-domestic outer isle oil buildings to ASHP	Enter fraction of outer isle oil heated buildings (by energy consumption) to be converted to ASHP	0%	2025	8
Non-domestic storage heaters to air-to-air HP	Enter fraction of storage heaters to be replaced with air-to-air heat pumps	50%	2025	8
Non-domestic oil to hydrogen boilers	Enter fraction of oil heated buildings (by energy consumption) to be converted to hydrogen	0%	2023	7
Non-domestic PV installation	Enter fraction of buildings to undergo PV installation	15%	2023	7
Domestic				
Domestic new development	Enter total number of new dwellings	0	2023	17
Domestic new development	Enter fraction of dwellings heated by heat pump	0%		
Domestic new development	Enter fraction of dwellings heated with storage heaters	0%		
Domestic new development	Enter fraction of dwellings heated by the Lerwick district heat network	0%		

	Measure description	Modelled value	Implementation year	Implementation period
Domestic new development	Enter fraction of dwellings heated with oil	0%		
Domestic new development	Enter fraction of dwellings heated with biomass	0%		
Domestic EE upgrades	Enter target fraction of properties for EPC B or higher. Assumes 26% are already at EPC B.	100%	2023	17
Domestic Lerwick to DHN	Enter fraction of non-heat pump heated properties in Lerwick to be brought onto the DHN	0%	2023	17
Domestic Lerwick upgrade storage heaters to high retention alternatives	Enter fraction of storage heaters in Lerwick to upgrade to high retention storage heaters	100%	2023	17
Domestic Mainland/inner isles - Oil to ASHP	Enter fraction of mainland/inner isle oil heated properties to be converted to ASHP	0%	2023	17
Domestic Mainland/inner isles - Oil to storage heater	Enter fraction of mainland/inner isle oil heated properties to be upgraded to high retention storage heaters	100%	2023	17
Domestic Mainland/inner isles - Storage to air-to-air HP	Enter fraction of suitable mainland/inner isle storage heaters to be replaced with air-to-air heat pumps	0%	2023	17
Domestic Mainland/inner isles - Upgrade storage heaters to high retention alternatives	Enter fraction of mainland/inner isle storage heaters to be upgraded to high retention storage heaters	100%	2023	17
Domestic Outer isles - Oil to ASHP	Enter fraction of suitable outer isle oil heated properties to be converted to ASHP	0%	2023	17
Domestic Outer isles - Oil to storage heater	Enter fraction of outer isle oil heated properties to be upgraded to high retention storage heaters	0%	2023	17
Domestic Outer isles - Storage to air-to-air HP	Enter fraction of suitable outer isle storage heaters to be replaced with air-to-air heat pumps	0%	2023	17
Domestic Outer isles - Upgrade storage heaters to high retention alternatives	Enter fraction of outer isle storage heaters to be upgraded to high retention storage heaters	100%	2023	17
Domestic PV installation	Enter fraction of properties to undergo PV installation	0%	2023	17
Infrastructure				
Infra. Islands waste reduction targets	Enter Shetland Islands wide waste reduction target	15%	2022	18
Infra. Islands increase recycling rates	Enter Shetland Islands wide target for recycling rates	15%	2022	18
Infra. SIC waste reduction targets	Enter council waste reduction target	30%	2022	18
Infra. SIC increase recycling rates	Enter council target for recycling rates	30%	2022	18
Infra. AD plant for Lerwick bio waste & bio waste in landfill	Install anaerobic digestion plant for all Lerwick biogenic waste?	Yes	2029	1
Infra. Import waste to ERP to make up Islands shortfall	Import waste to ERP to makeup the shortfall in Shetlands Islands wide waste generation?	Yes	2025	15
Infra. ERP CCS	Install carbon capture technology at the ERP?	No	2029	1
Transport				
Fixed links to replace ferries to Whalsay	Include fixed link?	No	2022	18
Fixed links to replace ferries to Unst	Include fixed link?	No	2022	18
Fixed links to replace ferries to Yell	Include fixed link?	No	2022	18
Fixed links to replace ferries to Bressay	Include fixed link?	No	2022	18
Inter island ferries - low carbon fuels	Enter fraction of retained ferries (by energy consumption) to be replaced with low carbon alternatives	100%	2025	15

