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Examination Principle Issues	• **Climate Change** • **Scope of Development and Environmental Impact Assessment** • **Benefit cost ratio (BCR) and case for scheme**

Pre-D7, Pre-ISH3 SUBMISSION

I am an independent scientist and environmental consultant, working at the intersection of science, policy, and law, particularly relating to ecology and climate change. I work as a consultancy called Climate Emergency Policy and Planning (CEPP).

In so far as the facts in this statement are within my knowledge, they are true. In so far as the facts in this statement are not within my direct knowledge, they are true to the best of my knowledge and belief.

SUMMARY

This submission contains indicative recalculations of the BCR for the A47NTE scheme following the publication by the Government of new carbon prices for policy and assessment, based on price updates to align with recent changes in national Climate Change policy.

The BCR for the scheme reduces to "medium" from "high" with the new carbon pricing data.

My calculations are indicative, not definitive. The Applicant must now provide the additional BCR calculations identified.

I respectfully ask the ExA, if with his agreement, I can raise the issue (but not the detail here) at the ISH3 Hearing on Climate Change on 6th January. The purpose would be to identify the necessary follow up actions required on the part of the Applicant.

Contents

1 INTRODUCTION

1.1 Pre-D7, Pre-ISH3 Submission

1 This submission follows my deadline D6 submission [REP6-020] which covered carbon quantification with a further submission on carbon assessment due for deadline D7.

2 In REP6-020, section 1.2, I drew attention to some recent changes to relevant policy. This submission makes an initial appraisal of the effect of the three of these below. These relate to new carbon price values released by the Government for appraisal, including of transport schemes. These new carbon prices are significantly greater than the previous values used in the case for the scheme [APP-140], reflecting changes in climate change policy over the last few years. The new values have a significant impact on the Benefit Cost ratio (BCR) calculation, and, therefore, the BCR needs to be recalculated.

(a) Government policy paper[1] setting out a revised approach to valuing GHG emissions, and revised carbon prices, in policy appraisal was published on 2nd September 2021. (Reproduced in Appendix 1).

(b) HM Treasury Green Book supplement providing specific guidance on how analysts should quantity and value emissions of GHGs[2] was published in October 2021.

(c) An updated version of the DfT's WebTAG guidance[3] and TAG data book, including changes to emissions factors, was published on 29th November 2021.

[redacted]

1.2 Relevant documents from other DCO schemes beyond Norfolk

4 I draw the ExA's attention to these recent new consultations by the SoS on the following schemes:

A. A1 in Northumberland – Morpeth to Ellingham [TR010059] (Secretary of State Consultation 3, 22nd December 2021[4])

B. M25 junction 10/A3 Wisley interchange improvement [TR010030] (Secretary of State Consultation 8, 22nd December 2021[5])

C. M25 junction 28 improvements [TR010029] (Secretary of State Consultation 3, 22nd December 2021[6])

5 Each of these consultations requires additional information from the Applicant on the cumulative assessment of climate impacts, and specifically asks for:

> *"The Secretary of State invites the Applicant to update its response of [date] to provide (or, to the extent that it has already been provided, identify)* ***its assessment of the cumulative effects of Greenhouse Gas emissions from the scheme with other existing and/or approved projects on a local, regional and national level*** *on a consistent geographical scale (for example an assessment of the cumulative effects of the Roads Investment Strategy RIS 1 and RIS 2 at a national level).*
>
> *This should: take account of both construction and operational effects; identify the baseline used at each local, regional and national level; and identify any relevant local, regional or national targets/budgets where they exist and how the assessment complies with these (including the carbon budgets, the 2050 zero target under the Climate Change Act 2008, and the UK's Nationally Determined Contribution under the Paris Agreement). It should be accompanied by reasoning to explain the methodology adopted, any likely significant effects identified, any difficulties encountered in compiling the information, and how the assessment complies with the Environmental Impact Assessment Regulations.*
>
> *The Secretary of State would also welcome confirmation that the response to all parts of this question has been prepared by a competent expert. Please can links be provided to any documents referenced and their relevance fully explained."*
>
> **{my emphasis}**

[4] Response by 19 January 2022

[5] Response by 19 January 2022

[6] Response by 19 January 2022

6 This is clearly relevant to my previous submissions, especially REP6-020 which demonstrates without doubt that cumulative carbon emissions have not been assessed on the A47NTE scheme. No assessment has been made of carbon emissions in cumulation with other existing and/or approved projects on a local, regional and national level. In REP6-020, I lay out the necessary additional traffic model configurations which are required for carbon quantification that may then be carried forward to cumulative carbon assessment at the local level (including the other A47 schemes, A47BNB and A47THI, and the Norwich Western Link (NWL)).

2 QUANTIFICATION OF ECONOMIC COSTS OF CARBON

7 This section gives a very brief overview of the relevant methodology. Table 5-1 of the Case for the Scheme document [APP-140] provides a summary of the results of the economic appraisal of the A47NTE scheme. This includes the cost of "Greenhouse Gases (Carbon)" as £21.61m, or a negative "benefit" of -£21.61m.

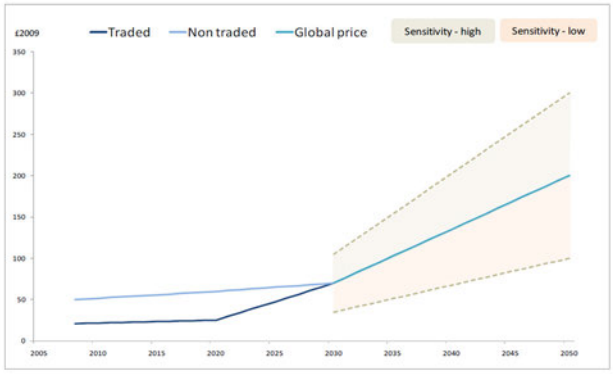
8 I have noted above that new guidance and carbon pricing values for appraisal were published by the Government in September and October 2021, followed by an update of the DfT WebTAG guidance and TAG data book.

9 In 2011, the previous approach (before the policy changes outlined above) of working towards a fully working carbon market was outlined by BEIS' predecessor department DECC[7].

