Setting Climate Change Commitments for West Midlands Combined Authority Area

Tyndall Centre
for Climate Change Research

Setting Climate Change Commitments for West Midlands Combined Authority Area:

Quantifying the Implications of the United Nations Paris Agreement on Climate Change for West Midlands Combined Authority

Client:	West Midlands Combined Authority (Dr Simon Slater)
Document Reference:	WMCA
Version:	FINAL
Date:	29 June 2019
Prepared by:	Dr Jaise Kuriakose, Dr Chris Jones, Prof Kevin Anderson, Dr John Broderick & Prof Carly McLachlan

NB: All views contained with this report are attributable solely to the authors and do not necessarily reflect those of researchers within the wider Tyndall Centre.

Key Messages

This report presents climate change targets for West Midlands Combined Authority (WMCA)[1] 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 WMCA with budgets for carbon dioxide (CO_2) 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 United Nations Paris Agreement to a national UK carbon budget [1].[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-CO_2 emissions are considered separately to the energy CO_2 budget in this report.

Based on our analysis, for WMCA to make its 'fair' contribution towards the Paris Climate Change Agreement, WMCA needs to:

1) Stay within a maximum cumulative carbon dioxide emissions budget of 126 million tonnes ($MtCO_2$) for the period of 2020 to 2100. At 2016 CO_2 emission levels[3], the WMCA would use this entire budget within 6 years from 2020.

2) Initiate an immediate programme of CO_2 mitigation to deliver annual cuts in emissions averaging 13% to deliver a Paris Agreement aligned carbon budget. These annual reductions in emissions require national and local action and would be part of a wider collaboration with local authorities in the region.

3) Reach zero or near zero carbon no later than 2041. This report provides two CO_2 reduction pathways which both stay within the recommended 126 $MtCO_2$ 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] WMCA area comprising of the geography of the Black Country, Coventry and Warwickshire, and Greater Birmingham and Solihull Local Enterprise Partnerships. This made up of the unitary and district councils of Walsall, Wolverhampton, Sandwell, Dudley, Birmingham, Solihull, Cannock Chase, East Staffordshire, Lichfield, Wyre Forest, Bromsgrove, Redditch, Tamworth, Coventry, North Warwickshire, Nuneaton and Bedworth, Rugby, Stratford Upon Avon and Warwick.

[2] We base our global carbon budget on the latest IPCC Special Report on 1.5°C (IPCC SR1.5) findings on how carbon emissions relate to global temperatures. The budget value we have selected provides a 'likely' chance of staying below 2°C and offers an outside 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 WMCA's 2016 CO_2 emissions (excluding aviation, shipping, process CO_2 emissions from cement production and those from LULUCF).

1. Introduction

This report presents advisory climate change targets for the WMCA 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 (CO_2) associated with energy use in WMCA area that can be emitted to meet this commitment. This report translates this commitment into; 1) a long-term carbon budget for WMCA; 2) a sequence of recommended five-year carbon budgets; 3) a date of effective zero carbon for the region.

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 CO_2 from human activity are the principle driver of long-term global warming.[4] It is the relationship between CO_2 and global temperatures which means that staying within a given temperature threshold requires that only a certain total quantity of CO_2 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 CO_2 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 CO_2 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 CO_2-only emissions. In this report we have discussed non-CO_2 emissions and CO_2 emissions associated with land use, land use change and forestry separately.

Ultimately staying within a global temperature threshold (e.g. "well below 2°C") requires limiting cumulative CO_2 emissions over the coming decades. Carbon budgets can be an effective way to understand the amount of CO_2 emissions that can be released into the atmosphere in order to do this. End point targets such as 'net zero' by 2050, with very clear assumptions, can be useful

[4] This is due to the near-linear relationship between cumulative CO_2 emissions and temperature is the result of various feedback processes and logarithmic relationship between atmospheric CO_2 concentrations and radiative forcing, as well as the changes in the airborne fraction of CO_2 emissions [19].

indicators of ambition, but it is ultimately the cumulative CO_2 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 CO_2 emissions (and therefore varying global temperature with consequent climate impacts) depending on their reduction pathways, carbon budgets specify the limits to CO_2 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 CO_2 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 now legislates for a commitment to 'net zero' greenhouse gas emissions by 2050[5], with five yearly carbon budgets to set actions and review progress [7]. The carbon budgets for this target were not available at the time of our analysis for direct comparison, however the recommended budget in this report will most likely be more stringent. This is primarily due to two key differences between our approach and the current recommendations of the UK Government's advisory body the Committee on Climate Change (CCC) that inform the revised UK net zero target:

