GUIDANCE ON ESTIMATING CARBON VALUES BEYOND 2050:

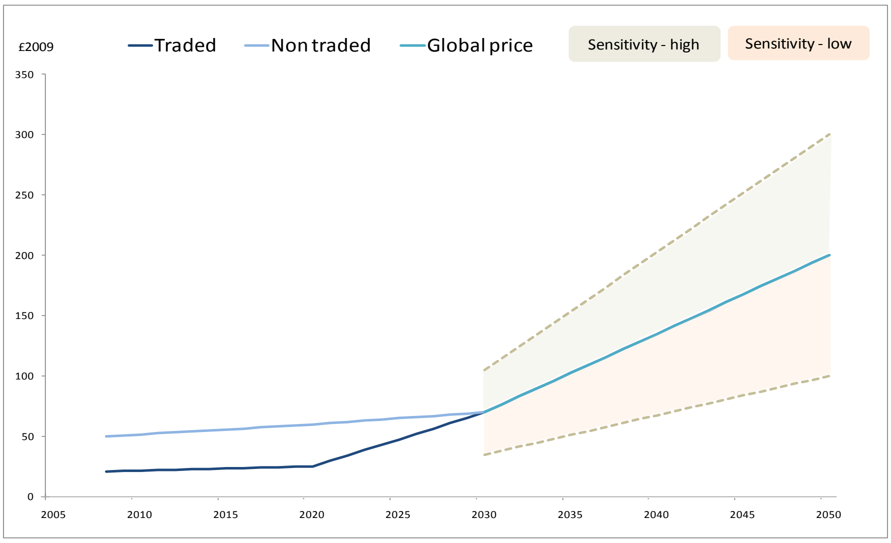
AN INTERIM APPROACH

Introduction

1. DECC has recently adopted a new target-consistent approach to value carbon savings to 2050. The new methodology sets the valuation of carbon at a level that is consistent with the UK Government's domestic and international targets in the short and long term.[1] This new methodology has replaced the previous approach based on damage cost estimates.[2]

2. 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 that reflects the costs required to achieve the EU long term target of limiting dangerous climate change to 2 degree centigrade.[3]

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



[1] http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx
[2] http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/shadow_price/shadow_price.aspx
[3] In 1996, the EU Governments have established a climate protection target of 2 degree centigrade limit. This limit was reaffirmed by the Environmental Council 2003 and European Council, 2005, 2007. See http://ec.europa.eu/environment/climat/pdf/brochure_2c.pdf.

3. This externally peer reviewed approach provides a sound methodology to value carbon savings to be included in standard cost/benefit analysis until 2050. However, some government projects have a significant impact well beyond 2050. There is thus a need to extend the new carbon valuation approach until 2100 to ensure that such analysis is taken forward in a transparent and consistent way.

4. This note sets out an interim and pragmatic approach to derive a carbon value profile beyond 2050 to be used for economic appraisal consistent with the recently agreed carbon values up to 2050. This approach aims to provide interim guidance, recognising the need for longer-term carbon values to be used in economic appraisal until more accurate and robust evidence is available. In the longer term, in recognition of the need for more detailed analyses, DECC will set up an interdepartmental working group aimed to improve our understanding of the key drivers of the carbon price beyond 2050 and to agree a longer term price. This will be supported by an independent peer review of the analysis underpinning the longer-term values.

Main challenges in estimating carbon values beyond 2050

5. There are three notable challenges in modelling carbon values beyond 2050. First, 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.

6. Second, the economic models used for the new approach to carbon valuation published in July 2009, including the DECC Global Carbon Finance (GLOCAF) model, do not extend beyond 2050. Therefore, it is not possible to produce a model-based estimate of the carbon price in 2100 on the same basis as the 2030 and 2050 values.

