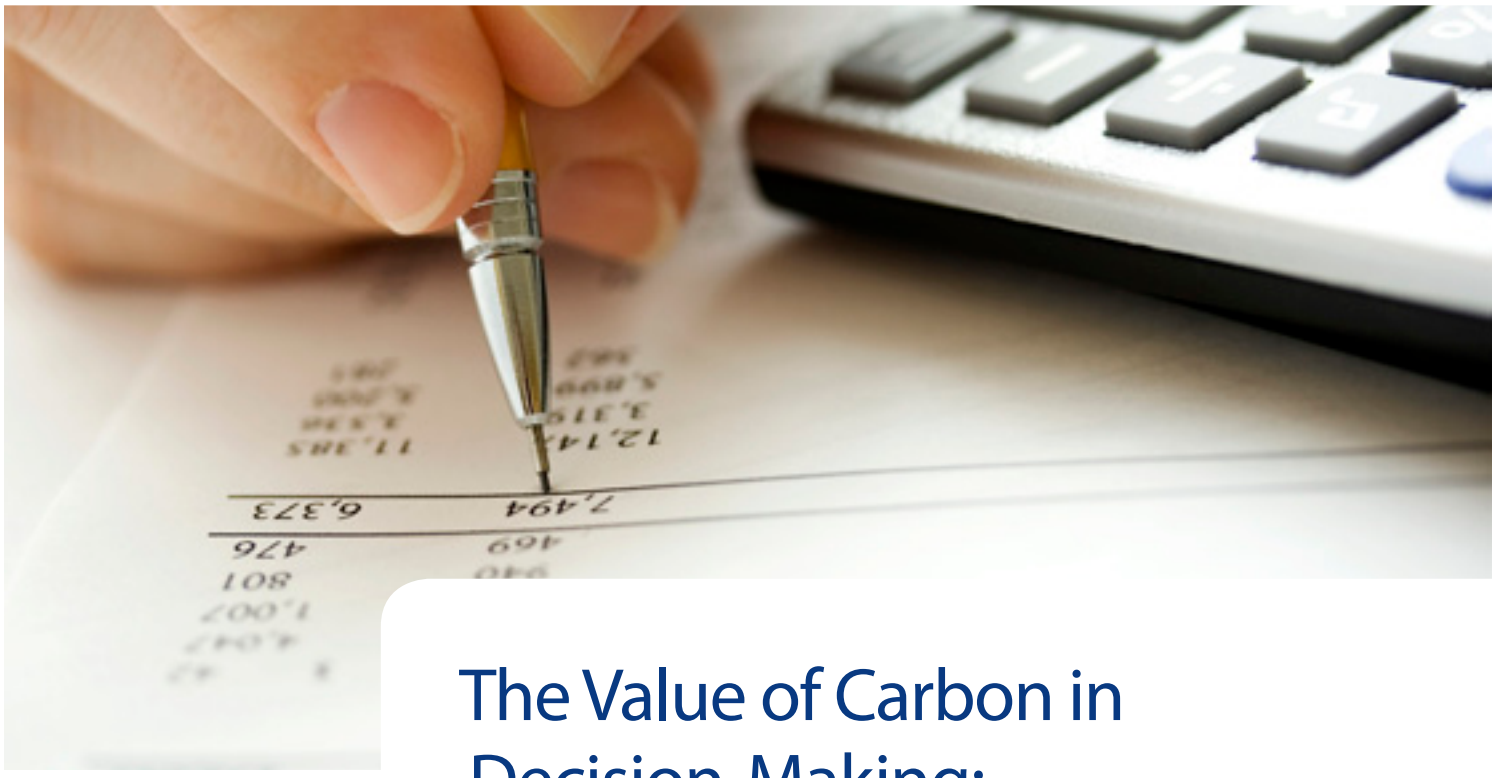
Sustainable Prosperity

Policy Brief November 2011

FOR A LOW CARBON ECONOMY



The Value of Carbon in Decision-Making:

The Social Cost of Carbon and the Marginal Abatement Cost[1]

Sustainable Prosperity is a national research and policy network, based at the University of Ottawa. SP focuses on market-based approaches to build a stronger, greener, more competitive economy. It brings together business, policy and academic leaders to help innovative ideas inform policy development.

Key messages

- Economists use two main tools to inform policy and business decision-making in relation to valuing carbon: the Social Cost of Carbon (SCC) or the Marginal Abatement Cost (MAC). The SCC and the MAC are often applied alongside each other, because they measure different things.
- The SCC represents the marginal cost of global damage from climate change, and is used by policy-makers to examine the benefits of climate policy in a cost-benefit analysis.
- The MAC reflects the cost of one unit of emission reduction to meet a specific emissions target. It allows policy-makers to make three critical policy decisions: what the emission reduction target should be, the best way to achieve it, and how much each approach will cost. Further, it facilitates the comparison of the cost of emission reductions across sectors, and to assess the overall economic cost of a particular policy.
- The SCC and MAC are valuable tools, but users of these metrics must understand their strengths and weaknesses, and where they can be used appropriately. For the SCC, it is more prudent to examine a range of values by means of sensitivity analysis, versus relying on one absolute number.
- The absence of a precise value for any of the two main methods of carbon cost estimates (SCC or MAC) should not delay action on implementing climate change policy. In fact, some

Sustainable Prosperity
c/o University of Ottawa
555 King Edward Avenue
Ottawa, ON K1N 6N5
613-562-5800 x3342
www.sustainableprosperity.ca

1 Sustainable Prosperity would like to thank Dr. Joel Bruneau of the University of Saskatchewan, Ruth Greenspan Bell of the Woodrow Wilson International Center for Scholars and the World Resources Institute, Fabian Kesicki of the UCL Energy Institute, University College London, and Current Analysis and Economic Research Division, Economic Analysis Directorate, Environment Canada for their thoughtful comments and contributions to this Brief. Responsibility for the final product and its conclusions is Sustainable Prosperity's alone, and should not be assigned to any reviewer or other external party.

