

Setting Climate Commitments for the City of Sheffield:

Quantifying the implications of the United Nations Paris
Agreement for Sheffield

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Key Messages

This report presents climate change targets for Sheffield¹ that are derived from the commitments enshrined in the Paris Agreement [1], informed by the latest science on climate change [2] and defined in terms of science based carbon setting [3]. The report provides Sheffield with budgets for carbon dioxide (CO₂) emissions from the energy system for 2020 to 2100.

The carbon budgets in this report are based on translating the “well below 2°C and pursuing 1.5°C” global temperature target and equity principles in the Paris Agreement to a national UK carbon budget [3].² The UK budget is then split between sub-national areas using different allocation regimes [4]. Aviation and shipping emissions remain within the national UK carbon budget and are not scaled down to sub-national budgets. Land Use, Land Use Change and Forestry (LULUCF) and non-CO₂ emissions are considered separately to the energy CO₂ budget in this report.

Based on our analysis, for Sheffield to make its ‘fair’ contribution towards the Paris Climate Change Agreement, the following recommendations should be adopted:

- 1) Stay within a cumulative carbon dioxide emissions budget of 16 million tonnes (MtCO₂) for the period of 2020 to 2100.** At 2016 CO₂ emission levels³, Sheffield would use this entire budget within 6 years.
- 2) Initiate an immediate programme of CO₂ mitigation to deliver cuts in emissions averaging 14% per year to deliver a Paris aligned carbon budget.** These annual reductions in emissions require national and local action, and would be part of a wider collaboration with other local authorities in the region.
- 3) Reach zero or near zero carbon no later than 2038.** This report provides two CO₂ reduction pathways which both stay within the recommended 16 MtCO₂ carbon budget; 1) with a long term decay in residual emissions at a consistent percentage reduction rate over time, 2) emissions dropping to zero following the point at which 95% of the budget has been used.

¹ Defined in terms of the administrative boundary of the Sheffield Local Authority area.

² We base our global carbon budget on the latest IPCC Special Report on 1.5°C study of how carbon emissions relate to global temperatures. The budget value we have selected provides a very good chance of staying below 2°C and offers some chance at holding temperatures to 1.5°C. As IPCC SR1.5, notes there are no emissions pathways for limiting warming to 1.5°C that do not rely upon significant carbon dioxide removal technology deployment [2].

³ Based on Sheffield’s 2016 CO₂ emissions (excluding aviation, shipping, process CO₂ emissions from cement production and those from LULUCF).

1. Introduction

This report presents advisory climate change targets for Sheffield to make its fair contribution to meeting the objectives of the United Nations Paris Agreement on Climate Change. The latest scientific consensus on climate change in the Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C [2] is used as the starting point for setting sub-national carbon budgets [3, 4] that quantify the maximum carbon dioxide (CO₂) associated with energy use in Sheffield that can be emitted to meet this commitment. This report translates this commitment into; 1) a long-term carbon budget for Sheffield; 2) a sequence of recommended five-year carbon budgets; 3) a date of 'near zero'/zero carbon for the city.

The United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement commits the global community to take action to "*hold the increase in global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C*" [1]. Cumulative emissions of CO₂ from human activity are the principle driver of long-term global warming.⁴ It is the relationship between CO₂ and global temperatures which means that staying within a given temperature threshold requires that only a certain total quantity of CO₂ is released to the atmosphere. This is the global carbon budget.

In addition to setting global average temperature targets, the UNFCCC process also includes foundational principles of common but differentiated responsibility [1]. This informs the fair (equitable) distribution of global emissions between nations at different stages of economic development. Industrialised nations are expected to show leadership towards a low carbon future, while it is acknowledged that a greater total share of future emissions will be associated with other countries as they develop (though their emissions per capita will remain low). Any sub-division of the global carbon budget must therefore account for the development needs of what the Paris Agreement refers to as "developing country Parties" in setting a fair/equitable national or sub-national carbon budget.