> *"In the short term (up to 2030), different targets in the Traded (ETS) and Non-Traded (non–ETS) sectors imply that emissions in the two sectors are essentially different commodities and the approach to valuing carbon needs to reflect this reality. Therefore, traded and non-traded carbon values will be used over the 2008-2030 period (Chart 1). Beyond 2030, a fully working global carbon market is assumed implying a single carbon value for economic appraisal over the 2031-2050 period ...*

[7] DECC publication, 2011, "*Guidance on estimating carbon values beyond 2050: an interim approach*",

Chart 1: Traded and Non Traded carbon values (2008-2050)



"

10 The latest Green Book supplement updates the method to recent Government policy on climate change, and the UK Emissions Trading Scheme, and "to give equal weight to emissions from the traded and non-traded sectors"[8]. This means that from 2020 traded and non-traded emissions are equally valued, as shown in the graph below, in the latest carbon pricing figures are shown below graphically as clipped from the policy paper guidance (reproduced in Appendix 1).

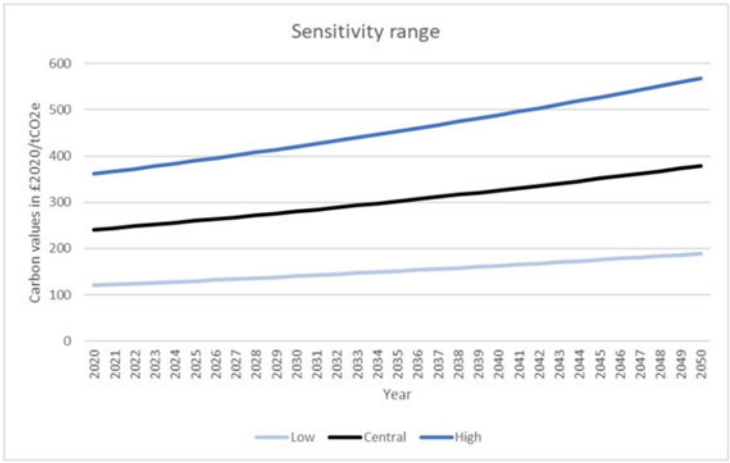


Figure 3: Sensitivity range of the updated carbon values.

11 Note that previously 60-year appraisals of road schemes have split the carbon emissions into the traded and non-traded sectors, with fossil fuel vehicles being non-traded and electric vehicles being traded. The fossil fuel vehicle / non-traded sector has been the numerically predominant sector in the appraisal data.

[8] See "*Traded and non-traded carbon*" under "*Valuation of greenhouse gas emissions: for policy appraisal and evaluation*", September 2nd 2021 at

12 It can be seen that the new carbon prices are significantly greater than the previous ones. For example, for the predominant non-traded sector, the 2020 carbon price in the new policy data is c. £240/tCO2e compared to of c. £60/tCO2e on the previous data (ie 4 times greater).

3 INDICATIVE CALCULATION OF REVISED BCR

13 I now present an indicative calculation of revised BCR(s) for the A47NTE scheme, given the new carbon pricing data for appraisal.

3.1 Lack of data transparency

14 The starting place for the calculation is the 60-year appraisal table for carbon and greenhouse gases. Previously in my written representation REP1-023, I noted:

N C-15: The applicant has not provided the traded and non-traded operational emissions, and should make the 60-year appraisal and the TAG GHG workbook available to the Examination.

15 The lack of such basic data presents a general problem to scrutiny of the carbon quantification of the scheme, already noted, and is an unacceptable lack of data transparency not just under the Aarhus Convention, but also under the recent UK Algorithmic Transparency Standard, as noted in section 7 of REP6-020. For the current issue of recalculating the BCR, it could also present a problem in making a precise recalculation.

16 However, I have been able to reverse engineer much of the necessary data via a set of assumptions which I now outline below.

3.2 Calculation method and assumptions

17 The full 60-year time series of absolute carbon quantities (ie tCO2e) between 2025 and 2084 for both the DM and DS (also referred to as DS0) cases is required so that each annual carbon value may be multiplied by the carbon price for that year. The Applicant provides just two such snapshot figures at REP1-023, Table 14-6 for the DM series: 954,647 tCO2e for Opening Year (2025), and 875,102 tCO2e for Design Year (2040).

Assumption 1: By assuming a linear interpolation of the carbon figures between 2025 and 2040, and then a constant value of 875,102 tCO2e for the years 2041 to 2084, I generate 53,142,480 tCO2e for the 60 years figure. This is 13 tCO2e greater than the Table 14-6 figure of 53,142,467 tCO2e. As this is an insignificant difference, possibly due to differences in rounding, assumption 1 is assumed to correctly reproduce the DM time series of absolute carbon emissions.

18 For the DS figures, Assumption 1 is assumed to apply the same way. In this case, the annual increment of the linear interpolated DS data series between 2025 and 2040 may be

calculated from the 5th and 6th carbon budget data in REP1-023, Table 14-10. I can reproduce the 60-year total DS figure of 53,739,257 tCO2e with a second assumption[9] (with insignificant numerical impact), and I also reproduce the 5th and 6th carbon budget total figures exactly, which validates the approach.

19 The DS-DM 60-year timeseries may then be calculated by a straightforward subtraction between each element of the DS and DM time series. **Note, that as described in REP6-020, this DS-DM time series is a solus calculation which significantly underestimates the carbon associated with the scheme.** Therefore although I proceed with this calculation to provide a like-for-like comparison with the Applicant's BCR calculation, there are further issues relating to the validity of the calculation output.

20 I then calculate the cost of carbon for the scheme using the "central" 60-year time series, 2025-2084, of carbon price data from TAG data book v1.13.1 (July 2020). Table A3.4. I also apply a discount factor based from 2010 (3.5% between 2010 and 2050, and 3.0% from 2051 onwards).

Assumption 3: I ignore the fact this previous carbon price data has different prices for traded and non-traded sector for the years between 2025 and 2030, as this is assumed to make a non-significant difference to the output[10].

This gives me a carbon cost of the A47NTE of £22,215,399 against the Applicant's figure from APP-140, Table 5-1 of £21,610,000.