SP-PB-2672-OCT-2011

researchers believe that instead of using the SCC, the focus should be on identifying 'the least-cost strategy for eliminating carbon emissions as rapidly as possible.'[2]

- Underestimating the SCC encourages weak climate policy and mitigation actions, and so will not spur the necessary stringency of regulations, and individual and company decisions, to shift towards a low-carbon economy. On the other hand, a low MAC just means that it is cheap to reduce emissions, which may encourage decision-makers to incentivize more abatement activities. So it is important to understand how and why the SCC and the MAC differ, and how they are estimated and used.

The Issue

Climatic changes are likely to generate substantial economic, social and other costs. In the absence of a carbon pricing framework that translates monetary value to one tonne of CO_2, either through a tax or through the market price set by an emission trading system, policy and corporate leaders must create their own carbon cost estimate to use in decision-making. The Social Cost of Carbon (SCC) attempts to put a price on damages arising from climate change, demonstrating what society or a company should be willing to pay now to reduce carbon emissions.[3] The Marginal Abatement Cost (MAC) represents the cost of abating the next unit of emissions for a given target level, and informs decisions about emission targets, as well as the design and cost of the policy to reduce emissions. The SCC and the MAC should be used by policy-makers seeking to implement the most economically efficient climate change mitigation and adaptation strategies. However, given the inherent uncertainty related to climate change impacts, the actual value is imperfectly known, so sensitivity analysis is required.

The Knowledge Base

The Social Cost of Carbon (SCC) represents the marginal cost of global damage arising from carbon emissions.[4] The SCC is usually estimated as the net present value of the long-term climate change impacts of one additional tonne of carbon emitted today.[5] The SCC is a useful tool for illustrating the scale of expected economic damages from climate change, and also of quantifying the benefits of a policy that will reduce greenhouse gas (GHG) emissions. The marginal cost expressed by the SCC represents the external societal costs of

2 Ackerman, Frank and Elizabeth Stanton. (2011). *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon.* Economics for Equity and the Environment. http://www.e3network.org/papers/Climate_Risks_and_Carbon_Prices_executive_summary+full_report+comments.pdf.

3 Price, Richard, Thornton, Simeon and Stephen Nelson. (December 2007). *The Social Cost of Carbon and the Shadow Price of Carbon: What they are, and how to use them in economic appraisal in the UK.* Department for Environment, Food and Rural Affairs (UK).

4 Watkiss, Paul. (2006). *The Social Cost of Carbon.* Paul Watkiss Associates, UK. Presented to OECD Global Forum on Sustainable Development: Economic Benefits of Climate Change Policies, 6–7 July 2006.

5 Ibid.

climate change.[6] The concept is based in economic theory; it is not economically efficient to emit GHGs beyond the point where the costs exceed the benefits from emissions.

The Marginal Abatement Cost (MAC) represents the cost to abate one tonne of CO_2 towards achieving an emission reduction target.[7] Abatement includes reductions in economic activity, switching fuel sources, altering production processes, and sequestering carbon in the soil, trees, or ground. The MAC can also be a negative number, meaning that abatement costs have a net positive return on investment. The MAC is usually presented on a curve, as a series of costs, showing how the MAC increases for each additional unit of emission reduction. MAC curves can be derived via consultation with experts, who assess the cost and emission reduction potential of individual technologies (e.g. the famous McKinsey curves), or by using an energy model.[8] Experts have determined that the model-based approach of developing a MAC curve is the most useful when considering a market-based instrument approach to climate policy.[9] The benefit of the MAC is that it allows policy-makers to give an indication of the cost of achieving a specific emission reduction target.[10] It also allows policy-makers to compare the cost of achieving specific emission reductions for specific sectors, so that policy can be targeted to balance costs, but also have a higher likelihood of achieving emission reduction targets.

The benefit of the MAC is that it allows policy-makers to give an indication of the cost of achieving a specific emission reduction target. It also allows policy-makers to compare the cost of achieving the specific emission reductions for specific sectors, so that policy can be targeted to balance costs, but also have a higher likelihood of achieving emission reduction targets.

The SCC and the MAC are both useful to help identify the optimal level of emission reduction. Whereas the SCC is determined purely by estimates of the damage caused by climate change, the MAC is concerned with the actual costs of emission reductions.[11] Estimates of the SCC for a target emissions and the estimated MAC to achieve it will typically differ due to different methodologies. The SCC decreases with abatement, while the MAC increases. In fact, the optimal government climate stabilization goal is, in theory, where the SCC and the MAC curves meet.[12, 13]

6 Baneman, Dan. (May 4, 2010). *Estimating the Social Cost of Carbon: A Numerical Approach and Sensitivity Analysis.* Yale University. nordhaus.econ.yale.edu/documents/ECON331_Baneman_FinalPaperSCC.pdf

7 Given that MAC curves can be established at various levels – for a given company, sector or country – the bearer of the costs varies accordingly.