7. In the July paper, we used the GLOCAF and other models to set the 2030 and 2050 carbon values. The emission trajectories used reflect the long term climate change objective of the EU and UK Government of limiting the expected rise in temperature to no more than 2 degrees C. Two emission trajectories were used (475ppm and 500ppm) consistent with this stabilisation goal and translated, in the GLOCAF model, to an average global carbon price of £65/tCO2e in 2030 and £255/tCO2e in 2050.

These model-based estimates were then refined through a model comparison exercise (using models that were also consistent with the 2 C target) that led to the finally-adopted central values of **£70 in 2030** and **£200 in 2050**.

8. As briefly mentioned above, the models reviewed for the July 2009 paper, including the Global Carbon Finance Model (GLOCAF), the OECD Env-Linkages, McKinsey and IEA ACTC do not have an estimate for the carbon price in 2100. Moreover, the few estimates that are available for 2100 are highly divergent and not consistent with the trajectories or modelling used in the carbon valuation paper.[4]

9. Third, although the EU has committed to limit dangerous climate change to 2 degrees, and there is agreement between scientists that global emission trajectories will have to continue to decline beyond 2050 to achieve this target, there are no specific annual emission targets beyond 2050. This introduces significant uncertainty as the cost of abatement beyond 2050 will depend on the trajectories and the associated effort levels required to achieve future targets, thereafter. In addition, the costs of abatement will be influenced by other factors including the abatement technologies and options adopted to meet the targets.

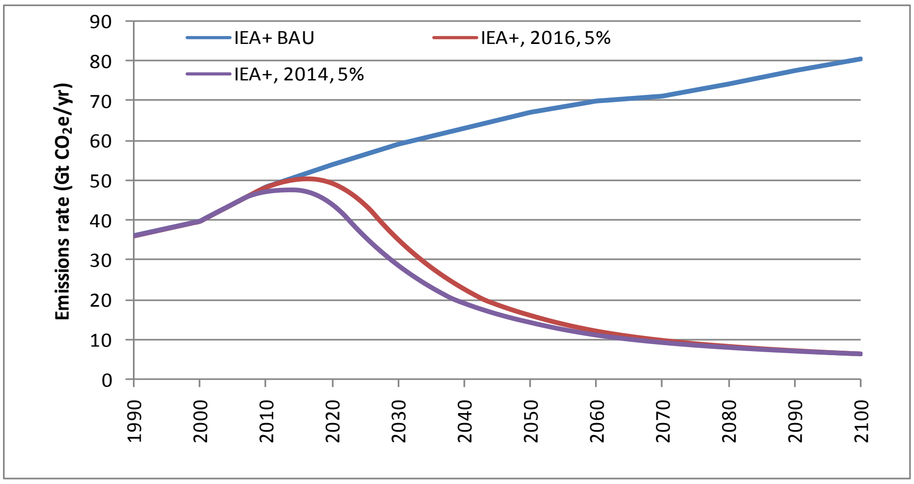
10. The Met Office through the AVOID project has analysed over 100 global emissions trajectories by adjusting certain key parameters:

    - the emissions rate in the very near future prior to a peak in emission rate;
    - the year in which emission rates peak;
    - the rate at which emissions decrease after the peak; and
    - the long-term level of emissions that is reached in the future.

11. A small subset of these trajectories provide a more than 50% chance of limiting temperature increases to 2 degrees by 2100, and of these two have been chosen for the purposes of this analysis as they most closely approximate the emissions trajectory up to 2050 used in GLOCAF for the original carbon valuation work: IEA+ 2016 (5%, low) and IEA+ 2014 (A1B aer, 5% low). These are shown in Chart 2.

[4] In addition, the model based estimates available vary significantly because of very different modelling assumptions reducing their ability to inform our analyses. For instance, the IPCCP (2007) reported a carbon price in 2100 below £166 (for a stabilisation level of 450ppme) and between £30 and £290 (for a stabilisation level of 550 ppme) whereas the USCCP (2007) found a carbon price between £505 and £5025. More recent work undertaken by the Stanford Energy Modelling Forum 22 (http://emf.stanford.edu/) in November 2009 reported an even wider range of estimates for the carbon price in 2100 for stabilisation targets consistent with the 2 degree target, although generally higher than the IPCCP (2007) and USCCP (2007) exercises.