The carbon budgets presented here apply to CO₂ emissions from the energy system only. Although all greenhouse gas (GHG) emissions, such as methane and other forcing agents, such as aircraft contrails, affect the rate of climate change, long term warming is mainly driven by CO₂ emissions [5]. Furthermore the physical or chemical properties of each GHG vary, with different life-times causing warming in different ways, and with subsequent, and often large, uncertainties in their accounting [6]. As such the global carbon budgets in the Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C (SR1.5) [2], relate to CO₂-only emissions. In this report we have discussed non-CO₂ emissions and CO₂ emissions associated with land use, land use change and forestry separately.

⁴ This is due to the near-linear relationship between cumulative CO₂ emissions and temperature is the result of various feedback processes and logarithmic relationship between atmospheric CO₂ concentrations and radiative forcing, as well as the changes in the airborne fraction of CO₂ emissions [18].

Ultimately meeting a climate change target such as the Paris Agreement requires limiting cumulative CO₂ emissions over the coming decades. Carbon budgets can be effective way to understand what we need to limit our CO₂ emissions to in order to do this. End point targets such as net zero by 2050 can be useful indicators of ambition, but it is ultimately the cumulative CO₂ released on the way to that target that is of primary significance to achieving climate change goals. Whereas end point focused targets can be met with varying levels of CO₂ emissions (and therefore climate impacts) depending on their reduction pathways, carbon budgets specify the limits to CO₂ emissions within the period of the commitment. This is a reason why the UK Climate Change Act has legislated 5-year carbon budget periods, as well as a long term target, to keep CO₂ emissions consistent with the framing goal of the climate change commitment. It is also the reason why we recommend a carbon budget based approach.

1.2 Wider UK Policy Context

The UK Climate Change Act 2008 legislates a commitment to at least an 80% reduction in greenhouse gas emissions by 2050 from 1990 levels, with five yearly carbon budgets to set actions and review progress [7]. However, the level of these budgets is not aligned to the Paris Agreement (Box 2 of [4]).

This report presents climate change targets that go beyond the ambition of the 2008 Climate Change Act and the current recommendations of the UK Government's advisory body the Committee on Climate Change (CCC) that inform revised UK targets for 'net zero' greenhouse gases emissions by 2050. This is primarily due to two key differences between our approach and that of the CCC to date:

- a) The equity principles of the Paris Agreement and wider UNFCCC process are explicitly and quantitatively applied. Our approach allocates a smaller share of the global carbon budget to the 'developed country Parties', such as the UK, relative to 'developing country Parties'. This approach is also distinct in including global 'overheads' for land use, land use change and forests (LULUCF) and cement production related to development.
- b) Carbon removals via negative emissions technologies (NETs) are not included. The CCC include a significant role for NETs such as bioenergy carbon capture and storage and direct air capture in their analysis. Doing so increases the size of a carbon budget compatible with a given global temperature target. However carbon removal technologies are at a very early stage of development and whether they can be successfully deployed at sufficient scale is highly uncertain. While they are an important technology to develop, it is a major risk to prematurely adopt a carbon budget that allows for additional CO₂ on the basis that future generations will be in a position to deploy planetary-scale NETs.

We regard our UK carbon budget to be at the upper end of the range that is aligned with the Paris Agreement's objectives. Early results from the latest Earth system models suggest that the climate

may be more sensitive to greenhouse gases than previously thought implying a smaller global carbon budget is required [8]. In addition, assuming that developing countries will, on aggregate, implement rapid emissions reduction measures in line with a 2025 peak year is far from certain.

Therefore, we recommend that these budgets are taken as reflective of the minimum commitment required to deliver on the Paris Agreement.

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2. Method

The Setting City Area Targets and Trajectories for Emissions Reduction (SCATTER) project [4] commissioned by the Department for Business Energy and Industrial Strategy (BEIS) developed a methodology for Local Authorities to set carbon emissions targets that are consistent with United Nations Paris Climate Agreement. This report uses the SCATTER methodology with revised global carbon budgets, based on the latest IPCC Special Report on 1.5°C and updated CO₂ emissions datasets, to downscale global carbon budgets to Sheffield. This methodology has been successfully piloted with Greater Manchester Combined Authority and is being made available nationally to support all local authorities and groupings of local authorities.

Step 1: A global carbon budget of 900 GtCO₂ is taken from the Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C [2]. This global carbon budget represents the latest IPCC estimate of the quantity of CO₂ that can be emitted and still be consistent with keeping global temperatures well below 2°C with some chance of stabilising at 1.5 °C. This budget assumes no reliance on carbon removal technologies.