8 Kesicki, Fabian. (2010). *Marginal Abatement Cost Curves for Policy Making – Expert-Based vs. Model-Derived Curves.* Energy Institute, University College London. Available at: www.homepages.ucl.ac.uk/~ucft347/Kesicki_%20MACC.pdf.

9 Ibid.

10 Ibid.

11 Price, Richard, Thornton, Simeon and Stephen Nelson. (December 2007). *The Social Cost of Carbon and the Shadow Price of Carbon: What they are, and how to use them in economic appraisal in the UK.* Department for Environment, Food and Rural Affairs (UK).

12 UK Department of Energy & Climate Change. (2009). *Carbon Appraisal in UK Policy Appraisal: A Revised Approach.* http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx.

13 In theory, if there were a fully comprehensive international trading scheme in place covering all emissions, with a cap set consistent with the optimal stabilisation goal, then the market price of carbon would equal both the MAC and SCC for the stabilisation goal. From: UK Department of Energy & Climate Change. (2009). *Carbon Appraisal in UK Policy Appraisal: A Revised Approach.* http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx.

The International Knowledge Base

The United Kingdom

Led by the Department for Environment, Food and Rural Affairs (Defra), the United Kingdom (UK) government used the SCC to inform policy decisions across various departments between 2002 and 2009.[14] Defra organized an interagency working group with a steering committee, which was supplemented by an expert peer review panel. The working group commissioned two research reports on the SCC, and undertook consultations with climate change experts and government economists (the end users of the SCC).[15]

The UK government believes that the MAC approach provides greater certainty that emission reduction targets can be met, which will strengthen the cost-effectiveness of climate policy-making.

The UK government has now moved away from using the SCC, due to its inherent uncertainty, and the need for a metric that is more consistent with reaching its emission targets. It now uses marginal abatement cost (MAC) estimates for sectors not covered by a market price for carbon in the European Union Emissions Trading System, which are subject to a target of reducing emissions by 16% below 2005 levels by 2020.[16] In October 2011, the UK government released low, central and high MAC estimates up to the year 2100 to be used in sensitivity analysis. The UK government believes that the MAC approach provides greater certainty that emission reduction targets can be met, which will strengthen the cost-effectiveness of climate policy-making.[17]

When initially assessing whether to use the SCC, the UK government identified four possible uses:[18]

- Project appraisal (project cost-benefit analysis);
- Regulatory Impact Assessment (policy cost-benefit analysis);
- Economic instrument design (input to the setting of taxes, charges, or subsidies); and,
- Long-term sustainability objectives or targets, particularly climate policy.

Even when the SCC was being used in the UK government, there was not a uniform price across all departments.[19] A study was conducted to look at how the SCC had actually been used across the UK government between 2002 and 2006, summarized in Table 1.

14 UK Department of Energy & Climate Change. (2009). *Carbon Appraisal in UK Policy Appraisal: A Revised Approach.* http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx.

15 Ibid.

16 UK Department of Energy and Climate Change. (October 2011). *A brief guide to the carbon valuation methodology for UK policy appraisal.* http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-valuation/3136-guide-carbon-valuation-methodology.pdf.

17 UK Department of Energy & Climate Change. (2009). *Carbon Appraisal in UK Policy Appraisal: A Revised Approach.* http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx.

18 Watkiss, Paul with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol. (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra.

19 Ibid.

Table 1: Examples of the Use of the SCC value across the UK Government (2006)

GOVERNMENT DEPARTMENT	Example Applications
Department for Environment, Food and Rural Affairs (Defra)	• Regulatory Impact Assessment of the proposed F Gas regulations • Cost-benefit analysis of UK Emission Trading Scheme • Analysis of waste tax charges (review and consultation)
Office of the Deputy Prime Minister (OPDM)	• Proposals for Part L amendment (energy efficiency provisions) of Building Regulations
Department for Transport (DfT)	• Incorporation into New Approach to Appraisal for Road Transport infrastructure appraisal • Incorporation into National Transport Model/Social Pricing Model • Analysis of aviation tax in Aviation White Paper (for consultation) • Analysis of road user charging and differential charges (consultation paper)
Department for Trade and Industry (DTI)	• Energy White Paper • Regulatory Impact Assessment for Renewables Obligation II
Office of Gas and Electricity Markets (Ofgem)	• Energy investment appraisal (gas network extension, electricity transmission infrastructure)
Environment Agency (EA)	• Assessment of Asset Management Programme 4 for Water Sector (AMP4)

Source: Watkiss, Paul with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol. (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra.

The United States

The SCC has been used by the United States (US) government since 2008, though not in a coordinated way.[20] The US recently conducted a year-long intra-agency consultation to develop a SCC for use across the US government in cost-benefit analysis to assess potential federal regulations.[21] Technical experts met on a regular basis to discuss the model inputs and assumptions, which were informed by a literature review, and public comments. Though the government-wide SCC figures were just released in 2010, they have already been used for assessing at least seven major rules (with costs over USD $100 million), including in the model year 2011 Corporate Average Fuel Economy (CAFE) standards, as well as in several court case testimonies.[22, 23]

Table 2 shows the range of 2010 values used by the US government, developed through the intra-agency process. The values will grow over time in accordance with the assumptions built into each model.[24, 25] How the SCC is calculated, as well as the role of the discount rate, is discussed in detail later in the Brief.