21 My figure is within 3% of the Applicant's figure. I take this as an acceptable benchmark of my assumptions – I have reproduced the Applicant's GHG cost in its BCR calculation reasonably accurately. So I can apply the same methodology for the indicative recalculation of the BCR which follows.

However, as my figure is slightly higher, I multiply each of the subsequent 60-year carbon figures which I calculate by 97.27% to adjust, or normalise, my assumptions against the Applicant's data. The difference may be explained by a number of possible reasons, including using a different TAG data book version. In order to precisely reproduce the Applicant's figure, further information as previously requested is required to be made transparently available by the Applicant to the Examination.

22 I then use the new carbon price data published as supplementary guidance[11] to Treasury's Green Book. The data is given in Table 3 of the spreadsheet called "Data tables[12] 1 to 19:

[9] **Assumption 2**: To generate the 60-year total figures, the 13 tCO2e of non-vehicle operational emissions has to be added in on top of the main times-series (ie: it is not included in the DS data given).

[10] An indicative side-calculation suggests the effect is less than 0.01% on the final figure

[11] "Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal", October 7th 2021,

supporting the toolkit and the guidance", and I extended it to 2084 from 2050 using the guidance[13].

23 The resulting carbon cost data for the A47NTE scheme is then substituted into the BCR calculation at APP-140, Table 5-1.

3.3 Results

		Indicative calculations based on HMT Green Book data Oct 2021			TAG Data Book v1.17 Nov 2021
	A47NTE, APP-140, Table 5-1	**Central**	**High**	**Central + Construction**	
60 years carbon tCO2e	596,790	596,777	596,777	596,777	596,777
Construction emissions (2024-2025) tCO2e				87,727	
Total cost £CO2	-£21,610,000	-£48,476,081	-£72,714,121	-£62,348,930	-£38,974,769
ADJUSTED (* 97.27%) Total cost £CO2		-£47,155,044	-£70,732,566	-£60,649,840	-£37,912,655
Discounted Average cost carbon/tonne	-£36.21	-£79.02	-£118.52	-£88.60	-£63.53
NPV (Level 1)	£87,920,000	£62,374,956	£38,797,434	£48,880,160	£71,617,345
BCR (Level 1)	1.72	1.51	1.32	1.40	1.58
NPV (Level 1 & 2)	£143,700,000	£118,154,956	£94,577,434	£104,660,160	£127,397,345
BCR (Level 1 & 2)	**2.17**	**1.96**	**1.77**	**1.85**	**2.04**

Table 1

24 I note that the carbon price figures for each year published in the TAG Data Book v1.17 (Nov 2021) are 80.4% in value of the figures for the same years in the HMT Green Book data (Oct 2021). I have made a request to DfT Transport Appraisal and Strategic Modelling (TASM) Division to explain this. In the meantime, I have calculated using both set of figures.

25 I have also made a calculation which includes the A47NTE construction emissions in the calculation. It is not clear why construction emissions which are a significant carbon impact in the 4th Carbon budget, and therefore also not subject to significant discounting, is not included in the standard method of generating GHG costs for the BCR. My view is that construction emissions should be included in the calculation.

26 The overall result is that the Level 1 and Level 2 BCR reduces from 2.17 to 1.96 on the central HMT Green book data. That is with carbon correctly valued in line with current

[13] Under "Post-2050 values" at https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation "To obtain values post-2050, it is advisable to apply a real annual growth rate of 1.5% starting at the most recently published value for 2050."

policy on climate change, the value for money of the scheme become "medium" rather than "high". The BCR reduces to 1.85 when construction GHG emissions are included.

27 As noted above, there are major caveats around this BCR calculation which is based on the Applicant's. First, the DS-DM calculation is only one of many possible solus calculations of the effects of the scheme (see REP6-020). It is the solus calculation which most underestimates the impacts of the scheme as the baseline for it includes every other possible development and scheme in the locality, and therefore, journeys that may be attributable to the A47NTE scheme are assigned to the baseline instead. Second, as noted construction emissions are not included in the Applicant's calculation. Third, no attempt is made to quantify and assess cumulative emissions of the A47NTE with other schemes, or for that quantification to be taken forward into the BCR. Each of these three effects, when properly quantified (as I have done for the construction emissions) will act to reduce the BCR further.

4 CONCLUSIONS

28 This submission is indicative. It is not intended to be definitive. I have submitted it as background to the ISH3. However, it has the implications below.

29 The necessary consequence of this submission is that the Applicant must recalculate the BCR given the revised carbon pricing data from the government. The Applicant must also provide BCR calculations with: a (solus) carbon quantification which does not underestimate the GHGs from the scheme; including construction emissions; and a cumulative carbon quantification.

30 In REP6-020, I note that the Applicant must provide "traffic modelling, carbon quantification and assessment based on the three EIA Regs compliance-oriented traffic models which I define at [REP6-020] Table 2." An output of this will be a solus DS-DM calculation of the A47NTE against the baseline of the current transport network, and provide a (solus) carbon quantification which does not underestimate the GHGs from the scheme.

31 I request the ExA to request this additional information for the Environmental Statement and the Case for the Scheme documents from the Applicant.

Dr Andrew Boswell,
Climate Emergency Policy and Planning, January 4th, 2022

5 APPENDIX 1

Policy paper, Department of Business, Energy and Industrial Strategy (BEIS)
"Valuation of greenhouse gas emissions: for policy appraisal and evaluation"
Published 2 September 2021

Supplied as separate document

Policy paper

Valuation of greenhouse gas emissions: for policy appraisal and evaluation

Published 2 September 2021

Contents

This publication is available at https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation

Introduction

This document sets out a revised approach to valuing greenhouse gas (GHG) emissions in policy appraisal, following a cross-government review during 2020 and 2021. It replaces the previous guidance on carbon valuation [redacted].

What are carbon values?

Greenhouse gas emissions values ("carbon values") are used across government for valuing impacts on GHG emissions resulting from policy interventions. They represent a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO2e). They differ from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme).

The government uses these values to estimate a monetary value of the greenhouse gas impact of policy proposals during policy design, and also after delivery.

Why value GHG emissions in policy appraisal?