Chart 2: AVOID global emissions trajectories consistent with 2° increase



12. The two global emissions trajectories follow historical emissions up to 2000 and then the IEA+ business-as-usual scenario (used in the GLOCAF model) prior to the peak in emission rates and assume strong action following the peak via a high reduction rate (5%) and low levels of emissions in the long term (6 Gt CO_2e per year). However, the year of peak emissions and the reduction rate that is applied to aerosol emissions differ. IEA+ 2014 (A1B aer, 5% low) features a very early peak year of 2014 and this is achieved by assuming that action to move away from the BAU trajectory is first taken in 2007. IEA+ 2016 (5%, low) has a slightly later peak year of 2016 and action is assumed to start in 2010 following COP15. IEA+ 2014 (A1B aer, 5% low) also incorporates a higher reduction rate of aerosol emissions (based on the SRES A1B scenario) than in IEA+ 2016 (5%, low). It is worth highlighting that these scenarios illustrate potential carbon emissions trajectories consistent with meeting the objective of limiting dangerous climate change to 2 degrees by 2100. However, these two illustrative scenarios do not represent a Government view on near term global trajectories.

13. The fact that global emissions will need to continue to decline beyond 2050 (albeit at a slower rate) has important implications for the carbon price over this period. Most notably, as shown in Chart 3, declining global emissions imply that more effort – relative to a notional Business As Usual (BAU) trajectory which is in itself subject to significant uncertainty – is required to achieve a given target. Assuming the Marginal Abatement Cost Curve (MACC) is upward sloping, rather than (say) flat, this shift in effort would therefore require a higher carbon price because, for a given set of technologies and limits on their deployment in that particular year, the additional

abatement could be achieved only with more expensive abatement technologies in that particular year. [5]

14. However, technological change is another important factor that would be likely to influence the carbon price beyond 2050. Abatement costs, and how they may change over time, are very sensitive to technological progress and positive technological shocks could significantly reduce the costs of achieving a given target (Chart 4).[6] The carbon values adopted for the 2030 - 2050 period take into account the role of technological progress because the GLOCAF model (used to inform the 2030 and 2050 estimate) allows for induced technological change.

Chart 3: Declining global emissions and carbon values (assuming anything else constant)

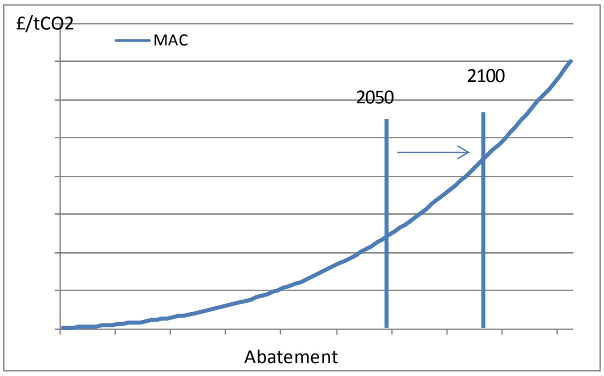
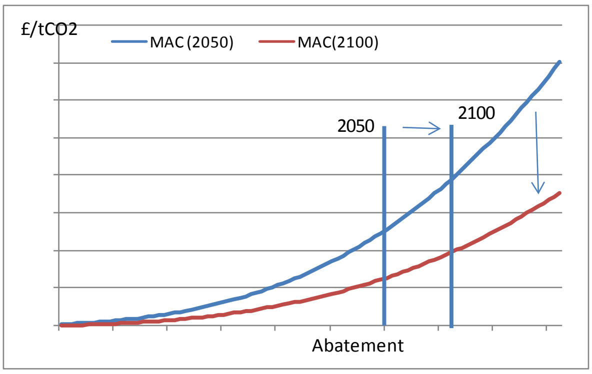


Chart 4: Technological progress and carbon values



15. Declining global emissions trajectories will translate into higher carbon prices if the increase in marginal abatement costs (from moving up the MAC curve – assuming it is upward sloping - is higher than the reduction in abatement costs due to technological progress (that leads to a downward shift in the MAC curve).