20 Greenstone, Michael, Kopits, Elizabeth and Ann Wolverton. (2011). *Estimating the Social Cost of Carbon for Use in US Federal Rulemakings: A Summary and Interpretation.* National Bureau of Economic Research.

21 Ibid.

22 Ibid.

23 The Department of Transportation (DOT) used both a "domestic" SCC value of $2 per tonne of CO_2 and a "global" SCC value of $33 per tonne of CO_2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at $80 per tonne of CO_2.

24 Greenstone, Michael, Kopits, Elizabeth and Ann Wolverton. (2011). *Estimating the Social Cost of Carbon for Use in US Federal Rulemakings: A Summary and Interpretation.* National Bureau of Economic Research.

25 For an in-depth discussion of the models used in the US SCC calculations, see: Bell, Ruth Greenspan and Diane Callan. (July 2011). *More than meets the eye: The social cost of carbon in US climate policy, in plain English.* World Resources institute. http://www.wri.org/publication/more-than-meets-the-eye-social-cost-of-carbon.

Table 2: Range of 2010 SCC values to be used in the US government, with accompanying discount rate (USD)

	Low value	Central value	High value	95th percentile of the SCC distribution
SCC value (2007$)	$5	$21	$35	$65
Discount Rate (%)	3	5*	2.5	3

Source: Sustainable Prosperity, based on data from: Greenstone, Michael, Kopits, Elizabeth and Ann Wolverton. (2011). *Estimating the Social Cost of Carbon for Use in US Federal Rulemakings: A Summary and Interpretation.* National Bureau of Economic Research.
*The central value of the range of discount rates is 3%

The SCC estimates until 2030 are broadly similar to the Congressional Budget Office 2009 estimates of the market price of carbon under comprehensive cap-and-trade legislation; after 2030 there is a growing discrepancy.[26] In terms of calculation technique, which is discussed in more detail later in this Brief, the US did not use an equity weighting.[27]

The US's USD$21 SCC estimate is very low because the working group opted for the most conservative parameters to calculate it.[28] Using what some believe to be more realistic assumptions with the same economic model, the SCC could be as high as USD$900 in 2010, rising to USD$1500 by 2050.[29]

Europe

In the European Union, a SCC has not been used, since actual carbon prices from the European Union Emissions Trading System (EU ETS) are available, which reflect the MAC. However, a "carbon switching value" of €5–125/t CO_2e has been used by the European Investment Bank for energy appraisal.[30] The European Commission has also used a carbon cost of €70–170/t CO_2e based on the marginal abatement costs from sectoral targets.[31]

Other European countries have recently used MAC curves. For example, they have been used in France in the consultation process for a potential carbon tax.[32]

26 Cline, William R. (January 2011). *Remarks at the conference on Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis, Environmental Protection Agency and US Department of Energy, Washington DC, January 27–28, 2011.* Peterson Institute for International Economics.

27 Greenstone, Michael, Kopits, Elizabeth and Ann Wolverton. (2011). *Estimating the Social Cost of Carbon for Use in US Federal Rulemakings: A Summary and Interpretation.* National Bureau of Economic Research.

28 Ackerman, Frank and Elizabeth Stanton. (2011). *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon.* Economics for Equity and the Environment. http://www.e3network.org/papers/Climate_Risks_and_Carbon_Prices_executive_summary+full_report+comments.pdf.

29 Ibid.

30 Watkiss, Paul with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol. (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra.

31 Ibid.

32 République Française: Centre d'analyse stratégique. (2009). « La valeur tutélaire du carbone. » http://lesrapports.ladocumentationfrancaise.fr/BRP/094000195/0000.pdf.

The Knowledge Base in Canada

In Canada, the SCC use has been limited. For example, Environment Canada used a SCC estimate of CAD$25/t CO_2e in its Regulatory Impact Analysis Statement on the Renewable Fuels Regulations, as shown in more detail in table 3.[33] This value was chosen because at the time it was consistent with carbon price estimates in the United States, and the value of European carbon permits. A sensitivity analysis on values in the CAD$10–100 range was also conducted.[34]

Table 3: Present Value of Estimated Net Benefits of GHG Emission Reductions (2010–2034) (Constant 2007 CAD$M)

LOCATION	GHG Emission Reductions (MT CO_2e)	Low Estimate $10/tonne	Regulated Scenario Estimate $25/tonne	High Estimate $100/tonne
West	7.6	72.1	180.3	721.2
Ontario	5.0	46.6	116.4	465.7
Quebec and Atlantic Provinces	11.2	105.6	264.1	1056.3
Total for Canada	**23.8**	**224.3**	**560.8**	**2243.2**

Source: Government of Canada. (April 10, 2010). *Renewable Fuels Regulations: Regulatory Impact Analysis Statement.* http://www.gazette.gc.ca/rp-pr/p1/2010/2010-04-10/html/reg1-eng.html.

In Canada, the SCC use has been limited. For example, Environment Canada used a SCC estimate of CAD$25/t CO_2e in its Regulatory Impact Analysis Statement on the Renewable Fuels Regulations.