	Measure description	Modelled value	Implementation year	Implementation period
Tugs - low carbon fuels	Enter fraction of tugs (by energy consumption) to be replaced/retrofitted with low carbon alternatives	60%	2025	15
HDVs to dual-fuel diesel LH2	Enter fraction of HDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	0%	2028	12
HDVs to H2 ICE	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	100%	2028	12
HDVs to H2 fuel cell	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	0%	2028	12
MDVs to dual-fuel LH2	Enter fraction of MDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	0%	2028	12
MDVs to H2 ICE	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	50%	2028	12
MDVs to H2 fuel cell	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	50%	2028	12
MDVs to BEVs	Enter fraction of MDVs (by energy consumption) to be replaced with battery electric alternatives	0%	2028	12
LDVs to BEVs	Enter fraction of LDVs (by energy consumption) to be replaced with battery electric alternatives	100%	2028	12
Aircraft - electric planes	Enter number of aircraft to be replaced with electric alternatives	0	2033	2
Aircraft - fuel cell planes	Enter number of aircraft to be replaced with hydrogen fuel cell alternatives	0	2033	2
Aircraft - sustainable aviation fuel	Enter number of aircraft to utilise a jet fuel/SAF blend	2	2025	5
Vehicles per charge point	Enter number of vehicles per charge point	2		
Home working target	Enter council wide homeworking target (fraction of working days)	30%	2022	18
Active travel target	Enter council wide active travel target (fraction of distance travelled)	0%	2022	18
Business travel reduction target	Enter council wide business travel reduction target (i.e. video conferencing instead of in person meetings)	30%	2022	18

A.6.3 2040 ambitious pathway

	Measure description	Modelled value	Implementation year	Implementation period
Non-domestic				
Care center rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Community, services & office buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Depot & workshop buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Education buildings rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Misc. buildings & site rationalisation	Enter percentage of buildings (by energy consumption) to be removed from estate	0%	2022	8
Lighting upgrade	Enter fraction of buildings (by energy consumption) to undergo lighting upgrade	27%	2022	8
BMS & controls upgrades	Enter fraction of buildings (by energy consumption) to undergo control system upgrade (inc. both new systems and upgrades)	67%	2023	7
Metering and management improvements	Enter extent of metering and management improvements	High	2022	8
Water saving fittings	Enter fraction of tap and shower fittings to be replaced with water saving alternatives	100%	2022	8
Building fabric improvements	Enter fraction of buildings (by floor area) to undergo fabric upgrades	20%	2023	7
HVAC upgrades	Enter fraction of ventilation systems to be upgraded	100%	2023	7
Commissioning & re-balancing mechanical systems	Enter fraction of mechanical systems to be re-balanced	100%	2022	8
Catering	Enter fraction of catering systems to be electrified	100%	2024	6
Non-domestic Lerwick oil buildings to DHN	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be brought onto the DHN	100%	2025	8
Non-domestic Lerwick oil buildings to ASHP	Enter fraction of oil heated buildings in Lerwick (by energy consumption) to be converted to ASHP	0%	2022	8
Non-domestic mainland/inner isle oil buildings to ASHP	Enter fraction of mainland/inner isle oil heated buildings (exc. Lerwick & by energy consumption) to be converted to ASHP	100%	2025	8
Non-domestic outer isle oil buildings to ASHP	Enter fraction of outer isle oil heated buildings (by energy consumption) to be converted to ASHP	100%	2025	8
Non-domestic storage heaters to air-to-air HP	Enter fraction of storage heaters to be replaced with air-to-air heat pumps	50%	2025	8
Non-domestic oil to hydrogen boilers	Enter fraction of oil heated buildings (by energy consumption) to be converted to hydrogen	0%	2023	7
Non-domestic PV installation	Enter fraction of buildings to undergo PV installation	25%	2023	7
Domestic				
Domestic new development	Enter total number of new dwellings	0	2023	17
Domestic new development	Enter fraction of dwellings heated by heat pump	0%		
Domestic new development	Enter fraction of dwellings heated with storage heaters	0%		
Domestic new development	Enter fraction of dwellings heated by the Lerwick district heat network	0%		