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'. Moreover the approach is also distinct in including global 'overheads' for land use, land use change and forests (LULUCF) and cement process emissions related to development.

b) Carbon dioxide removals, via negative emissions technologies (NETs), and carbon offsets[6] are not included. The UK Climate Change Act's 'net zero' framing means that the commitment is met when greenhouse gas emissions and removals from the UK's carbon 'account' balance at zero. Hence the 2050 target can be met using carbon dioxide removal technologies, including land use sequestrations, and potentially carbon offsetting. The CCC include a significant role for NETs such as bioenergy carbon capture and storage and some direct air capture in their analysis supporting the UK net zero target. Doing so theoretically increases the size of a carbon budget, but increases the risk of failing to deliver on the Paris global temperature target. The UK Government has also rejected the CCC's advice to explicitly exclude international carbon offsetting as an approach to meeting the net zero target. Allowing for future carbon dioxide removal technologies and international carbon offsetting ostensibly increase the size of the UK's carbon budget. However carbon removal technologies are at a very early stage of development and

[5] The 2019 amended UK Climate Change Act commits the UK to at least a 100% reduction in greenhouse gas emissions by 2050 from 1990 levels on the basis that the UK's 'carbon account' is 'net zero' by this point. This is not the same as zero greenhouse gas emissions by 2050. In this framing of the Climate Change Act, greenhouse gas emissions are net zero on the provision that they are balanced by greenhouse gas removals in the UK's carbon account. This may include future balancing of the carbon account through carbon removal technologies.
[6] Carbon offsetting refers to the purchase of a tradeable unit, representing emissions rights or emissions reductions, to balance the climate impact of an organisation, activity or individual.

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 CO_2 on the basis that future generations will be in a position to deploy planetary-scale NETs. Similarly, as the CCC note in their advice, the efficacy of carbon offsetting as a contribution to meeting global climate change commitments is not robust enough to incorporate into recommended carbon budgets.

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.***

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 CO_2 emissions datasets, to downscale global carbon budgets to the WMCA area. 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 $GtCO_2$ 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 CO_2 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 $GtCO_2$) [9][7]. 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"[8] of emissions for the most recent period up to the Paris Agreement (2011 to 2016).

Step 5: Aviation and shipping emissions deducted. Aviation and shipping emissions are 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 CO_2 emissions of this path are >25% lower than Department for Transport's central forecast 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 aviation and shipping emissions (1,518 $MtCO_2$) 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

[7] Based on IEA's ambitious 2 degree scenario on process CO_2 for the period 2020-2050, subsequently extrapolating to zero by 2075

[8] Grandfathering is based on the average proportion of CO_2 emissions from each Party in recent years.

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 WMCA area.

Step 6: WMCA 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 CO_2 emissions in WMCA area [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 WMCA is then apportioned based on WMCA's average proportion of UK CO_2 emissions for the 2011-2016 period.

Step 7: Carbon emission pathways and year of carbon neutrality. The carbon budgets for WMCA are related to a set of illustrative emission pathways. These pathways show annual CO_2 emissions from energy use in WMCA and how these emissions reduce over time to stay within the budget. The energy-only CO_2 emissions for 5-yearly interim carbon budget periods are calculated in line with the framework set out in the UK Climate Change Act (2018). The combination of a Paris Agreement based carbon budget and the projected emissions pathways enable a zero carbon year for WMCA to be derived. The zero carbon year is defined here as the point at which WMCA's annual average carbon dioxide emissions fall below a threshold level of 0.9 $MtCO_2$ (i.e over 96% lower than 2015 levels). The threshold year relates to less than 5% of the total carbon budget remains as residual CO_2 emissions out to the end of the century. CO_2 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 WMCA area end-use electricity demand).

Table 1: *Summary of the scope of emissions included in the WMCA carbon budget. 'Direct CO_2' refers to CO_2 from non-power station fossil fuel combustion (e.g. natural gas, oil, coal, petrol and diesel).*

Source of Emissions	Relation to WMCA Carbon Budget
International and Domestic Aviation CO_2	UK national budget
Shipping CO_2	UK national budget
Electricity use (all sectors within WMCA area) CO_2	WMCA carbon budget – end use based (Scope2)
Surface transport - direct CO_2	WMCA carbon budget – fuel use allocated to WMCA in BEIS data based on DfT model [13] Electricity emissions associated with electric train use in WMCA are incorporated into the commercial and industrial electricity set in the BEIS data.
Commercial and industrial energy use - direct CO_2	WMCA carbon budget
Domestic energy use - direct CO_2	WMCA carbon budget
Imported goods	Not included in WMCA budget
LULUCF CO_2 – (emissions and removal of CO_2 by forestry and land use and land use change)	Not included in WMCA budget – separate recommendation made
Non-CO_2 greenhouse gas emissions	Not included in WMCA budget – separate recommendation made

2.1 Baseline Emissions for WMCA

Based on the statistics provided by BEIS the energy only CO_2 emissions for the WMCA area in 2016 are shown in Figure 1. Electricity emissions associated with electric trains are incorporated into the commercial and industrial electricity set in the BEIS data. This data offers an indication of the starting point for the WMCA area in targeting inventions. As is common for most areas there is a relatively even split between commercial/industrial, domestic and transport sectoral emissions.