33 Government of Canada. (April 10, 2010). *Renewable Fuels Regulations: Regulatory Impact Analysis Statement.* http://www.gazette.gc.ca/rp-pr/p1/2010/2010-04-10/html/reg1-eng.html.

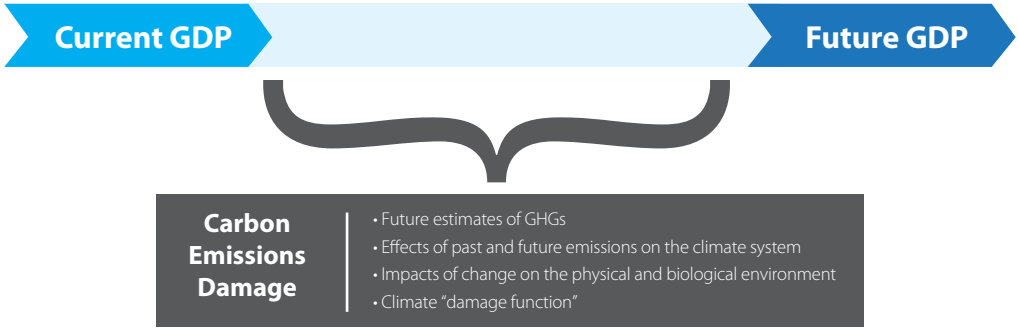
34 Ibid.

Estimating the Social Cost of Carbon

How to estimate the SCC[35]

The SCC is calculated using integrated assessment models (IAMs), which combine climate processes and economic growth into a single model. The SCC is commonly estimated as the difference between the present Gross Domestic Product (GDP) and future GDP, taking into account carbon emissions damage, as shown in figure 1.[36] While some authors use the difference in GDP as an indicator of climate change impacts, it should be noted that it may also be misleading since many climate change impacts are not captured in the GDP (e.g. health impacts and loss of biodiversity).

Figure 1: Estimating the Social Cost of Carbon



Source: Sustainable Prosperity, based on Ingham, Alan and Alistair Ulph. (2003). *Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon.* Tyndall Centre Working Paper N°. 37. Tyndall Centre for Climate Change Research and Economics Division, University of Southampton.

Making this calculation involves estimating future GDP and GHG emissions damage over the course of hundreds of years, and then discounting it back to the present. The discount rate accounts for the time-value of money and uncertainty with a higher degree of uncertainty reflected in a higher discount rate.[37] It is important to remember that the further into the future the estimation, the more a number is discounted to the present (meaning the value will be lower). There is inherant uncertainty in predicting how climate change impacts, in the form of higher temperatures and more extreme weather, will generate economic and societal costs, especially in specific countries. Estimating the costs associated with climate change requires relying on trends and scenario analysis. Some models generate a wide range of possible scenarios and require a simplification of climate change effects, which tends to diminish their costs. As a result, most researchers calculate a range of SCC values based on probabilities (which can be based on expert opinion), then calculate the mean (average) or median (middle number) of the distribution.[38]

35 The SCC is usually calculated on a country level. The global SCC is an aggregation of domestic SCCs.

36 Baneman, Dan. (May 4, 2010). *Estimating the Social Cost of Carbon: A Numerical Approach and Sensitivity Analysis.* Yale University. nordhaus.econ.yale.edu/documents/ECON331_Baneman_FinalPaperSCC.pdf.

37 HM Treasury. (2011). *THE GREEN BOOK: Appraisal and Evaluation in Central Government.* http://www.hm-treasury.gov.uk/d/green_book_complete.pdf. Pages 97–98.

38 Ingham, Alan and Alistair Ulph. (2003). *Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon.* Tyndall Centre Working Paper N°. 37. Tyndall Centre for Climate Change Research and Economics Division, University of Southampton.

Once the cost of damages associated with carbon emissions have been estimated for various time periods, they must be discounted back to the present. Choosing the appropriate discount rate is a challenge, because it is a key determinant of the SCC. Some estimates of the SCC use today's prevailing interest rate, though others adjust the discount rate to account for intergenerational equity issues.[39] Today's discount rates tend to be higher than a rate that has been adjusted for intergenerational equity. Because the lower the discount rate, the higher the SCC, accounting for intergenerational equity raises the SCC substantially.

Some researchers have added a "learning premium" to the SCC, to account for the fact that there is more value to acting now rather than later, because of the potential for learning (i.e. lowering the cost of abatement).[40]

Estimates of the SCC

Due to the range of estimates of the inputs into the SCC, the need for individual judgement (in the choice of discount rate in particular), and the use of different models, there is a wide range of estimates for the SCC. However, the more than 200 estimates of the SCC are based on nine estimates of the total cost of climate change.[41]

Due to the range of estimates of the inputs into the SCC, the need for individual judgement (in the choice of discount rate in particular), and the use of different models, there is a wide range of estimates for the SCC.

The key parameters that affect the SCC estimate are:[42]

- Discount rate (higher discount rate leads to lower value, whether to use today's interest rate or make an ethical judgement based on intergenerational impacts);
- Equity weighting (approach to weighting impacts in different regions);
- Time horizon; and,
- Whether the mean or median value is used.