Carbon values post 2050

16. Following from the above discussion, modelling carbon values beyond 2050 requires account to be taken of the impact both of declining global emissions against a notional BAU and technological progress. As an interim approach, until more formal modelling evidence is available, we derive the carbon values beyond 2050 using:

- future global emission projections;

[5] It is probably worth noting that this approach assumes that the world follows an optimal, least cost abatement path to 2050 and beyond. This will not necessarily be the case as in reality more expensive abatement technologies might be push forward for political reasons.
[6] Chart 4 only shows the impact of technological change on costs. Another possible impact of technological progress will be more abatement available from any particular technology by 2100 than there is by 2050.

- the negative relationship between annual changes in the carbon values and annual changes in global emissions over the 2030-2050 period.

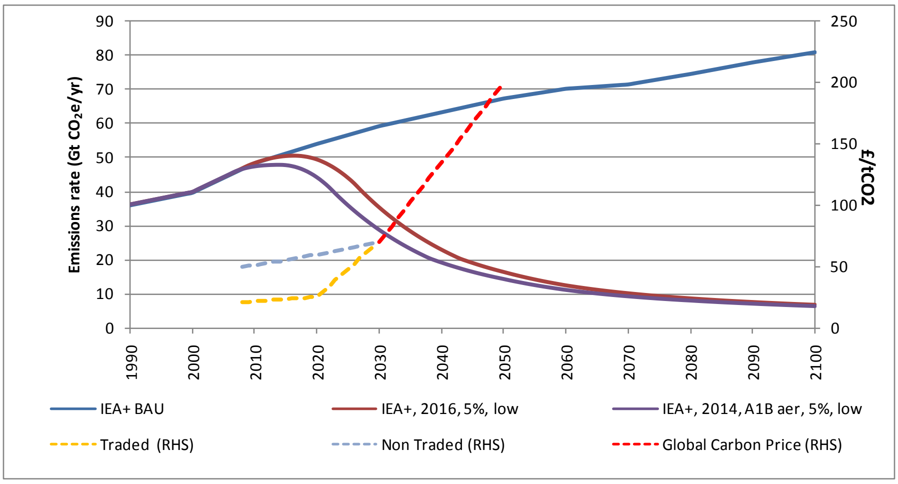
18 In developing the methodology and values for post-2050 carbon prices, even simpler methodologies were considered, e.g. extrapolating prices forward from the 2030-2050 values or keeping prices constant in real terms at the level of the 2050 price. However, given our understanding of the key dynamics that will likely impact carbon prices post-2050, these were considered too simplistic and in fact potentially misleading. Instead, we have opted for a methodology that tries to strike the right balance between pragmatism, on one hand, and appropriate reflection of the key drivers of carbon prices post-2050, on the other hand. Global emissions trajectories are taken from recent analyses conducted by the Met Office for the AVOID project. These emissions trajectories are widely considered the best reflection of the most recent scientific evidence consistent with the 2 degree target. More precisely, for the purposes of this analysis, we focus on the two AVOID trajectories discussed above (i.e. IEA + (2014) and IEA + (2016)) that best fit the GLOCAF emissions trajectories.

19 As for the carbon values, we focused on the recommended carbon price profile because GLOCAF results are available only for 2030 and 2050. The modelling over the period to 2050 relied on an assumed notional BAU which in turn allowed the level of abatement to place us on a target consistent trajectory to be estimated. For the purposes of this analysis, the level of abatement required beyond 2050 is also driven by these pathways. It is of course important to recognise that BAU emissions, and the level of abatement required in the long term are subject to significant uncertainty which will be explored further as part of the longer term work.