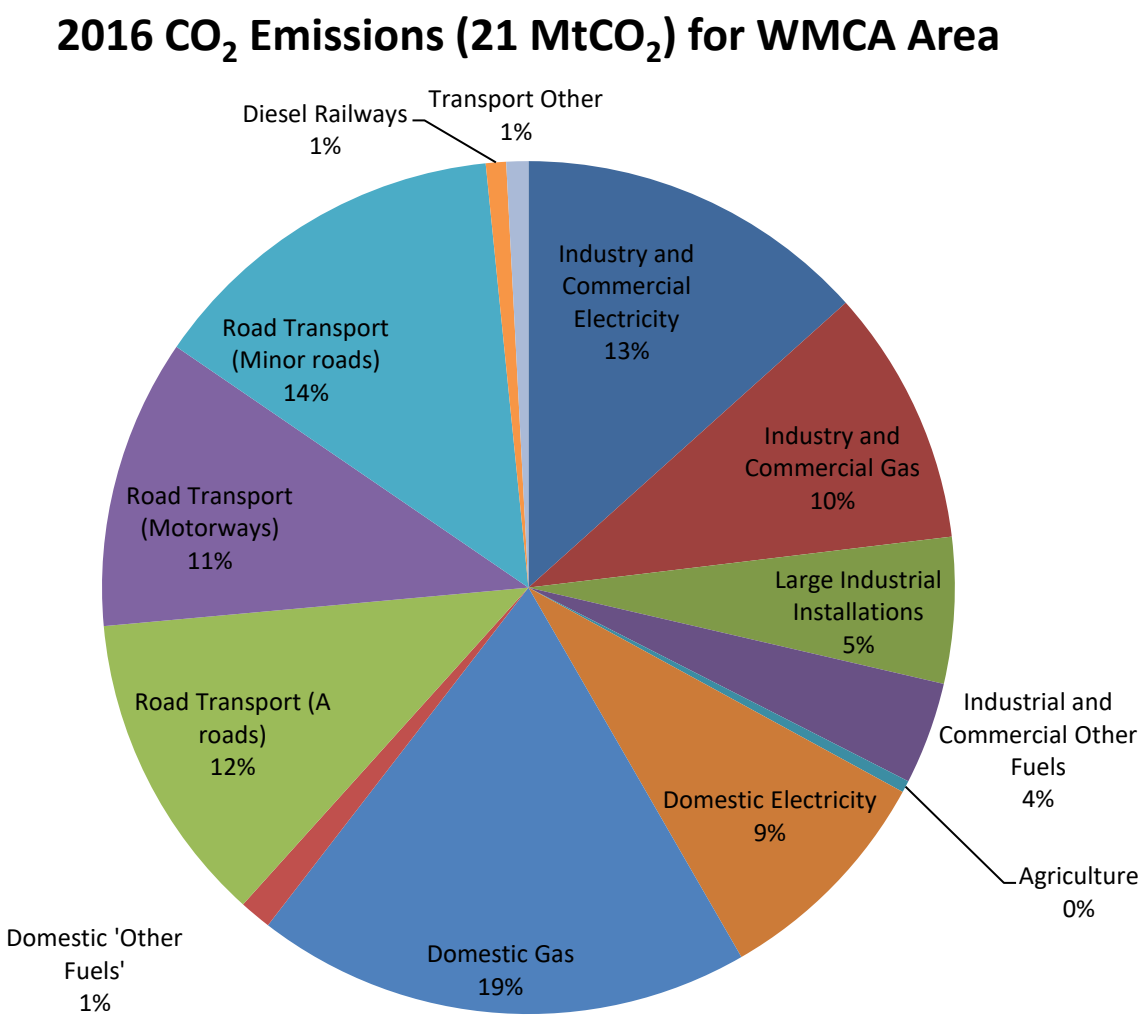

Figure 1: Sectoral split of 2016 CO2 Emissions (21 MtCO2) for WMCA Area from BEIS Statistics [12]. NB Electricity use for rail travel attributed to WMCA is included in 'Industrial and Commercial Electricity'.