Richard Tol, an Irish economist, examined 232 estimates of the SCC, and calculated their characteristics, as shown in table 4. It is evident that there is a wide variety in the estimates, as the standard deviation is USD$243/tC. The mean is high at USD$105/tC, driven by some very high estimates in the sample, such as USD$1500/tC in the 99th percentile.[43] At the same time, the SCC figure used in the Stern Review was USD$85.[44]

39 Anthoff, David, Hepburn, Cameron and Richard S. J. Tol. (2008). Equity weighting and the marginal damage costs of climate change. *Ecological Economics* 68(3), 836–849.

40 Ingham, Alan and Alistair Ulph. (2003). *Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon.* Tyndall Centre Working Paper N°. 37. Tyndall Centre for Climate Change Research and Economics Division, University of Southampton.

41 Tol, Richard S. J. (2009). The Economic Effects of Climate Change. *Journal of Economic Perspectives* 23(2), 29–51.

42 Watkiss, Paul with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol. (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra.

43 Tol, Richard S. J. (2009). The Economic Effects of Climate Change. *Journal of Economic Perspectives* 23(2), 29–51.

44 Stern, Nicholas. (2007). *The Stern Review: The Economics of Climate Change.* Cambridge University Press.

Table 4: Unweighted estimates of the SCC (measured in 1995 dollars per metric tonne of carbon (USD$/tC))

	All	Pure rate of time preference (Discount rate)		
		0%	1%	3%
Mean	105	232	85	18
Standard Deviation	243	434	142	20
Mode	13	–	–	–
33rd percentile	16	58	24	8
Median	29	85	46	14
67th percentile	67	170	69	21
90th percentile	243	500	145	40
95th percentile	360	590	268	45
99th percentile	1500	–	–	–
Number of estimates (N)	232	38	50	66

Source: Tol, Richard S. J. (2009). The Economic Effects of Climate Change. *Journal of Economic Perspectives* 23(2), 29–51.

Limitations

Uncertainty

Researchers make decisions about each of the inputs that enter into the SCC calculation (e.g. the discount rate) based on their understanding and outlook on climate change. This means that every SCC estimate has a bias. The major unknown is the actual impact of climate change, in terms of frequency, timing, location and magnitude, and possible catastrophic effects, and how these will impact society and the economy.[45] Most of these unknowns are left out of studies that make SCC estimates, because they cannot be predicted with any degree of certainty.[46] They also omit, due to uncertainty, the role of technological change.[47] Or, they assume that future technological improvements favour delayed action.[48] The omission of these factors also contributes to a SCC estimate being lower than it probably should be.[49, 50] In addition to omissions, there are big uncertainties in every aspect of the SCC calculation.[51] Improvements in the accuracy of SCC estimates are only possible if the underlying calculations of the impacts of climate change could be improved, which may not be possible due to climate change's inherent unpredictability, as well as the unpredictability of adaptation by humans and ecosystems.

45 Ingham, Alan and Alistair Ulph. (2003). *Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon.* Tyndall Centre Working Paper N°. 37. Tyndall Centre for Climate Change Research and Economics Division, University of Southampton.

46 Watkiss, Paul and Thomas E. Downing. (2008). The social cost of carbon: Valuation estimates and their use in UK policy. *The Integrated Assessment Journal: Bridging Sciences & Policy* 8(1), 85–105.

47 Greenstone, Michael, Kopits, Elizabeth and Ann Wolverton. (2011). *Estimating the Social Cost of Carbon for Use in US Federal Rulemakings: A Summary and Interpretation.* National Bureau of Economic Research.

48 Ackerman et al. (2010). *The Need for a Fresh Approach to Climate Change Economics.* Pew Climate Workshop proceedings. http://www.pewclimate.org/docUploads/ackerman-decanio-howarth-sheeran-climate-change-economics.pdf.

49 Ackerman, Frank and Elizabeth A. Stanton. (April 2010). *The Social Cost of Carbon: A Report for the Economics for Equity and the Environment Network.* Stockholm Environment Institute – US Center.

50 Ingham, Alan and Alistair Ulph. (2003). *Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon.* Tyndall Centre Working Paper N°. 37. Tyndall Centre for Climate Change Research and Economics Division, University of Southampton.

51 Weitzman, Martin L. (February 23, 2011). *Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change.* REEP Symposium on Fat Tails. http://www.economics.harvard.edu/faculty/weitzman/files/REEP2011%2Bfat-tail.pdf.