Step 2: A 'global overhead' deduction is made for process emissions arising from cement production (60 GtCO₂) [9]⁵. Cement is assumed to be a necessity for development [5]. We also assume that there is no *net* deforestation at a global level (2020 to 2100) so none of the global carbon budget is allocated to this sector. This will require a significant global effort to rapidly reduce deforestation and significantly improve forestry management as well as increase rates of reforestation and potentially afforestation.

Step 3: A share of the global carbon budget is allocated to "developing country parties" assuming a trajectory for those countries from current emissions to a peak in 2025 then increasing mitigation towards zero emissions by around 2050. The remaining budget is allocated to "developed country parties" which includes the UK [10]. This approach of considering developing countries first, is guided by the stipulation of equity within the Paris Agreement (and its earlier forebears, from Kyoto onwards)[10].

Step 4: The UK is apportioned a share of the 'developed country Parties' budget after Step 3 to provide a national carbon budget. The apportionment is made according to "grandfathering"⁶ of emissions for the period with most recent available data (2011 to 2016).

Step 5: Aviation and shipping emissions deducted. Assumptions and estimates are made about the level of future emissions from aviation, shipping and military transport for the UK. These emissions are then deducted from the national budgets as a 'national overhead' to derive final UK energy only carbon budgets. Emissions from aviation including military aircraft are assumed to be static out to 2030, followed by a linear reduction to complete decarbonisation by 2075. The total CO₂ emissions of this path are >25% lower than DfT central forecast (e.g. no third runway at Heathrow) followed by reduction to zero by 2075. Shipping emissions are based on Walsh et al [11] 'big world' scenario out to 2050 followed by full decarbonisation from this sector by 2075. These

⁵ Based on IEA's ambitious 2 degree scenario on process CO₂ for the period 2020-2050, subsequently extrapolating to zero by 2075

⁶ Grandfathering is based on the average proportion of CO₂ emissions from each Party in recent years.

aviation and shipping emissions (1,518 MtCO₂) are then deducted as a 'national overhead' from the UK budget to derive the final carbon budgets for the UK, from which local authority budgets are subsequently derived [4]. The budgets provided are therefore aligned with "well below 2°C and pursuing 1.5°C" provided that aviation and shipping emissions do not exceed the pathway assumed in our analysis [4]. Failure to hold aviation and shipping emissions within the outlined allocation will reduce the carbon budget for UK regions, including for Sheffield.

Step 6: Sheffield is apportioned a part of the remaining UK carbon budget. Our recommended budget is based on sub-national allocation through 'grandfathering'. A grandfathering approach allocates carbon budgets on the basis of recent emissions data. Data for recent annual CO₂ emissions for Sheffield [12] (2011-2016) is averaged and compared to averaged data for the whole UK [13] over the same period. The carbon budget (2020-2100) for Sheffield is then apportioned based on Sheffield's average proportion of UK CO₂ emissions for the 2011-2016 period. CO₂ emissions in the carbon budget include emissions from fossil combustion within the region and a share of the emissions from national electricity generation (relative to the Sheffield area end-use electricity demand).

Step 7: Carbon emission pathways. The carbon budgets for Sheffield are related to a set of illustrative emission pathways. These pathways show projected annual CO₂ emissions from energy use in Sheffield and how these emissions reduce over time to stay within the budget. The energy-only CO₂ emissions for 5-yearly interim carbon budget periods are calculated in line with the framework set out in the UK Climate Change Act (2018). It is the cumulative carbon budget and the 5 year interim budgets that are of primary importance as opposed to a long term target date. The combination of a Paris Agreement based carbon budget and the projected emissions pathways can however be used to derive a definition for a zero carbon year for Sheffield. The zero carbon year of 2038 is defined here as the point at which on the consistent reduction rate curve only 5% of Sheffield's recommended budget remains. Annual CO₂ emissions at this point fall below 0.1 MtCO₂ (>96% lower than 2015 CO₂ levels). Two illustrative emissions pathways can be derived in relation to this; 1) the residual 5% carbon budget pathway continues at the consistent reduction rate, diminishing until the end of the century; 2) emissions fall to zero in this year and the recommended budget pathway is revised to account for this. Both pathways are consistent with the Paris Agreement if CO₂ emissions stay within the cumulative CO₂ budget and 5-year interim budgets.