3. Results

3.1 Energy Only CO_2 Budgets for WMCA

Following the Method the recommended energy only-CO_2 carbon budget for the WMCA area for the period of 2020 to 2100 is 126 $MtCO_2$. To translate this into near to long term commitments two CO_2 reduction pathways that are within the 126 $MtCO_2$ are proposed here:

(1) A consistent emissions reduction rate of 13.4% out to the end of the century. In 2041 95% of the recommended budget is used by 2041 and low level CO_2 emissions continue at a diminishing level to 2100

(2) Informed by the end of the century pathway (1), 2041 is identified as a 'stop year' at which CO_2 emissions drop to zero. A pathway that distributes the 126 $MtCO_2$ budget from 2020 to 2041 is calculated. The annual average emissions reduction rate for this pathway is 12.8%. A final change in emissions of -1.1 $MtCO_2$ for 2041 is therefore assumed

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

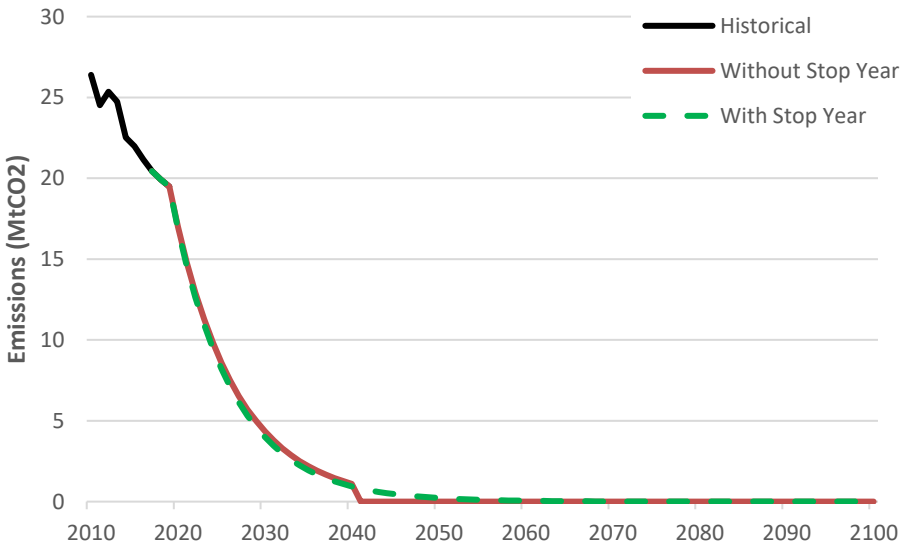

Figure 2: *Energy related CO_2 only emissions pathways (**2010-2100**) for WMCA premised on the recommended carbon budget*

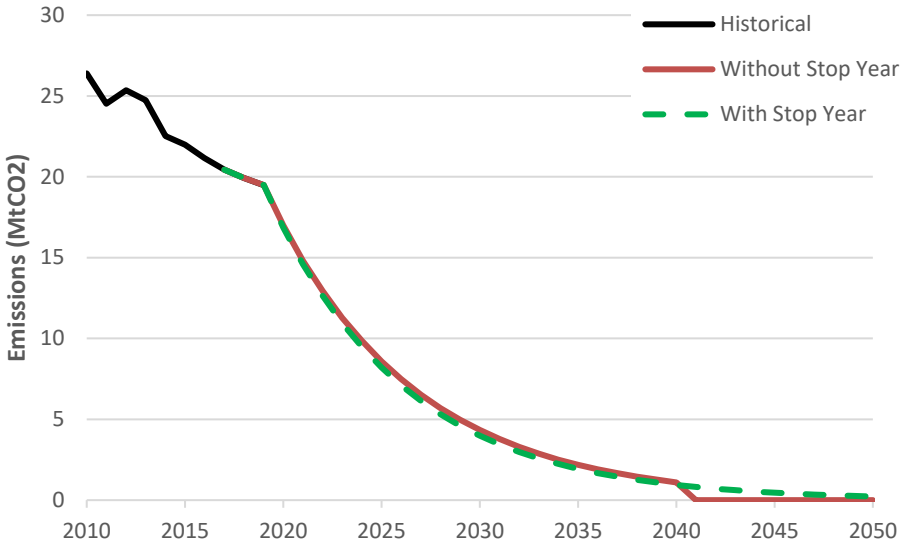

*Figure 3: Energy CO_2 only emissions pathways (**2010-2050**) for WMCA premised on the recommended carbon budget*

Table 2 presents the WMCA area energy CO_2 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 CO_2 emissions for the WMCA area 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 165 $MtCO_2$.