	Measure description	Modelled value	Implementation year	Implementation period
Domestic new development	Enter fraction of dwellings heated with oil	0%		
Domestic new development	Enter fraction of dwellings heated with biomass	0%		
Domestic EE upgrades	Enter target fraction of properties for EPC B or higher. Assumes 26% are already at EPC B.	100%	2023	17
Domestic Lerwick to DHN	Enter fraction of non-heat pump heated properties in Lerwick to be brought onto the DHN	0%	2023	17
Domestic Lerwick upgrade storage heaters to high retention alternatives	Enter fraction of storage heaters in Lerwick to upgrade to high retention storage heaters	100%	2023	17
Domestic Mainland/inner isles - Oil to ASHP	Enter fraction of mainland/inner isle oil heated properties to be converted to ASHP	23%	2023	17
Domestic Mainland/inner isles - Oil to storage heater	Enter fraction of mainland/inner isle oil heated properties to be upgraded to high retention storage heaters	77%	2023	17
Domestic Mainland/inner isles - Storage to air-to-air HP	Enter fraction of suitable mainland/inner isle storage heaters to be replaced with air-to-air heat pumps	23%	2023	17
Domestic Mainland/inner isles - Upgrade storage heaters to high retention alternatives	Enter fraction of mainland/inner isle storage heaters to be upgraded to high retention storage heaters	77%	2023	17
Domestic Outer isles - Oil to ASHP	Enter fraction of suitable outer isle oil heated properties to be converted to ASHP	66%	2023	17
Domestic Outer isles - Oil to storage heater	Enter fraction of outer isle oil heated properties to be upgraded to high retention storage heaters	34%	2023	17
Domestic Outer isles - Storage to air-to-air HP	Enter fraction of suitable outer isle storage heaters to be replaced with air-to-air heat pumps	50%	2023	17
Domestic Outer isles - Upgrade storage heaters to high retention alternatives	Enter fraction of outer isle storage heaters to be upgraded to high retention storage heaters	50%	2023	17
Domestic PV installation	Enter fraction of properties to undergo PV installation	0%	2023	17
Infrastructure				
Infra. Islands waste reduction targets	Enter Shetland Islands wide waste reduction target	20%	2022	18
Infra. Islands increase recycling rates	Enter Shetland Islands wide target for recycling rates	20%	2022	18
Infra. SIC waste reduction targets	Enter council waste reduction target	50%	2022	18
Infra. SIC increase recycling rates	Enter council target for recycling rates	50%	2022	18
Infra. AD plant for Lerwick bio waste & bio waste in landfill	Install anaerobic digestion plant for all Lerwick biogenic waste?	Yes	2029	1
Infra. Import waste to ERP to make up Islands shortfall	Import waste to ERP to makeup the shortfall in Shetlands Islands wide waste generation?	No	2025	15
Infra. ERP CCS	Install carbon capture technology at the ERP?	Yes	2030	1
Transport				
Fixed links to replace ferries to Whalsay	Include fixed link?	No	2022	18
Fixed links to replace ferries to Unst	Include fixed link?	No	2022	18
Fixed links to replace ferries to Yell	Include fixed link?	No	2022	18
Fixed links to replace ferries to Bressay	Include fixed link?	No	2022	18
Inter island ferries - low carbon fuels	Enter fraction of retained ferries (by energy consumption) to be replaced with low carbon alternatives	100%	2025	15