20 As shown in Chart 5, over the 2030-2050 period, carbon values increase approximately 5.5% (on average per year) whereas global emissions of IEA + 2014 (IEA + 2016) declines on average of approximately 3.5% (3.8%) per year.

Chart 5: Global emissions (1990-2100) and carbon values (2008-2050)[7]

[7] The carbon values shown are as published in the DECC guidance in July and only central values are shown here, for illustration.



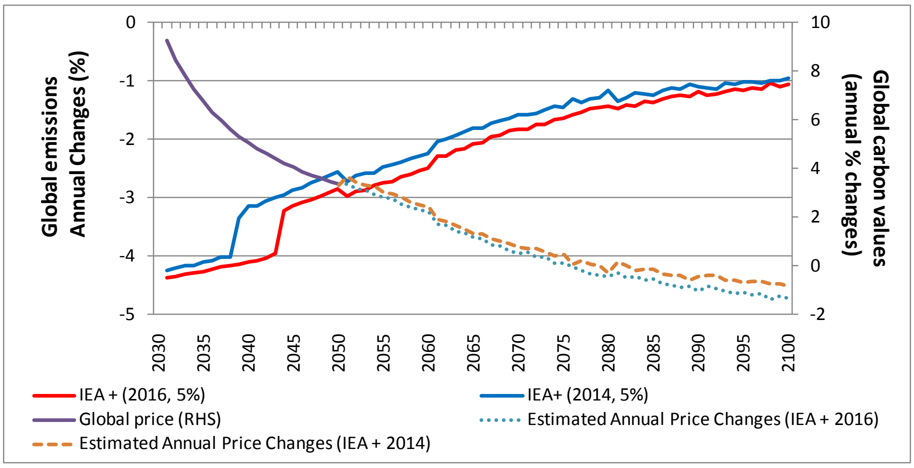
21 The annual change in price over the 2030 - 2050 period is positive but declining (Chart 6). As for annual emissions, the annual rate of change is negative but slowing through time, suggesting that the level of emissions are expected to level off at some point in the future. Using standard OLS we estimated a linear relationship (inclusive of a constant) between the annual changes in the recommended carbon values and annual changes in global emissions over the 2030 - 2050 period for the two emissions trajectories discussed above. More precisely, the two estimated linear equations are reported below (Annex 1 provides more details):

i) annual changes in carbon values = -3.3 – 2.5 * (annual changes in global emissions) (IEA + 2014, 5%);

ii) annual changes in carbon values = -4.0 - 2.5 * (annual changes in global emissions) (IEA + 2016, 5%).

22 These two estimated relationship are then used to estimate annual changes in the carbon price over the 2051-2100 period (Chart 6, dotted lines).

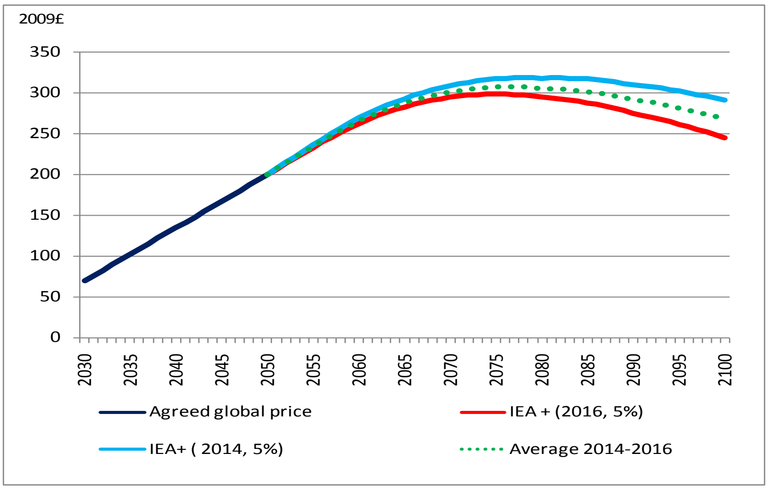
Chart 6: Global emissions and carbon values (annual changes %)



23 The negative estimated linear relationship captures the link between annual changes in emissions and carbon values. More precisely, an increase in the global emissions reduction rate would, on the basis of assumptions used here, lead to an increase in annual changes in the carbon price. The presence of a constant in the linear specification provides a transparent way to account for the expected impact of technological progress on the carbon price. More precisely, if global emissions remain unchanged, the carbon value would decline by the level of the constant reflecting the role of technological progress.