Table 2: Periodic carbon budgets from 2018 for WMCA. *This includes the projected emissions for 2018-2019 and the 2020 to 2100 recommended carbon budget for the two emissions pathways.*

		Grandfathering (End of Century Run)	Grandfathering (Stop Year at 95% of Budget)
Carbon Budget Period	2018-2022	83.5	84.2
	2023-2027	41.9	43.7
	2028-2032	20.3	22.1
	2033-2037	9.9	11.2
	2038-2042	4.8	3.8
	2043-2047	2.3	0.0
	2048-2100	2.2	0.0

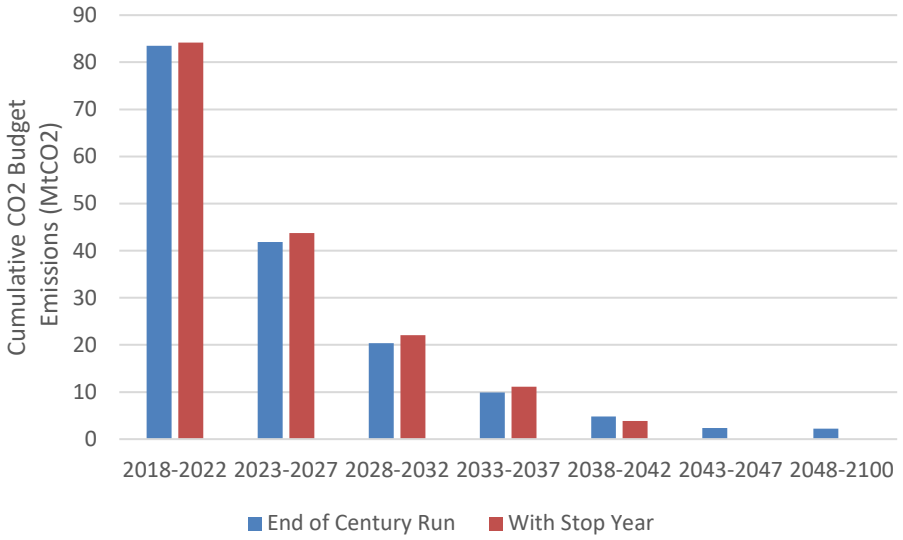

Figure 4: Cumulative CO_2 emissions per budget period for End of Century and Stop Year projections

The recommended budgets here are the minimum requirement for meeting the Paris Agreement – i.e. the maximum CO_2 emissions budget. Therefore adopting a smaller cumulative CO_2 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 CO_2 emissions within the proposed 5 year budget periods are the same or lower that those specified in Figure 4. Earlier zero carbon years that have pathways leading to cumulative CO_2 emissions greater than the recommended interim budgets, or the use of carbon offsets to meet an earlier target year, are not however consistent with this approach.

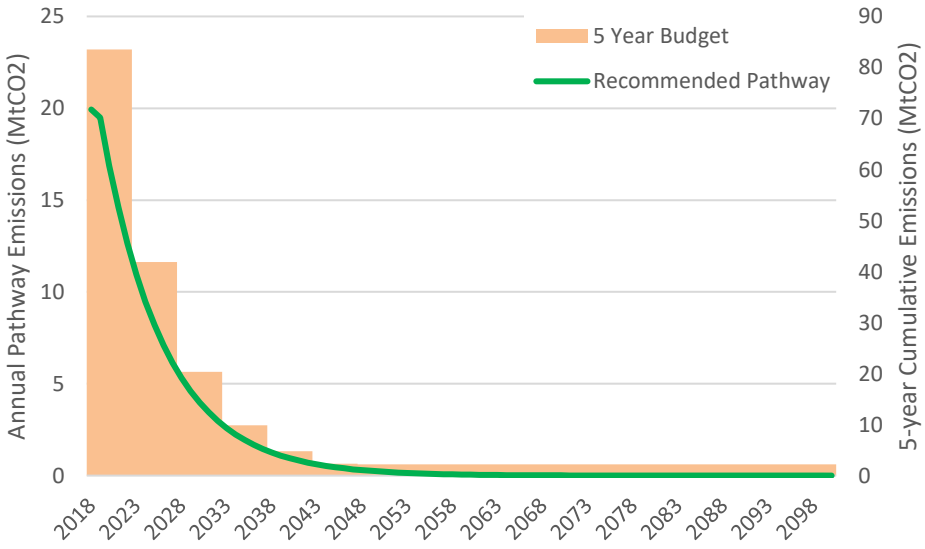

Figure 5: Annual emissions pathway (primary axis) overlaying 5-year budget cumulative periods (secondary axis) for End of Century projection

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 CO_2 only carbon budget. There are three distinct allocation regimes that could be applied to determine sub-national budgets. We have opted to recommend one common approach for allocating carbon budgets most suitably applied to all Local Authority areas. This enables straightforward compatibility between carbon budgets set at different administrative scales. For example this simplifies the process of individual Local Authorities calculating 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 the largest carbon budget available, 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 on balance the most widely applicable regime within the UK.