The fundamental purpose of assigning a value to the GHG emissions impacts that arise from potential government policies is to allow for an objective, consistent and evidence-based approach to determining whether such policies should be implemented. Carbon values are used in the framework of broader cost-benefit analysis to assess whether, taking into account all relevant costs and benefits (including impacts on climate change and the environment), a particular policy may be expected to improve or reduce the overall welfare of society.

To reach net zero in 2050 and meet our [redacted] robust approach to valuing emissions is vital to ensure that government takes full account of climate change impacts in appraising and evaluating public policies and projects, whether those policies are intended to reduce emissions or are likely to have the effect of increasing emissions. Such policy decisions often involve making choices between competing policy objectives.

Assigning a value to carbon helps to ensure that such choices are made in a transparent fashion and in a way that seeks to be cost-effective for UK society as a whole.

Valuing emissions impacts explicitly when making policy decisions helps to:

- ensure the climate impacts of policies are fully accounted for
- ensure consistency in decision making across policies
- improve transparency and scrutiny of decision making

Valuing emissions impacts robustly is important, however it is often the case that some of the most strategically important benefits of climate policy cannot always be quantified. For example; strengthening of decarbonisation supply chains; or increases in the UK's resilience to deal with extreme climate events. As a result, quantified benefits of carbon saving policies can underestimate the true benefits. Therefore, policy makers and decision makers should consider all qualitative and quantitative evidence in the round as set out in the Green Book, even if a project has a low estimated benefit-cost ratio.

Greenhouse gas emissions should be valued for all policies that may have an impact on emissions, whether these impacts are positive or negative. This includes policies whose primary objective is not related to progressing the net zero target, but where there are indirect impacts on emissions.

It should be stressed that the carbon values discussed in this paper apply to all types of policy, providing there is some impact on emissions. It is not the aim of this document to discuss how these policies should be designed but rather to provide carbon values to be used in the economic appraisal or evaluation of these policies. Detailed practical guidance for analysts on how to apply the carbon values in appraising policies is available in the [redacted]

Rationale for reviewing and updating carbon values

[redacted]

Since 2009, a 'target consistent' approach has been used to estimate the values, where these are calculated as the marginal abatement cost of meeting targets.

BEIS has conducted a review and update of the carbon values because several factors have changed since the last review, the most significant of which are the following.

Changes in international targets

The UK signed the Paris Agreement in 2016, which sets out a more ambitious goal - to keep global temperature rise well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.

Changes in domestic targets

In June 2019, the UK adopted in law the recommendations of the Climate Change Committee, to achieve net zero GHG emissions by 2050 (compared to the previous target of an 80% reduction by 2050 on 1990 levels).

EU Exit

The UK has left the EU Emissions Trading System (EU ETS) and from January 2021 introduced a UK Emissions Trading Scheme (UK ETS).

New understanding of technology costs and availability

Some of the key technologies for decarbonisation such as renewable power generation and batteries have seen larger-than-predicted price reductions over the last 10 years which should reduce abatement costs in relevant sectors.

Previous reviews of the value of carbon

In 2009 the government conducted a review of the approach taken to developing carbon values. The conclusion of the review was to move to a "target-consistent" or "abatement cost" approach to carbon valuation rather than a "social cost of carbon" (SCC) approach. The main rationale for moving away from the SCC is further outlined in the 2009 publication of [redacted]

Under the target consistent approach, the appraisal of individual policies is based on target-consistent values of carbon. Previously these were be based on a "traded value of carbon" for appraising policies that affected emissions in sectors covered by the EU ETS and, in the short term, a "non-traded value of carbon" for appraising policies that affected emissions in sectors not covered by the EU ETS. In the long term (post-2030), a single series of carbon values was used covering emissions across the economy based on global abatement cost estimates.

Since 2009, the government has ensured that the values remain fit-for-purpose, by taking the following actions:

- the values were updated annually to update the real terms price base year and also reflect developments within the EU ETS
- policy analysis used high and low ranges as part of sensitivity analysis to account for uncertainties
- in 2011, BEIS produced guidance on valuing emissions post-2050. This ensured that policies with a longer time horizon correctly accounted for their emissions impact during the appraisal stage

Methodology

Aproach taken to updating the values

We have given due consideration to the following criteria while updating the current values:

- consistent: the new values must be consistent with the UK's national and international climate commitments
- simple and transparent: the series should be intuitive, resistant to modelling artefacts, easily understandable and replicable
- evidence-based: the values should be supported by the latest evidence available
- pragmatic: the series should be stable, and allow effective decision-making in its application, and represent a reasonable balance of the factors above

The new carbon values are based on a Marginal Abatement Cost (MAC) or "target-consistent" valuation approach. This involves setting the value of carbon at the level that is consistent with the level of marginal abatement costs required to reach the targets that the UK has adopted at a UK and international level. This is illustrated, in simplified form, below in Figure 1 which illustrates how a "target-consistent" carbon value would be set. From our understanding of emissions projections and abatement options, we can determine the effort level, A*, that is required in order to meet the UK's targets. Reading across from the abatement curve produces the corresponding carbon value level.