3. Results

3.1 Energy Only CO₂ Budgets for Sheffield

Following the Method the recommended energy only CO₂ carbon budget for the Sheffield area for the period of 2020 to 2100 is 16 MtCO₂. To translate this into near to long term commitments two CO₂ reduction pathways that are within the 16 MtCO₂ are proposed here:

- 1) End of Century Run: A consistent emissions reduction rate of 14.2% out to the end of the century is applied. In 2038 95% of the recommended carbon budget is emitted and low level CO₂ emissions continue at a diminishing level to 2100.
- 2) Informed by the end of the century pathway (1), 2038 is identified as a 'stop year' at which CO₂ emissions drop to zero. A pathway that distributes the 16 MtCO₂ budget from 2020 to 2038 is calculated. The annual emissions reduction rate for this pathway is 13.2%.

Both of these pathways are consistent with the recommended budget for a minimum commitment to meeting the objectives of the Paris Agreement.

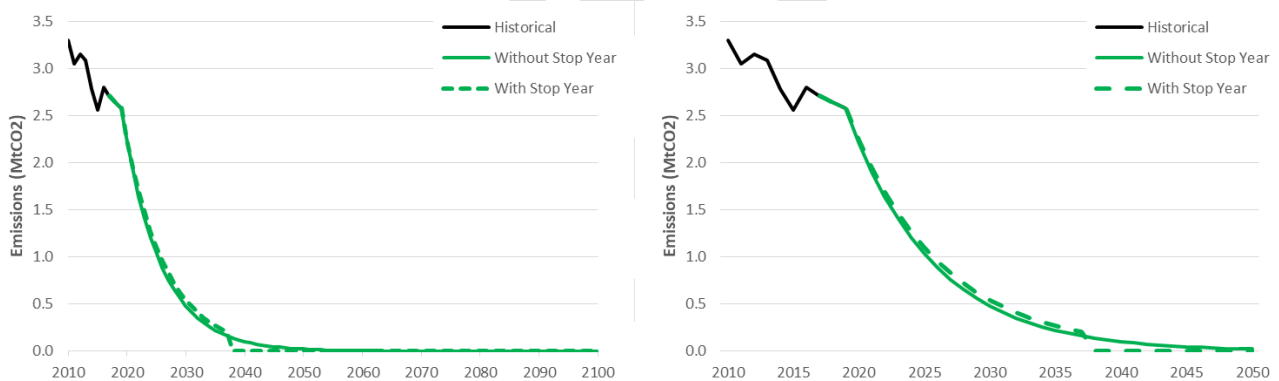


Figure 1a (left): Energy related CO₂ only emissions pathways (2010-2100) for Sheffield premised on the recommended carbon budget. **Figure 1b (right):** Energy CO₂ only emissions pathways (2010-2050) for Sheffield premised on the recommended carbon budget.

Table 1 presents the Sheffield energy CO₂ only budget in the format of the 5-year carbon budget periods in the UK Climate Change Act. To align the 2020 to 2100 carbon budget with the budget periods in the Climate Change Act we have included estimated CO₂ emissions for Sheffield for 2018 and 2019, based on BEIS provisional national emissions data for 2018 [14] and assuming the same year on year reduction rate applied to 2019. The combined carbon budget for 2018 to 2100 is therefore 20.8 MtCO₂.

Table 1: Periodic carbon budgets from 2018 under various regimes for Sheffield. Includes budgets for different allocation regimes.

| | | Grandfathering (End of Century Run) | Grandfathering (Stop Year at 95% of budget) |
|----------------------|-----------|-------------------------------------|---|
| Carbon Budget Period | 2018-2022 | 11.0 | 11.1 |
| | 2023-2027 | 5.3 | 5.6 |
| | 2028-2032 | 2.5 | 2.8 |
| | 2033-2037 | 1.1 | 1.4 |
| | 2038-2042 | 0.5 | 0.0 |
| | 2043-2047 | 0.2 | 0.0 |
| | 2048-2100 | 0.2 | 0.0 |