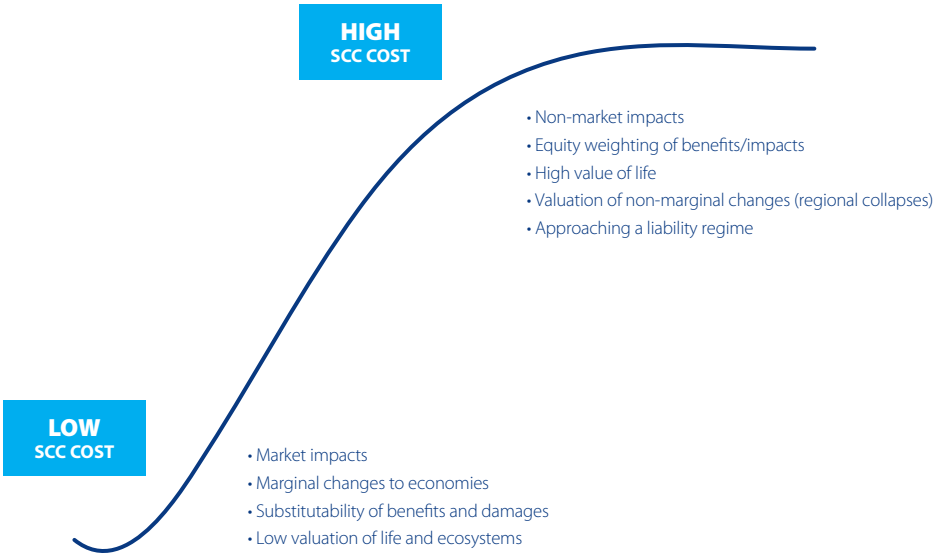
Equity

The SCC raises a number of equity concerns – between current and future generations, and between rich and poor. It tends to favour the needs of the present generation over those of future generations, since future damages are heavily discounted due to the inherent uncertainty facing longer-term projections. It also has a propensity to value rich people more than poor people, due to their increased willingness and ability to pay now to avoid carbon damage.[52, 53] Equity can be accounted for by adjusting the discount rate: a lower rate places a higher value on future damages, meaning that the impact on future generation is weighted more fairly. Given that the present generation bears responsibility for carbon emissions, some argue that it should incur the cost of carbon abatement, not future generations who bear no responsibility.[54]

Low Price

There is a trend in the literature towards lower SCC values in recent years.[55] There are a variety of reasons for this, including the assumption that there is substitutability of benefits and damages, and the low valuation of life and ecosystems. The low estimates are driven by the use of high discount rates. Figure 2 shows the difference in assumptions and what is accounted for in low and high SCC estimates.

Figure 2: Low vs. high SCC estimates



Source: Downing, Thomas E. *Impacts of climate change as a (social) risk assessment.* Stockholm Environment Institute. http://www.oecd.org/dataoecd/42/52/37116960.pdf.

52 Pearce, David. (2002). *The Social Cost of Carbon and Its Policy Implications.* Environmental Policy Seminar, Oxford University.

53 The use of either market exchange rates or purchasing power parity can also contribute to the discrepancy.

54 Pearce, David. (2002). *The Social Cost of Carbon and Its Policy Implications.* Environmental Policy Seminar, Oxford University.

55 Watkiss, Paul with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol. (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra.

At a low social cost, there is less justification for emission reductions, which can lead to weak climate change policy. Therefore, the higher the SCC, the more stringent the regulatory standards should be with regards to reducing carbon emissions.[56] There are those concerned that with a high SCC, it will induce "too much" spending on emissions abatement. However, others believe that the risk of this is far less than the risk of spending too little to avoid irreversible climate change.[57] The SCC increases with aggregate carbon emissions, as the damages from temperature increases are more severe at higher temperature levels.[58]

Estimating the Marginal Abatement Cost

How to Estimate the MAC

MAC curves are derived from expert opinions, assumptions about emissions growth, and the emission reduction potential and cost of various technologies. In order to make their assumptions, experts consider factors such as the discount rate, the lifetime of the technology, investment and operating costs, and energy prices.[59] As mentioned previously, the MAC curves can be constructed using solely expert opinions, or by using expert assumptions to input into a system-wide model.

MAC curves are derived from expert opinions, assumptions about emissions growth, and the emission reduction potential and cost of various technologies. In order to make their assumptions, experts consider factors such as the discount rate, the lifetime of the technology, investment and operating costs, and energy prices.

Estimates of the MAC

As mentioned, the UK government is now using the MAC in its policy analysis, and is using figures in the range of £30–90/tCO_2 in 2020, for sectors not covered by the EU ETS but are still subject to an emissions target of 16% below 2005 levels by 2020.[60]

The most famous cost curve is that derived based on expert opinion by the consultancy McKinsey & Company, though there are many others who have developed them as well, such as Bloomberg New Energy Finance, whose global cost curve is shown below in figure 3.

56 Ackerman, Frank and Elizabeth A. Stanton. (April 2010). *The Social Cost of Carbon: A Report for the Economics for Equity and the Environment Network.* Stockholm Environment Institute – US Center.