24 The approach discussed above leads to the price schedule shown in Chart 7. The carbon price for the less stringent IEA+ (2016) emissions trajectory is lower than the carbon price profile based on the IEA+ (2014) because of the lower effort implied by the former. More precisely, if the emissions trajectory IEA + (2016) is used, the estimated carbon price peaks at £298 in 2075 and then declines to £245 in 2100 whereas with IEA + (2014) the carbon price peaks at £318 in 2078 for then declining toward £290, a value reached in 2100. Given the uncertainty around the carbon price profile that is the most consistent with the recommended GLOCAF estimate over the 2030-2050 period, we averaged the price profile associated with the two emission trajectories obtaining a carbon price of **£268 in 2100** (Chart 7, dotted line).

Chart 7: Estimated carbon values (2030-2100)



25 This approach attempts to take account of the role of technological progress through the constant in the linear specification. That is, forecast annual price changes are lower than without the constant, reflecting the possible impact that technological progress could have in reducing the costs of achieving a given target. Effectively, this methodology assumes (in the absence of better information) that the role that technology will play post-2050 will have the same effect as it has in the period 2030-2050, which has been used to estimate the regression equation. However, in practice, the impact of technological progress is likely to change over time, according to a range

of complex factors. This is one of the key relationships that will need to be explored in more detail in further work.

Conclusion

26 This note proposes an interim and pragmatic approach to derive carbon values post 2050 to be used for economic appraisal that is consistent with the agreed carbon values over the 2008- 2050 period.

27 Carbon values beyond 2050 were estimated using a linear (inclusive of a constant) relationship between annual changes in global emissions and the recommended carbon values over the 2030 - 2050 period. This approach allows the negative relationship between the carbon values and the annual changes in global emissions to be reflected while also accounting for the offsetting impact on the carbon price of technological progress. However, the pragmatic approach taken here means this linear relationship translates into a constant role for technology across the period from 2030 to 2100 (as the 2051-2100 values are estimated on the basis of 2030-2050 values) whereas it is more likely that the impact of technological progress will change over time.

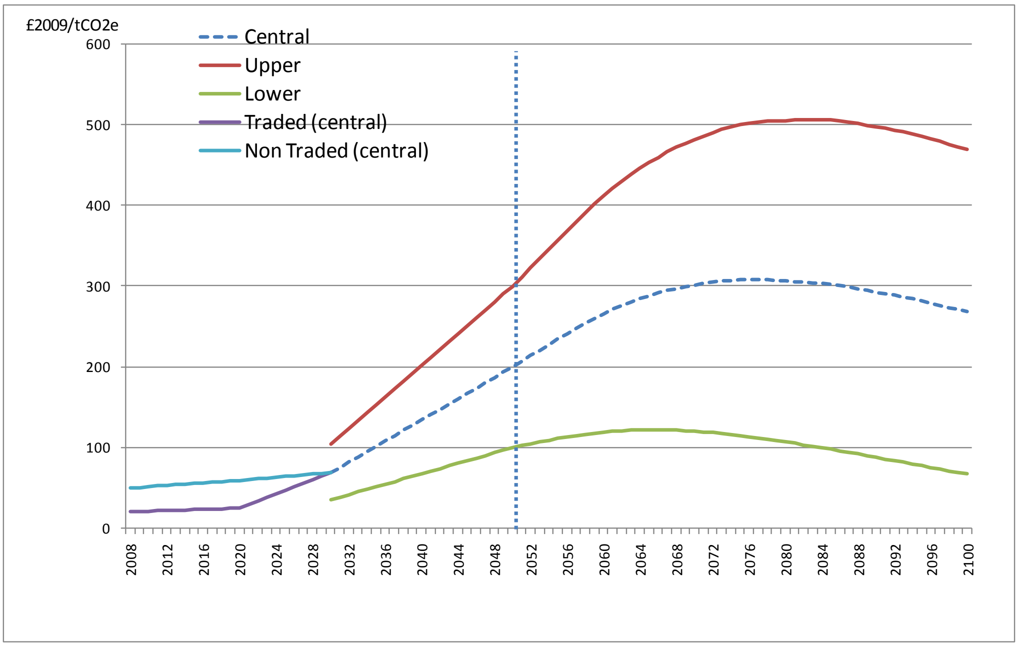
28 Recognising the significant uncertainties when looking over such a long timeframe, it is important to recognise that any central values must also be accompanied by a sensitivity range for use in appraisal. The July 2009 guidance on carbon values for use in appraisal to 2050 suggested a range of +/- 50% around the central value. Recognising the higher level of uncertainty when looking further out to 2100, it has been used a 75% per cent symmetrical band in 2100 rising linearly from 50 per cent in 2050.