As shown in Figure 2, opting for a nearer term 'zero'/stop year allocates more of the overall carbon budget to the pre-2038 budget periods. This slightly reduces the emissions reduction rate over this period (from 14.2% to 13.2%), but it means that there is no residual emissions budget for the post-2038 budget periods. As with any emissions projection, using more of the available carbon budget within the contemporary period (i.e. the next decade) reduces the emissions 'space' for future residents and this should be considered carefully. It is for this reason also that we do not recommend any zero carbon/stop dates earlier than this for the Sheffield recommended budget as the budget would be more significantly skewed towards the contemporary period. The recommended budgets here are the minimum requirement for meeting the Paris Agreement. Therefore adopting a smaller cumulative CO₂ budget than the one presented here, with accelerated reduction rates leading to an earlier zero carbon year, is compatible with this approach - assuming that cumulative CO₂ emissions within the 5 year budget periods are the same or lower than those specified in Table 1.

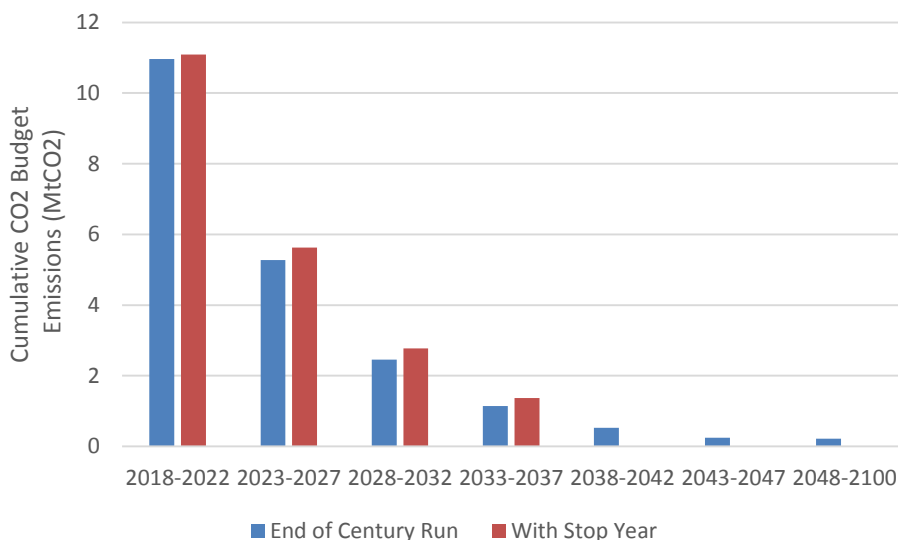


Figure 2: Cumulative CO₂ emissions per budget period for End of Century and Stop Year projections (based on Table 1)

3.2 Recommended Allocation Regime for Carbon Budget

The recommended carbon budget is based on a grandfathering allocation regime for sub-dividing the UK sub-national energy only carbon budget. There are three distinct allocation regimes that can be applied to determine sub-national budgets. We have opted to recommend one common approach for allocating carbon budgets that can be applied to all Local Authority areas. This enables straightforward compatibility between carbon budgets set at different administrative scales. For example this makes it easier for individual Local Authorities to calculate their own carbon budgets that are compatible with a budget set at Combined Authority scale. It also means that under the recommended carbon budgets, all Authorities are contributing to a common total UK carbon budget. If for example all Authorities selected the allocation regime that offered them largest carbon budget the UK the combined UK budget would not comply with the objectives of the Paris Agreement. The common approach to allocation we recommend therefore further assures that the carbon budget adopted is Paris Agreement compatible.

We have chosen a grandfathering as our common allocation approach because, based on our analysis, it is the most widely applicable regime within the UK.