	Measure description	Modelled value	Implementation year	Implementation period
Tugs - low carbon fuels	Enter fraction of tugs (by energy consumption) to be replaced/retrofitted with low carbon alternatives	100%	2025	15
HDVs to dual-fuel diesel LH2	Enter fraction of HDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	0%	2028	12
HDVs to H2 ICE	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	0%	2028	12
HDVs to H2 fuel cell	Enter fraction of HDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	100%	2028	12
MDVs to dual-fuel LH2	Enter fraction of MDVs (by energy consumption) to be replaced with dual-fuel (diesel and hydrogen) alternatives	0%	2028	12
MDVs to H2 ICE	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen combustion engines	0%	2028	12
MDVs to H2 fuel cell	Enter fraction of MDVs (by energy consumption) to be replaced with alternatives with hydrogen fuel cells	75%	2028	12
MDVs to BEVs	Enter fraction of MDVs (by energy consumption) to be replaced with battery electric alternatives	25%	2028	12
LDVs to BEVs	Enter fraction of LDVs (by energy consumption) to be replaced with battery electric alternatives	100%	2028	12
Aircraft - electric planes	Enter number of aircraft to be replaced with electric alternatives	2	2033	2
Aircraft - fuel cell planes	Enter number of aircraft to be replaced with hydrogen fuel cell alternatives	0	2033	2
Aircraft - sustainable aviation fuel	Enter number of aircraft to utilise a jet fuel/SAF blend	0	2025	5
Vehicles per charge point	Enter number of vehicles per charge point	2		
Home working target	Enter council wide homeworking target (fraction of working days)	30%	2022	18
Active travel target	Enter council wide active travel target (fraction of distance travelled)	0%	2022	18
Business travel reduction target	Enter council wide business travel reduction target (i.e. video conferencing instead of in person meetings)	30%	2022	18

A.7 Alternative pathway – non-domestic hydrogen heating

Hydrogen as a heating fuel has been excluded from the three pathways modelled in the main body of this report, predominantly due to high operational costs when compared to other low carbon heating systems. This alternative pathway explores the impact of using hydrogen as a heating fuel compared to using heat pumps. The following assumptions have been made when modelling the use of hydrogen:

- Hydrogen boilers are to only be considered where there is an existing fossil fuel fired, wet heating distribution system
- A hydrogen boiler is a drop-in replacement to the existing fossil fuel fired heating system
- Hydrogen boiler operates at similar conditions to existing fossil fuel fired heating systems, therefore building fabric upgrades are assumed to only be required at 50% of those sites requiring upgrade under the 2040 Ambitious scenario
- Each building where a hydrogen boiler is installed has its own dedicated storage tank with sufficient capacity for 3 months of usage (one-quarter of annual usage) – note that storage sized for 3 months and ancillaries is projected to account for approximately 94% of hydrogen CAPEX
- There are 34 Council non-domestic assets potentially suitable for hydrogen boilers
- Hydrogen is assumed in this scenario to be electrolysed using zero carbon electricity, and is therefore green hydrogen