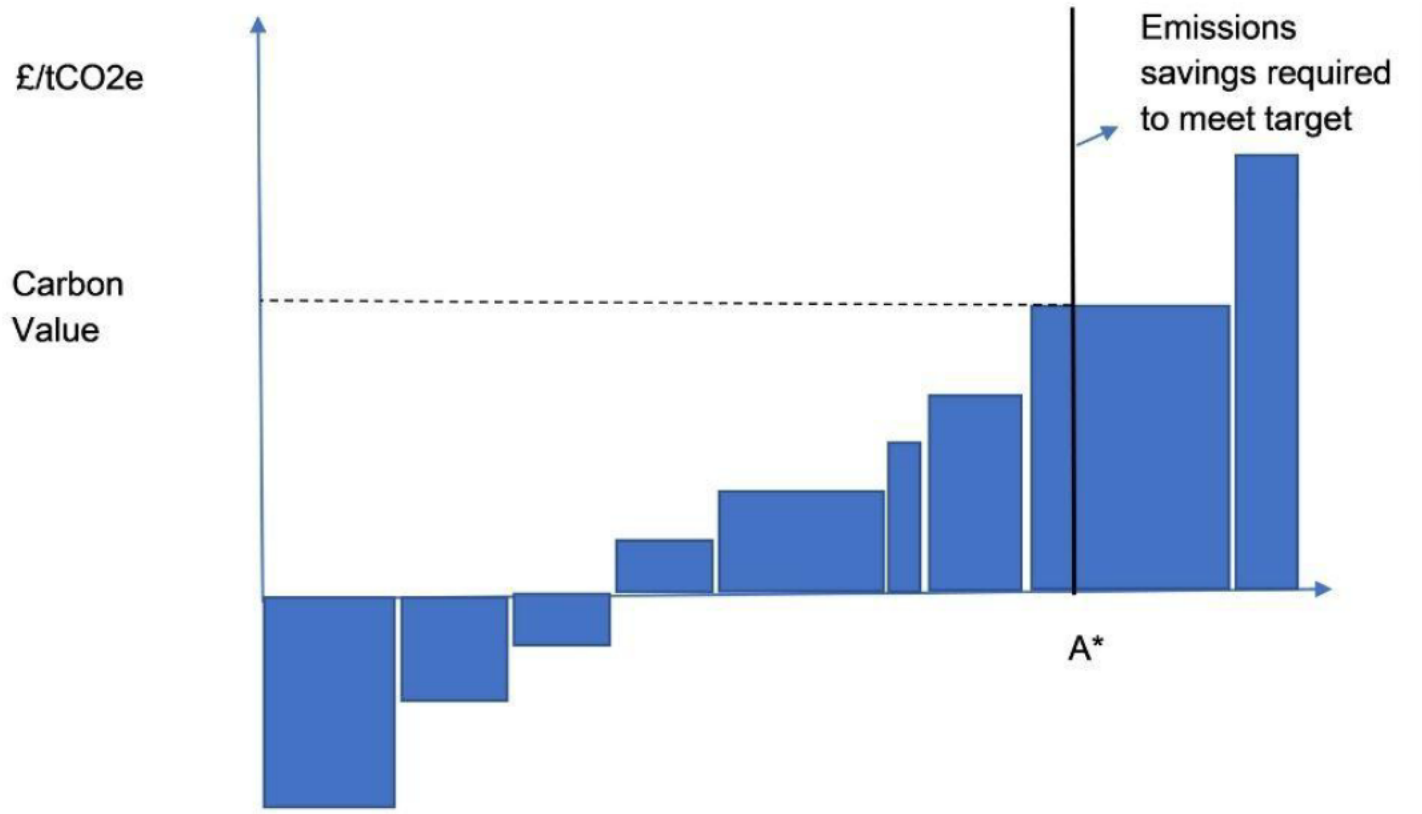


Figure 1: illustrative MAC curve

BEIS has consulted academics and commissioned a literature review, which confirmed that the SCC approach is not recommended for use and that the target-consistent approach remains the best option. The target-consistent approach is preferred in two main areas. First, it is more credible as the methodology is more transparent and relies less on unobserved factors and uncertain estimates about damages caused by GHG emissions. Second, the approach is well-aligned with the net zero target, which represents the UK's primary legal obligation.

BEIS has taken the following steps to produces the carbon value series:

- identifying appropriate targets
- selecting the modelling approach
- translating the range of modelling outputs into a single series
- defining an appropriate uncertainty range

Climate targets

The UK has both domestic and international climate targets. The updated carbon values presented in this publication are intended to be consistent with both targets.

Internationally, the UK has committed to climate targets under the Paris Agreement. The Paris Agreement provides for the international community to keep the increase in global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C. The government has a clearly stated focus on 1.5°C, with well below 2°C being inconsistent with its climate leadership intentions.

Domestically, the UK government has legal targets committing us to reaching net zero emissions by 2050, along with a series of interim carbon budgets (each covering a 5-year period) paving the trajectory towards the net zero target. Recently, the UK announced the [redacted] equivalent to reducing emissions around 78% by 2035 compared with 1990 levels. This is consistent with a pathway through our 2030 Nationally Determined Contribution (NDC) under the Paris agreement (which is more ambitious than the legislated 5th Carbon Budget).

The domestic targets are the UK's chosen implementation of our international commitments and represent a more ambitious end point and more front-loaded pathway than previous targets.

Modelling approach

The carbon values review has taken a range of evidence on abatement costs into consideration. It has been informed by internal BEIS modelling as well as international evidence from the Intergovernmental Panel on Climate Change (IPCC). The evidence base has been used by both the government and the Climate Change Committee in its advice and decisions on carbon budgets and net zero.

Evidence base

Global carbon prices from IPCC Modelling

The scientific and economic modelling literature underpinning the IPCC assessment reports provides a broad consensus on the global technological and emission trajectory changes that are needed to maintain climate change below 2°C of warming, but there is no consensus on the carbon price signals needed to trigger such transformations, with the exception of prices increasing throughout the end of the century[redacted]. Consistent with the 2009 values, the revised carbon values are anchored on long-run global abatement costs rather than UK costs, but as discussed later the trajectory over time reflects the UK's relatively front-loaded domestic targets.

There is a significant range of uncertainty in the carbon price trajectories deriving from the application of Integrated Assessment Models (IAM[redacted] The differences in carbon price trajectories are often driven by either structural differences in modelling approaches (that is, optimisation models v. dynamic recursive models) or by differences in underlying scenario assumptions on the future evolution of socioeconomic factors (that is, population or GDP forecasts). This means that there is no true or unique carbon price trajectory that is perfectly aligned with a given global temperature target. The trajectory will depend on the future uncertain evolution of socioeconomic factors and implementation of mitigation actions[redacted].

IPCC values, produced by a suite of IAMs, are[redacted]. In this case the modelled carbon prices and emissions projections were sourced from the 1.5°C low overshoot pathway class of modelling scenarios (including a constraint on Kyoto gas emissions in 2010 being sufficiently close to observed values) following the IPCC approach outlined in Chapter 2 of IPCC Special Report 1.5 and also followed by the CCC in their analyses. The median carbon price was calculated from the range of carbon prices and converted from USD2010 to GBP2020.