Population and Gross Value Added⁷ (GVA) are alternative allocation regimes. Population shares the carbon budget equally across the UK on a per capita basis. In this allocation regime the UK population [15] is compared to that of Sheffield [16] from 2011 to 2016. The carbon budget (2020-2100) for Sheffield is then apportioned based on its average proportion of the UK population for the period 2011-2016. For regions where per capita energy demand deviates significantly from the average (e.g. a large energy intensive industry is currently located there) the budget allocated may not be equitable for all regions, therefore it is not recommended as the preferred allocation. GVA is used as an economic metric to apportion carbon budgets. For example, the UK total GVA [17] is compared to that of Sheffield [17] from 2011 to 2016. The carbon budget (2020-2100) for Sheffield is then apportioned based on Sheffield's average proportion of UK GVA for the period 2011-2016. GVA can be useful as a proxy for allocation on economic value, however without an adjustment for the type of economic activity undertaken, areas with high economic 'value' relative to energy use can get a relatively large budget, while the inverse is true for areas with energy intensive industries, and/or lower relative economic productivity. GVA would therefore not be recommended for all regions.

Table 2 presents the result outcomes for alternative allocation regimes – population and gross value added (GVA). For Sheffield the variation in carbon budget between allocation regimes is +/- 11% of the median value.

Table 2: Energy only CO₂ budgets and annual mitigation rates for Sheffield (2020-2100) by allocation regime

⁷ Balanced approach at current basic prices

| Allocation regime (% of UK budget allocated to Sheffield) | UK budget ⁸ (MtCO ₂) | Sheffield budget (MtCO ₂) | Average annual mitigation rate (%) |
|---|--|--|--|
| Grandfathering to Sheffield from UK (0.7%) | 2,239 | 15.6 | 14.2% |
| Population split to Sheffield from UK (0.9%) | 2,239 | 19.6 | 11.6% |
| GVA split to Sheffield from UK (0.7%) | 2,239 | 15.6 | 14.2% |
| Midpoint value of the allocation regimes | | 16.9 | 13.4% |

Pathway projections for the change in annual energy-only CO₂ emissions pathways for Sheffield based on the carbon budgets in Table 2 are illustrated in Figure 2a & 2b and in Table 2.

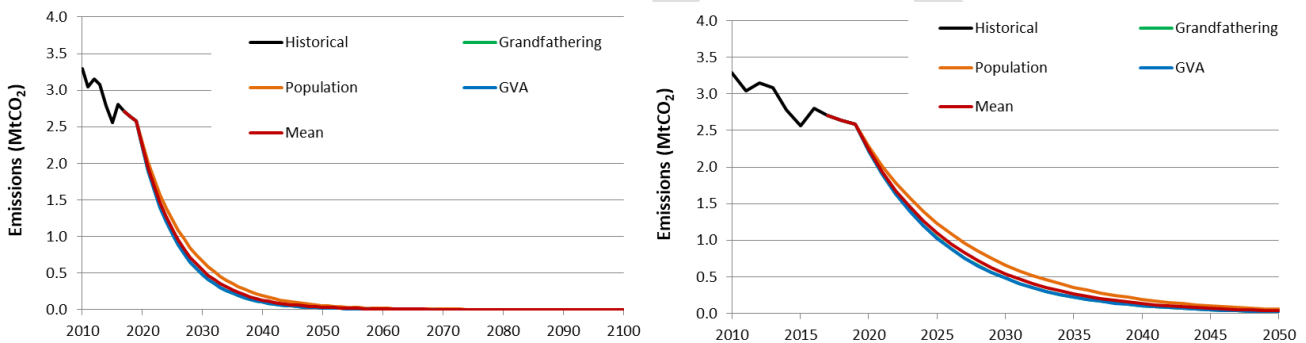


Figure 3a (left): Energy related CO₂ only emissions pathways (2010-2100) for Sheffield premised on carbon budgets shown in Table 2. **Figure 3b (right):** Energy CO₂ only emissions pathways (2010-2050) for Sheffield premised on carbon budgets shown in Table 2.

3.2 Land Use, Land Use Change and Forestry emissions for Sheffield

Land Use, Land Use Change and Forestry (LULUCF) consist of both emissions and removals of CO₂ from land and forests. Sheffield's CO₂-only emissions from LULUCF in 2016 were net negative (as were those of England as a whole) and estimated at around -251 ktCO₂ (i.e. equivalent to 0.9% of Sheffield's total CO₂ emissions) [12]. We recommend that CO₂ emissions and sequestration from LULUCF are monitored separately from the energy-only carbon budgets provided in this report. Sheffield should continue increasing the sequestration of CO₂ through LULUCF in the future aligned with Committee on Climate Change's high level ambition of tree planting, forestry yield improvements and forestry management [18]. Where LULUCF is considered to offset some residual energy CO₂ emissions this should first be considered in relation to mitigating the effects of non-CO₂ greenhouse gas emissions within the area that cannot be reduced to zero.