Population and Gross Value Added[9] (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 WMCA [16] from 2011 to 2016. The carbon budget (2020-2100) for WMCA 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 an equitable allocation through not fully representing incumbent infrastructure and economic structures. As population based allocation cannot be applied satisfactorily in all regions it is not recommended as the preferred allocation regime.

GVA is used as an economic metric to apportion carbon budgets. For example, the UK total GVA [17] is compared to that of WMCA [17] from 2011 to 2016. The carbon budget (2020-2100) for WMCA is then apportioned based on WMCA's average proportion of UK GVA for the period 2011-2016. GVA can be used as a proxy for economic value. This does not however adjustment for the type of economic activity undertaken, particularly the relationship between economic value, energy intensity and productivity. Incumbent economic structures (i.e. areas with energy intensive industries) been seen to substantially effect budgets based on this approach and therefore GVA would therefore would not be recommended for all regions.

Grandfathering allocates a share of the UK carbon budget based on average share of UK emissions attributed to a region in recent years (2011 to 2016). In principle this accounts for incumbent economic, population and infrastructure features of a region. A potential disadvantage of grandfathering is that is a large industry that significantly influenced the grandfathered allocation shuts down early into the budget period, emissions in that area fall quickly without specific action on energy related CO_2 being undertaken. ***In light of this we recommend that a***

[9] Balanced approach at current basic prices

Local Authority re-examines its carbon budget if a large industrial user (i.e. >10% of total LA energy use) shuts down completely within the first 5 year budget period (2018 to 2022).

Table 3 presents the results for alterative allocation regimes – population, gross value added (GVA) and grandfathering. For WMCA the variation in carbon budget between allocation regimes is +/- 8% of the median value.

***Table 3**: Energy only CO_2 budgets and annual mitigation rates for WMCA (2020-2100) by allocation regime*

Allocation regime (% of UK budget allocated to WMCA)	UK budget[10] ($MtCO_2$)	WMCA budget ($MtCO_2$)	Average annual mitigation rate (%)
Grandfathering to WMCA from UK (5.7%)	2,239	125.5	13.4%
Population split to WMCA from UK (6.4%)	2,239	139.9	12.2%
GVA split to WMCA from UK (5.4%)	2,239	119.4	14.0%
Mean of the allocation regimes		128.2	13.2%

Pathway projections for the change in annual energy-only CO_2 emissions pathways for WMCA based on the carbon budgets in Table 3 are illustrated in Figure 6a & 6b and in Table 2.

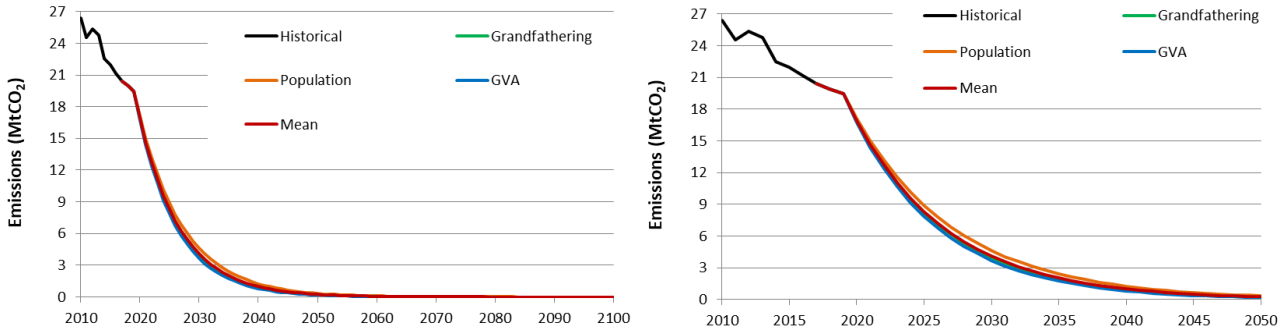

***Figure 6a (left)**: Energy related CO_2 only emissions pathways (**2010-2100**) for WMCA premised on carbon budgets shown in Table 3. **Figure 6b (right)**: Energy CO_2 only emissions pathways (**2010-2050**) for WMCA premised on carbon budgets shown in Table 3.*