GloCaF – BEIS Global Carbon Finance Model

GloCaF models an idealised carbon market. A global emission trajectory is set and by means of 100% free trade with no friction, each region mitigates up to the same marginal cost to meet the global target. Trade is modelled across 25 specified regions, giving global coverage, including International Bunkers (International Aviation and Maritime sectors). Trade is allowed across all 24 sectors of the model, giving economy-wide coverage. The result is the most cost-effective carbon price, by which the abatement target equivalent to the emissions target, might be achieved.

In setting the emissions target for the modelling of necessary abatement we used the median value of the range of IPCC climate model outputs for the 1.5°C target to limit global temperature increase to 1.5°C by 2100, allowing for a temporary marginal exceedance (low overshoot) prior to 2100 ("1.5LowOS"). In modelling of 2030 and 2040 abatement necessary to achieve emissions that correspond to the median emissions projected for 1.5LowOS, GloCaF carbon prices are within the interquartile range of carbon prices included in the IPCC model set. The 2030 value is marginally lower than the IPCC median (£147 vs £163) and the 2040 value higher than the corresponding IPCC median (£576 vs £326), while still within the interquartile range of IPCC carbon values.

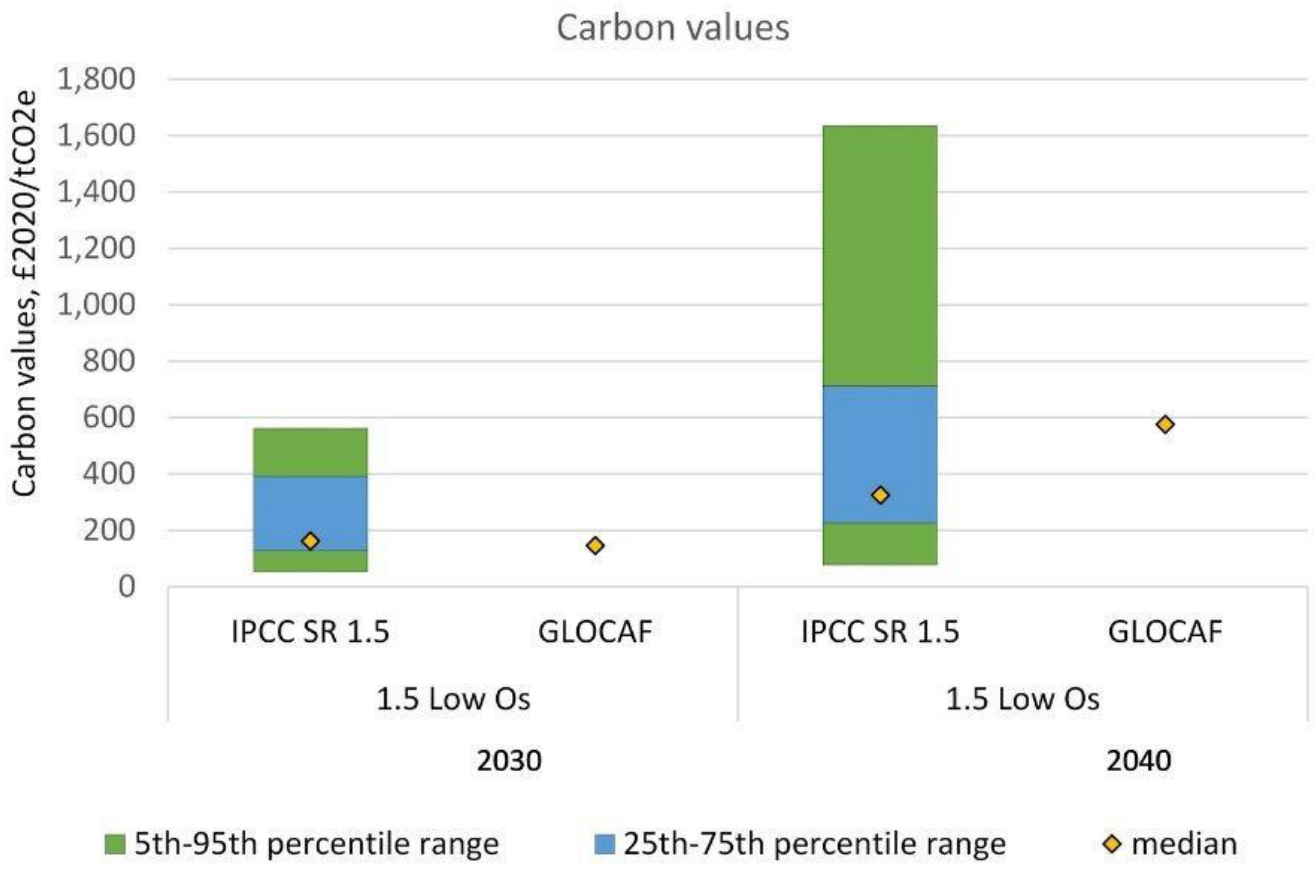


Figure 2: comparison of GloCaF modelled carbon values and IPCC median carbon value and carbon value range for 2030 and 2040, for IPCC 1.5 Low overshoot scenario

Each of the modelling approaches set out above has advantages and disadvantages. On the basis of the relative merits, BEIS has adopted the IPCC's evidence base as the starting point for constructing a series of values. The main advantages of the IPCC evidence is that it has been widely peer-reviewed and builds on a broad range of modelling and available evidence. Furthermore, it is a source independent to UK government and considered authoritative internationally.

Anchor points

Marginal abatement costs can be subject to large fluctuations between years modelled. This can be due to a number of factors, not least:

- assumptions about technology costs and availability
- emissions pathways within the modelling
- interdependency with modelling outcomes in other years

Therefore, the full series derived by models can have counterintuitive annual fluctuations, which are not practical for appraisal purposes. We therefore use a single point estimate in 2040 (anchor point) around which we apply a constant growth rate to derive annual values.

There is considerable uncertainty around technologies and corresponding abatement costs far into the future (beyond 2040) at these ambitious levels of domestic and global climate mitigation. Future technological advancements are most likely to happen at the higher cost end of current known technologies (reflecting that they are typically in earlier stages of development), on which marginal cost estimates depend. As a result, anchoring the value on 2050 is particularly uncertain as all models rely on indicative stopgap technologies, or extrapolated cost estimates that far in the future.