29 Following this approach, the carbon value in 2100 is £268 with a sensitivity range of +/- 75% in 2100, rising linearly from +/- 50% in 2050 (Chart 8).

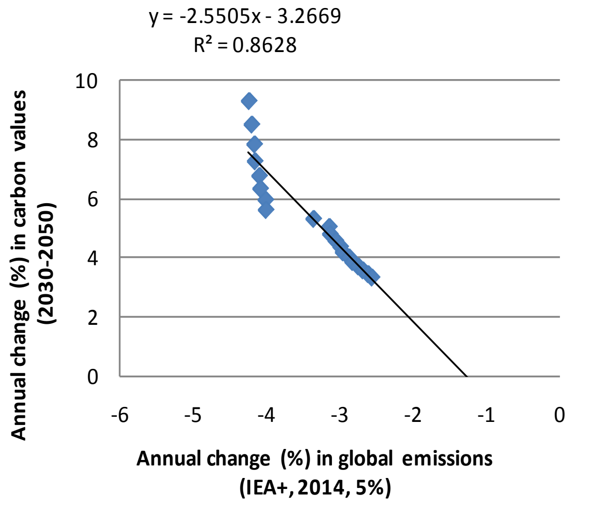
30 It is important to recognise that the approach and carbon values set out above are to be interpreted as interim guidance on carbon values for use in appraisal. In the longer term, further work will be taken forward to provide a greater understanding over the key drivers of the carbon price post 2050 along with the ways in which they and the significant uncertainties can be accounted for when developing guidance on long term carbon valuation.

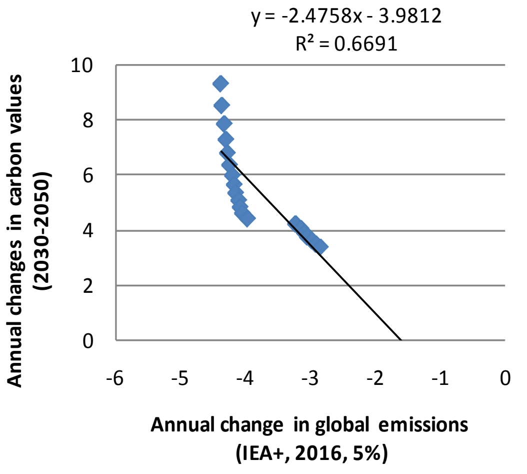
31 In order to achieve these objectives, DECC will set up an interdepartmental working group to review some of the key models and other evidence in order to inform a revised set of post 2050 numbers to be produced in 2011, to coincide with the timing for setting the 4th carbon budget (and hence revision of the non traded values). This will be supported by an independent peer review of the analysis underpinning the longer-term values.