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

Land Use, Land Use Change and Forestry (LULUCF) consist of both emissions and removals of CO_2 from land and forests. WMCA area's CO_2-only emissions from LULUCF in 2016 were net negative (as were those of England as a whole) and estimated at around -100 $ktCO_2$ (i.e. around 0.5% of WMCA total CO_2 emissions) [12]. We recommend that CO_2 emissions and sequestration from LULUCF are monitored separately from the energy-only carbon budgets provided in this

[10]After deducting an emissions budget for aviation, shipping and military transport of 1,518 $MtCO_2$.

report. The WMCA should continue increasing the sequestration of CO_2 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].

3.3 Non-CO_2 Emissions

The IPCC SR1.5 report identifies the importance of non-CO_2 climate forcers (for instance methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), sulphur dioxide (SO_2) and black carbon) in influencing the rate of climate change. However, a cumulative emission budget approach is not appropriate for all non-CO_2 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-CO_2 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-CO_2 emissions over time. Therefore to be consistent with carbon budgets WMCA 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-CO_2 emissions data at the regional level. Given the absence of robust non-CO_2 emissions data, any non-CO_2 emissions inventory by other organisations at scope 1 and 2 for WMCA may form the basis of monitoring and planning for these emissions. ***We recommend considering the adoption of a LULUCF pathway that includes CO_2 sequestration sufficient to help compensate for non-CO_2 emissions within WMCA.***

3.4 Recommended Allocation Regime for Carbon Budgets Within the Region

The WMCA area is the largest Combined Authority in the UK, covering a very diverse geography made up of 19 district or unitary council areas covered by three Local Enterprise Partnerships (LEP). Therefore the proportion and contribution to a collective WMCA area target will vary [20]. The Tyndall Centre is working to provide this methodology and datasets online so that individual local authorities in the WMCA area and the UK can produce an individual profile for their area. We recommend the Grandfathering allocation approach as a common approach for these budgets and this will allow compatibility between local authority, LEP area and Combined Authority budgets.

Using a common methodology at a Combined Authority area level, has the following benefits:

- Shared framework and starting point for understanding the scale of the challenge to develop individual local responses and set local targets
- Common framework and understanding to report on the collective progress required of an average 13% reduction per year from 2020 to 2041

These budgets may also be compatible with more ambitious carbon targets declared within a local authority. Such a target would only be more ambitious if it restricts energy CO_2 emissions to less than the absolute quantity (i.e. without offsetting) of CO_2 specified in this carbon budget (Table 2). This implies an average per annum reduction rate in energy related CO_2 emissions of

greater than 13% including an approach to ensure that UK national grid electricity is zero carbon in line with such a target. The recommended budgets presented here represent the minimum level of CO_2 emissions reduction we consider consistent with the Paris Agreement, therefore decarbonising energy provision within WMCA more quickly is welcomed.

5. Conclusions

The results in this report show that for WMCA 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.

Based on our analysis, for WMCA to make its 'fair' contribution towards the Paris Climate Change Agreement, WMCA needs to:

1) Stay within a maximum cumulative carbon dioxide emissions budget of 126 million tonnes ($MtCO_2$) for the period of 2020 to 2100. At 2016 CO_2 emission levels[11], the WMCA would use this entire budget within 6 years from 2020.

2) Initiate an immediate programme of CO_2 mitigation to deliver annual cuts in emissions averaging 13% 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 local authorities in the region.

3) Reach zero or near zero carbon no later than 2041. This report provides two CO_2 reduction pathways which both stay within the recommended 126 $MtCO_2$ 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.

This will require that WMCA rapidly transition away from unabated fossil fuel use. For context the relative change in CO_2 emissions from energy compared to a 2015 reference year are shown in Table 4.

Table 4: Percentage reduction of emissions for the recommended CO_2-only scenarios out to 2050 in relation to 2015

	GF – End of Century	GF – Stop Year
2020	23%	23%
2025	63%	61%
2030	82%	80%
2035	91%	90%
2040	96%	95%
2045	98%	100%
2050	99%	100%

These budgets for WMCA 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 WMCA seriously consider strategies for significantly limiting growth from aviation and shipping.***

[11] Based on WMCA's 2016 CO_2 emissions (excluding aviation, shipping, process CO_2 emissions from cement production and those from LULUCF).