Choosing an anchor point in the very near future risks underestimating the cost of abatement as the level of action required in the future will place us further up the marginal abatement cost curve.

Growth rate

Marginal costs are not constant over time, and are influenced largely by 2 primary driving forces:

- increased emissions reductions ambitions, requiring more expensive technologies to be adopted
- reductions in technology costs through innovation and deployment

Currently, there is no academic consensus on how these two factors interplay, and consequently what the precise optimal trajectory for carbon values is – although there is general consensus that they should rise over time. For simplicity and pragmatic application, we have adopted a constant growth rate to construct the carbon value series around the 2040 IPCC anchor point.

Relative to global trajectories for emissions, our domestic emissions reduction targets are relatively front-loaded, which implies that a flatter trajectory for carbon values is more appropriate as additional UK efforts should be made in the near-term. In the 2020s and 2030s the evidence is clear that the UK needs to implement many policies and technologies that have relatively high upfront investment costs and long lead times. In this case, early action will contribute to innovation in the clean technology space and thus encourage future cost advantages. Based on our assessment of the evidence base, including the CCC's estimates of UK abatement costs in their advice on the 6th Carbon Budget, we have concluded that an indicative 1.5% annual real growth rate around the 2040 anchor point is appropriate.

Uncertainty range

There is a significant range of uncertainty in the carbon values derived from any modelling. The differences in carbon price trajectories are often driven by either structural differences in modelling approaches or by differences in underlying scenario assumptions on future evolution of socioeconomic factors (for example, population or GDP forecasts).

To capture the full range of uncertainty, a plus or minus 50% sensitivity range has been deemed appropriate around the central series. This is consistent with the previous range used.

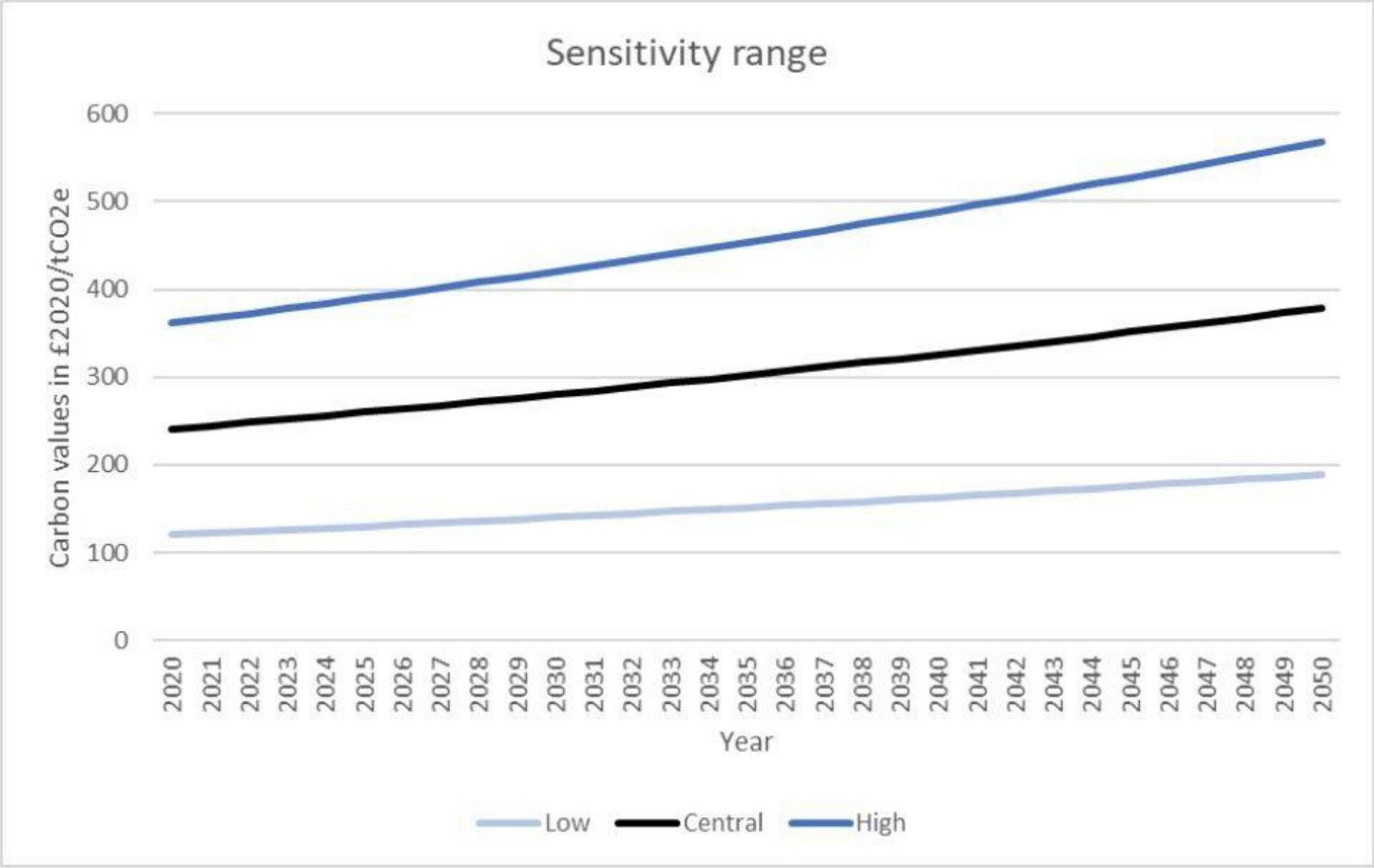


Figure 3: Sensitivity range of the updated carbon values.

Traded and non-traded carbon

[redacted] (ETS), whereas non-traded emissions are those which do not fall within scope of the UK ETS.

Currently, the UK ETS covers power generation, energy-intensive industries, and domestic aviation. To achieve the economy-wide decarbonisation required to meet our net zero goals in a cost-effective way, it is important that our decarbonisation strategy gives equal weight to emissions from the traded and non-traded sectors.

The UK ETS caps the total level of greenhouse gas emissions within the sectors in scope and allows firms with low emissions to sell their emissions allowances to higher emitters.