⁸After deducting an emissions budget for aviation, shipping and military transport of 1,518 MtCO₂.

3.3 Non-CO₂ Emissions

The IPCC SR1.5 report identifies the importance of non-CO₂ climate forcers (for instance methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), sulphur dioxide (SO₂) and black carbon) in influencing the rate of climate change. However, a cumulative emission budget approach is not appropriate for all non-CO₂ greenhouse gases, as the physical and chemical properties of each leads to differing atmospheric lifetimes and warming effects [19]. There are also substantial relative uncertainties in the scale, timing and location of their effects.

We do not provide further analysis or a non-CO₂ emissions reduction pathway in this report. However the global carbon budget in the IPCC Special Report on 1.5°C, that our analysis is based on, assumes a significant reduction in rate of methane and other non-CO₂ emissions over time. Therefore to be consistent with carbon budgets Sheffield should continue to take action to reduce these emissions.

The Department of Business Energy and Industrial Strategy's Local Authority emissions statistics do not provide non-CO₂ emissions data at the regional level. Given the absence of robust non-CO₂ emissions data, any non-CO₂ emissions inventory by other organisations at scope 1 and 2 for Sheffield may form the basis of monitoring and planning for these emissions. ***We recommend considering the adoption of a LULUCF pathway that includes CO₂ sequestration sufficient to help compensate for non-CO₂ emissions within the Sheffield.***

4. Conclusions

The results in this report show that for Sheffield to make its fair contribution to delivering the Paris Agreement’s commitment to staying well below 2°C and pursuing 1.5°C” global temperature rise, then an immediate and rapid programme of decarbonisation is needed. At 2016 CO₂ emission levels⁹, Sheffield will exceed the largest budget available (based on grandfathering allocation) within 6 years. **To stay within the recommended carbon budget Sheffield will, from 2020 onwards, need to achieve average mitigation rates of CO₂ from energy of around 14% per year** (depending on reduction pathway selected). This will require that Sheffield rapidly transitions away from unabated fossil fuel use. For context the relative change in CO₂ emissions from energy compared to a 2015 reference year are shown in Table 3.

Table 3: Percentage reduction of annual emissions for the recommended CO₂-only scenarios out to 2050 in relation to 2015

| | Recommended Budget – End of Century | Recommended Budget – Stop Year |
|-------------|-------------------------------------|--------------------------------|
| 2020 | 14% | 13% |
| 2025 | 60% | 57% |
| 2030 | 81% | 79% |
| 2035 | 91% | 90% |
| 2040 | 96% | 100% |
| 2045 | 98% | 100% |
| 2050 | 99% | 100% |

The carbon budgets recommended should be reviewed on a five yearly basis to reflect the most up-to-date science, any changes in global agreements on climate mitigation and progress on the successful deployment at scale of negative emissions technologies.

These budgets do not downscale aviation and shipping emissions from the UK national level. However if these emissions continue to increase as currently envisaged by Government, aviation and shipping will take an increasing share of the UK carbon budget, reducing the available budgets for combined and local authorities. **We recommend therefore that Sheffield seriously consider strategies for significantly limiting growth from aviation and shipping.** This could include interactions with the UK Government or other local authority and local enterprise partnership discussions on aviation that reflect the need of the carbon budget to limit aviation growth.

CO₂ emissions in the carbon budget related to electricity use from the National Grid in Sheffield are largely dependent upon national government policy and changes to power generation across the country. **It is recommended however that Sheffield promote the deployment of low carbon electricity generation within the region and where possible influence national policy on this issue.**

⁹ Based on Sheffield’s 2016 CO₂ emissions (excluding aviation, shipping, process CO₂ emissions from cement production and those from LULUCF).

We also recommend that the LULUCF sector should be managed to ensure that high levels of CO₂ sequestration should continue through reforestation, forestry yield improvements and forestry management. The management of LULUCF could also include action to increase wider social and environmental benefits.

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