CO_2 emissions in the carbon budget related to electricity use from the National Grid in WMCA are largely dependent upon national government policy and changes to power generation across the country***. It is recommended however that WMCA promote the deployment of low carbon electricity generation within the region and where possible influence national policy on this issue.***

We also recommend that the LULUCF sector should be managed to ensure that high levels of CO_2 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.

5. Reference List

1. United Nations, *Paris Agreement*, U. Nations, Editor. 2015, United Nations: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.
2. Masson-Delmotte, V., et al., *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,*. 2018, IPCC: https://www.ipcc.ch/sr15/.
3. Anderson, K. and A. Bows, *Beyond 'dangerous' climate change: emission scenarios for a new world.* Philos Trans A Math Phys Eng Sci, 2011. **369**(1934): p. 20-44.
4. Kuriakose, J., et al., *Quantifying the implications of the Paris Agreement for Greater Manchester*. 2018, Tyndall Centre for Climate Change Research: https://www.research.manchester.ac.uk/portal/en/publications/quantifying-the-implications-of-the-paris-agreement-for-greater-manchester(d2e50584-952e-472b-a2b0-1c7e7d1651e1).html.
5. IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, R.K. Pachauri and L.A. Meyer, Editors. 2014, IPCC: https://www.ipcc.ch/report/ar5/syr/. p. 151.
6. Davies, E., et al., *Quantifying Greenhouse Gas Emissions* 2017: https://www.theccc.org.uk/wp-content/uploads/2017/04/Quantifying-Greenhouse-Gas-Emissions-Committee-on-Climate-Change-April-2017.pdf.
7. Government, H., *Climate Change Act 2008 (c.27)*. 2008: http://www.opsi.gov.uk/acts/acts2008/ukpga_20080027_en_1.
8. Belcher S, Boucher O, and Sutton R., *Why results from the next generation of climate models matter*. 2019, Carbon Brief: https://www.carbonbrief.org/guest-post-why-results-from-the-next-generation-of-climate-models-matter.
9. Fernandez Pales, A. and Leung Y., *Technology Roadmap - Low-Carbon Transition in the Cement Industry*. 2018, International Energy Agency: https://webstore.iea.org/technology-roadmap-low-carbon-transition-in-the-cement-industry.
10. Anderson K and Broderick J., *Natural gas and climate change*. 2017: https://www.research.manchester.ac.uk/portal/files/60994617/Natural_Gas_and_Climate_Change_Anderson_Broderick_FOR_DISTRIBUTION.pdf.
11. Walsh, C., S. Mander, and A. Larkin, *Charting a low carbon future for shipping: A UK perspective.* Marine Policy, 2017. **82**: p. 32-40.
12. Pearson, B., J. Richardson, and I. Tsagatakis, *Local and Regional Carbon Dioxide Emissions Estimates for 2005–2016 for the UK*. 2018, BEIS: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/719073/Local_CO2_-_Technical_Report_2016.pdf.
13. Department for Business Energy and Industrial Strategy, *Final UK greenhouse gas emissions national statistics: 1990-2017*. 2019: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/776085/2017_Final_emissions_statistics_-_report.pdf.
14. Department for Business Energy and Industrial Strategy, *2018 UK GREENHOUSE GAS EMISSIONS, PROVISIONAL FIGURES* BEIS, Editor. 2019: file:///C:/Users/mbgnhcj2/AppData/Local/Temp/2018-provisional-emissions-statistics-report.pdf.
15. Park, N., *United Kingdom population mid-year estimate*, O.f.N. Statistics, Editor. 2018, Office for National Statistics: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/timeseries/ukpop/pop.
16. Nash, A., *Population projections for local authorities: Table 2* O.f.N. Statistics, Editor. 2018, Office for National Statistics:

https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/localauthoritiesinenglandtable2.

17. Fenton, T., *Regional economic activity by gross value added (balanced), UK: 1998 to 2017* O.f.N. Statistics, Editor. 2018, Office for National Statistics: https://www.ons.gov.uk/economy/grossvalueaddedgva/bulletins/regionalgrossvalueaddedbalanceduk/1998to2017.
18. Brown, K., et al., *Land use: Reducing emissions and preparing for climate change* 2018, Committee on Climate Change: https://www.theccc.org.uk/publication/land-use-reducing-emissions-and-preparing-for-climate-change/.
19. IPCC, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley Editor. 2013: https://www.ipcc.ch/report/ar5/wg1/.
20. Sustainability West Midlands, *Combined Authority Sustainability Benchmarking Technical Report –annual analysis of metrics* 2019: https://www.sustainabilitywestmidlands.org.uk/resources/combined-authority-sustainability-benchmarking-reports-analysis-of-metrics-2019/.