Previously this trade could occur between the UK and other countries in the EU ETS and this was reflected in accounting towards the UK's emissions targets.

The UK ETS is an important mechanism to achieve the UK's climate goals. However, it is likely that additional measures in the sectors covered by the UK ETS will need to be taken to reach net zero. Therefore, any emissions increases or savings resulting from policies (either traded or non-traded) should be considered and valued during appraisal. For emissions in the traded sector, appropriate adjustments should be made to account for any existing carbon pricing in the market prices of goods or services. For example, if a policy increases the production of a good where the price of that good already reflects a carbon price then this needs to be taken into account in order to avoid double counting some of the carbon costs.

Post-2050 values

The carbon series published in this report only extends to 2050. The main challenge in modelling carbon values beyond 2050 is that any analysis looking over such a long timescale is subject to significant uncertainty from a range of sources. Many of the input assumptions that are required to estimate future carbon prices – such as GDP growth and its sectoral composition, fossil and non-fossil fuel prices, and the costs and availability of different technologies – are extremely uncertain. Moreover, the way in which these variables interact over time in the complex, dynamic global climate, economic and social system is both uncertain and, in some areas, unknown. For these reasons, projections of future carbon prices based on modelling outputs can be highly sensitive to modelling methodology and assumptions and must therefore be seen and used in this context of uncertainty.

Nevertheless, some policy proposals will have long term impacts reaching beyond 2050. It is therefore necessary that any carbon impacts from such proposals are captured during policy appraisal. To obtain values post-2050, it is advisable to apply a real annual growth rate of 1.5% starting at the most recently published value for 2050.

Approach to future updates

The government is committed to using the best available evidence to inform the value placed on greenhouse gas emissions during appraisal. However, there is a trade-off to be struck between three factors:

- having the most up-to-date carbon valuation estimates
- avoiding spurious updates that do not reflect the high level of uncertainty
- ensuring stability in application to allow long-term policy decision-making to occur

A situation where the carbon values used in appraisal changed too often would be undesirable, as this would mean that policy options were being assessed against different criteria. Therefore, the carbon values will be reviewed every 5 years in line with setting the UK's carbon budgets. The review will take into account a broad evidence base. Under exceptional circumstances, reviews outside the 5-yearly cycle may be necessary if changes affecting the evidence or policy regime are significant enough in order to warrant a review.

Application

How to apply carbon values during policy appraisal

Incorporating a value of carbon into the appraisal of projects and policies ensures proper account of greenhouse gas emissions across government. By comprehensively and systematically using carbon valuation across appraisal in a consistent manner, it is intended that government should seek out cost-effective opportunities for reducing emissions across policies and projects – not only in areas such as energy and transport policies where emissions reductions are of primary or secondary importance, but also where this is not the case. Having consistent values across government also provides transparency and consistency for business.

A policy or project that increases or decreases GHG emissions domestically or internationally relative to a "business as usual" scenario is required to quantify the change in emissions, and then apply the carbon values. This calculation feeds into the overall cost benefit analysis to be considered alongside other quantitative and qualitative evidence in the overall policy appraisal. The values should be considered as a guide to the carbon cost-effectiveness of policies but account should be taken of the inherent uncertainty involved in estimating future abatement costs and unquantified costs and benefits.

Carbon valuation is not a policy instrument in itself. It is a £-value applied in appraisal in order to guide government decision-making, and further signal the level of ambition that should be factored into those policies. Unless it is translated into a tangible incentive (and the incentive may exceed the carbon value in order to overcome barriers), it will not act upon private economic agents, whether individuals or business.

Alongside setting the right carbon appraisal value, the selection of instruments to tap potential emissions reduction is key. A mix of carbon pricing (through taxes/trading), regulatory instruments, innovation support and information policies are likely to be required to address the multiple market failures and barriers which exist.

When carrying out a policy appraisal it is also necessary to take into account the impacts on the wider environment also known as natural capital. To help with this Defra has developed an online resource called [redacted] CA) . This provides guidance on natural capital, economic values, references on reports and data sources along with over 70 case studies.

Presenting the monetised change in greenhouse gas emissions

To appropriately quantify greenhouse gas emissions, analysts should consider the key drivers of emissions affected by a policy proposal or intervention. All assessments should include a baseline or Business as Usual (BaU) emissions against which the policy is assessed. There is no standardised or straightforward methodology for measuring the baseline, so this must be done on a case-by-case basis. Historical trends and statistically supported projections are the most commonly used, but historical trends are not effective

at taking changing circumstances into consideration (i.e. non-linearity). The annually updated [redacted] published by BEIS provide projections of greenhouse gas and energy demand to 2040 by sector and are a useful starting point.

Policies or projects can impact emissions in a number of different ways, either directly or indirectly. Analysts should refer [redacted] for how to calculate cost effectiveness indicators, including NPVs and £/tCO2.

Annex 1: Carbon values in £2020 prices per tonne of CO2

Year	Low series	Central Series	High Series
2020	120	241	361
2021	122	245	367
2022	124	248	373
2023	126	252	378
2024	128	256	384
2025	130	260	390
2026	132	264	396
2027	134	268	402
2028	136	272	408
2029	138	276	414
2030	140	280	420
2031	142	285	427
2032	144	289	433
2033	147	293	440
2034	149	298	447
2035	151	302	453
2036	153	307	460
2037	156	312	467
2038	158	316	474
2039	161	321	482
2040	163	326	489
2041	165	331	496
2042	168	336	504
2043	170	341	511
2044	173	346	519
2045	176	351	527
2046	178	356	535
2047	181	362	543
2048	184	367	551

Year	Low series	Central Series	High Series
2049	186	373	559
2050	189	378	568

1. World Bank, Report of the High-Level Commission on Carbon Prices, May 2017.
2. IAMs are the most widespread tool for assessing long-term emission trajectories in the context of global warming scenarios and they are the underlying modelling tool used to derive the pathways presented by the IPCC.
3. To narrow the scope of our analysis we focused on the median IPCC scenario to inform our global emissions abatement targets. As part of the validation of our Business-as-Usual trajectory we concluded that it was more aligned with the SSP1 and SSP2 scenarios, representing respectively the Sustainable Development and Middle of the Road scenarios in the IPCC classification.