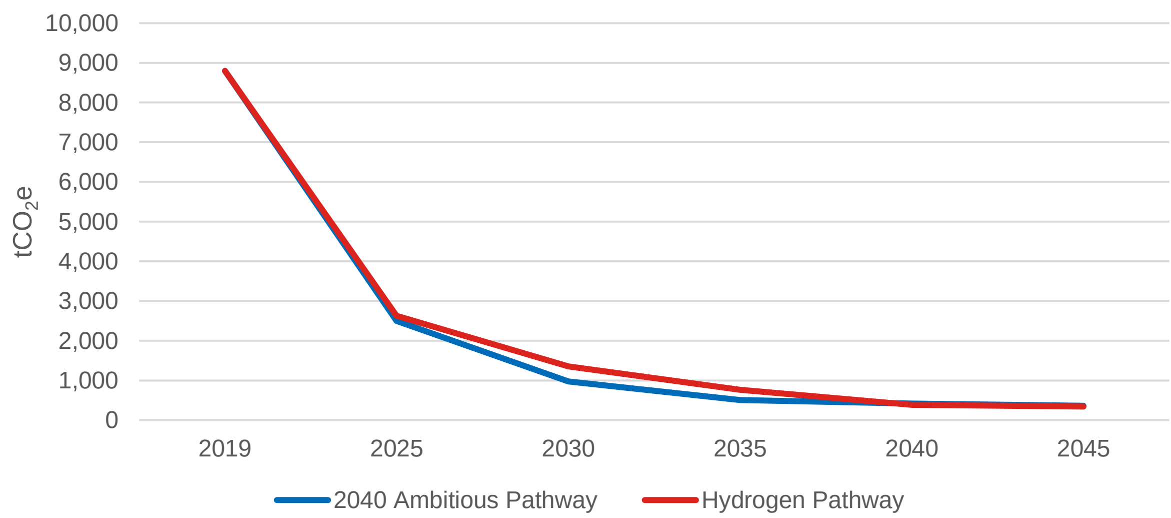

Figure 36 - 2040 ambitious pathway compared to the hydrogen led heating pathway for non-domestic emissions

Figure 36 above demonstrates that there is relatively little difference in terms of residual emissions by 2040/2045 between the 2040 ambitious and the hydrogen led pathways for non-domestic emissions. This is because by 2040, grid supplied electricity is significantly decarbonised and is therefore comparable to the zero-carbon electricity used for electrolysis. Both pathways achieve a 96% emissions reduction against the 2019 baseline.

The key difference is the timing of the measures. Green hydrogen is expected to be begin production on the Shetland Islands from 2025[32], as such, it is not expected that there will be a viable market before that. Therefore, the uptake of hydrogen as a heating fuel in this scenario is projected to begin from around 2027 to allow time for feasibility studies to be undertaken, and the hydrogen market to develop.

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The table below compares key performance metrics of each of the non-domestic heat decarbonisation measures.

Table 21 - Key performance metrics of each of the non-domestic heat and energy efficiency decarbonisation measures

	Carbon saving in 2045 vs BAU, tCO2e	Total carbon abated by 2045	CAPEX, £m	Cashflow at 2045, £k	NPV, £m	Abatement cost, £/tCO2e
2040 ambitious pathway	1,793	33,645	24.3	229	17.8	440
Hydrogen led pathway	1,813	30,105	25.3	-180	21.2	585

The table above demonstrates that the NPV by 2045 of using hydrogen as a heating fuel is approximately 20% higher than that using heat pumps, with a 33% greater cost for each tonne of carbon abated. Also significant is the cashflow difference between heat pump and hydrogen heating systems. It is expected that by 2045, heat pumps could achieve an annual cashflow saving of approximately £400k due to the improved energy efficiency associated with the upgrade of building fabric, the relative efficiency of a heat pump compared to a boiler and reduced energy costs.

This demonstrates that whilst heat pumps and hydrogen boilers are expected to have similar total upfront costs (when including the energy efficiency measures), in the long term they are projected to cost less due to reduced running costs. Note that without such high storage costs, hydrogen would be far more competitive though it still suffers from high operational costs when compared to other low carbon heating systems.

The Council must carefully monitor the price of hydrogen on the Shetland Islands with the aim of determining at what unit price it becomes more commercially viable to use hydrogen as a heating fuel than electricity. For example, if green hydrogen is produced using curtailed electricity from offshore wind farms, hydrogen price could come down significantly, therefore potentially making hydrogen more viable. Detailed economic and technical feasibility is required to appropriately assess the viability of hydrogen versus other low carbon heating systems.

Whilst outside the scope of this piece of work, the Council should also recognise and consider its own potential role within the Shetland Island community of helping to develop and provide early confidence in a local hydrogen market.

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