Chart 8: Carbon values over the 2008-2100 period



Annex 1: Annual changes in carbon values and global emissions (2030-2050)





Annex 2

Table 1: Carbon values (£/tCO2e) over the 2008-2100 period

2009 GBP/t CO2e	Traded			Non traded		
	Low	Central	High	Low	Central	High
2008	12	21	26	25	50	75
2009	12	21	27	25	51	76
2010	12	22	27	26	52	78
2011	12	22	27	26	52	79
2012	13	22	28	27	53	80
2013	13	23	28	27	54	81
2014	13	23	29	27	55	82
2015	13	23	29	28	56	84
2016	13	24	29	28	57	85
2017	14	24	30	29	57	86
2018	14	24	30	29	58	87
2019	14	25	31	30	59	89
2020	14	25	31	30	60	90
2021	16	30	39	31	61	92
2022	18	34	46	31	62	93
2023	20	39	53	32	63	95
2024	23	43	61	32	64	96
2025	25	48	68	33	65	98
2026	27	52	76	33	66	99
2027	29	57	83	34	67	101
2028	31	61	90	34	68	102
2029	33	66	98	35	69	104
2030	35	70	105	35	70	105
2031	38	77	115	38	77	115
2032	42	83	125	42	83	125
2033	45	90	134	45	90	134
2034	48	96	144	48	96	144
2035	51	103	154	51	103	154
2036	55	109	164	55	109	164
2037	58	116	173	58	116	173
2038	61	122	183	61	122	183
2039	64	129	193	64	129	193
2040	68	135	203	68	135	203
2041	71	142	212	71	142	212
2042	74	148	222	74	148	222
2043	77	155	232	77	155	232
2044	81	161	242	81	161	242
2045	84	168	251	84	168	251
2046	87	174	261	87	174	261
2047	90	181	271	90	181	271
2048	94	187	281	94	187	281
2049	97	194	290	97	194	290
2050	100	200	300	100	200	300

Table 1: Carbon values (£/tCO2e) over the 2008-2100 period (continued)

2009 GBP/t CO2e	Traded			Non traded		
	Low	Central	High	Low	Central	High
2051	103	207	312	103	207	312
2052	105	214	323	105	214	323
2053	107	221	335	107	221	335
2054	109	228	346	109	228	346
2055	111	234	357	111	234	357
2056	113	241	369	113	241	369
2057	115	248	380	115	248	380
2058	117	254	391	117	254	391
2059	118	260	402	118	260	402
2060	120	266	412	120	266	412
2061	121	271	421	121	271	421
2062	121	276	430	121	276	430
2063	122	280	438	122	280	438
2064	122	284	446	122	284	446
2065	122	288	453	122	288	453
2066	122	291	460	122	291	460
2067	122	294	466	122	294	466
2068	122	297	472	122	297	472
2069	121	299	477	121	299	477
2070	120	301	482	120	301	482
2071	120	303	486	120	303	486
2072	119	305	490	119	305	490
2073	118	306	494	118	306	494
2074	117	307	497	117	307	497
2075	115	308	500	115	308	500
2076	114	308	502	114	308	502
2077	112	308	503	112	308	503
2078	111	307	504	111	307	504
2079	109	307	505	109	307	505
2080	107	306	504	107	306	504
2081	105	306	506	105	306	506
2082	104	305	506	104	305	506
2083	102	304	506	102	304	506
2084	100	303	506	100	303	506
2085	98	302	506	98	302	506
2086	96	300	504	96	300	504
2087	94	298	503	94	298	503
2088	92	297	501	92	297	501
2089	90	294	499	90	294	499
2090	88	292	497	88	292	497
2091	86	291	495	86	291	495
2092	84	289	494	84	289	494
2093	82	286	491	82	286	491
2094	79	284	488	79	284	488
2095	77	281	485	77	281	485
2096	75	279	482	75	279	482
2097	73	276	480	73	276	480
2098	71	274	476	71	274	476
2099	69	271	473	69	271	473
2100	67	268	469	67	268	469