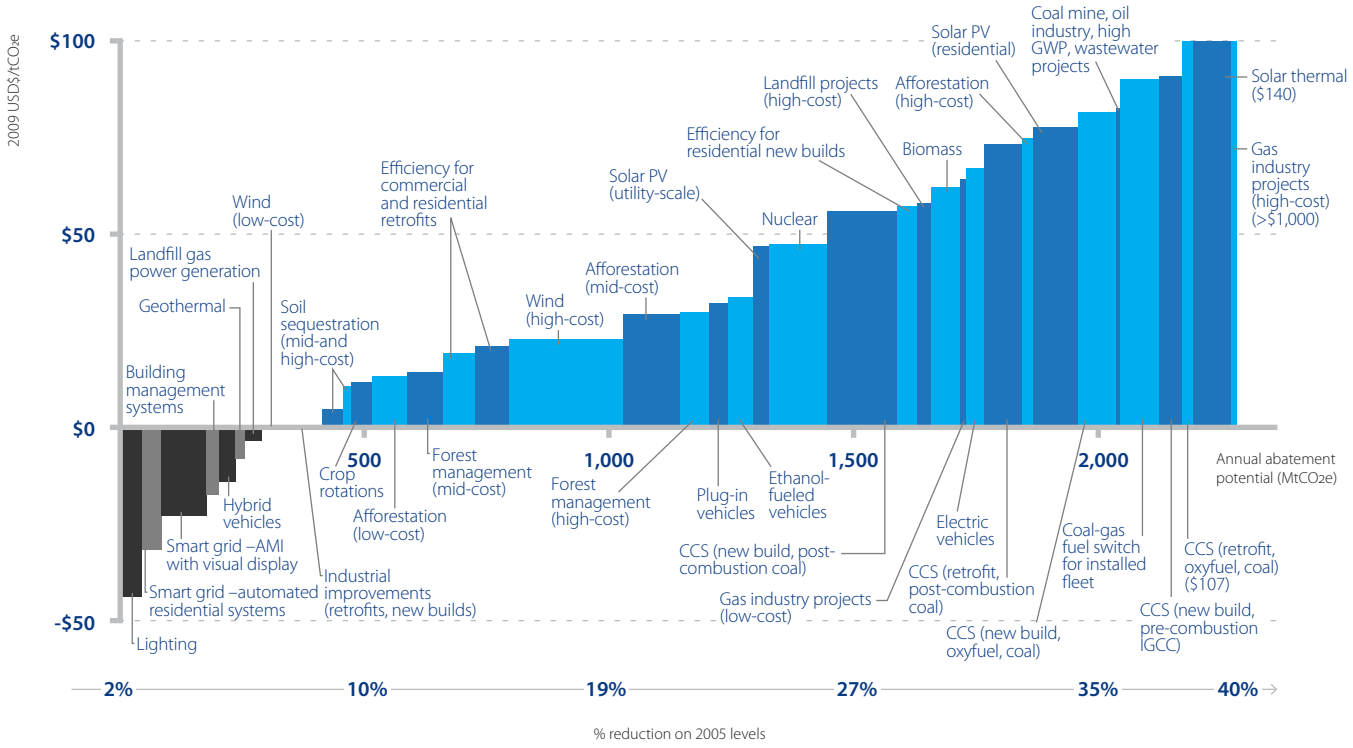
57 Ibid.

58 Watkiss, Paul and Thomas E. Downing. (2008). The social cost of carbon: Valuation estimates and their use in UK policy. *The Integrated Assessment Journal: Bridging Sciences & Policy* 8(1), 85–105.

59 Ekins, Paul, Kesicki, Fabian and Andrew Smith. (April 2011). *Marginal Abatement Cost Curves: A Call for Caution.* Energy Institute, University College London. http://www.ucl.ac.uk/energy/home-top-cols/image-link-docs/MACCCritGPUKFin.pdf.

60 UK Department of Energy & Climate Change. (2009). *Carbon Appraisal in UK Policy Appraisal: A Revised Approach.* http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx. Pounds sterling converted to dollars using an exchange rate of £1.00 = US$1.625.

Figure 3: 2030 US MAC curve (accounting for improving carbon intensity, key recent policies, and sector-specific discount rates)



Source: Bloomberg New Energy Finance[61]

Limitations

There are various weaknesses of the MAC approach, which experts suggest have been potentially overlooked, since the curves present complex information in a simple format.

Omissions

The MAC does not incorporate a variety of factors that will have an impact on whether the technologies can achieve their abatement potential. The MAC only presents the maximum abatement potential of a particular technology without fully considering institutional, implementation, and behavioural or other barriers.[62, 63] It also does not consider the wider social benefits (i.e. better health outcomes) of reducing carbon emissions.[64] The technology cost estimates represent a point in time, meaning that they are static numbers. They do not consider the path dependency, meaning that they cannot capture how dynamic decisions

61 Bloomberg New Energy Finance. (January 2010). *Carbon Markets – North America – Research Note.* bnef.com/WhitePapers/download/25

62 Kesicki, Fabian. (2010). *Marginal Abatement Cost Curves for Policy Making – Expert-Based vs. Model-Derived Curves.* Energy Institute, University College London. www.homepages.ucl.ac.uk/~ucft347/Kesicki_%20MACC.pdf.

63 Implementation costs are neglected in almost all MAC curves, but institutional costs are sometimes captured and part of behavioural barriers can be captured as well, depending on the approach used.

64 Ekins, Paul, Kesicki, Fabian and Andrew Smith. (April 2011). *Marginal Abatement Cost Curves: A Call for Caution.* Energy Institute, University College London. Available at: http://www.ucl.ac.uk/energy/home-top-cols/image-link-docs/MACCCritGPUKFin.pdf.

made over time will impact the estimates, including mitigation actions undertaken before or after the point in time captured.[65]

Uncertainty

Like the SCC, the MAC curves also face the inherent difficulties in making assumptions or projections about the future. Some of the technologies considered as part of the MAC curve may still be in development, so it is very difficult to assess their future deployment potential.

Transparency

The fact that MAC curves are based on expert estimates about a number of different technologies, means that there are a lot of underlying assumptions which are often not made explicit or easy to access.

Use in Policy-Making

Policy-makers face an important decision when looking at how to use the SCC or the MAC in their policy-making process, or whether to use them at all. The SCC and the MAC are applicable to different types of policy-making decisions.

Policy-makers face an important decision when looking at how to use the SCC or the MAC in their policy-making process, or whether to use them at all. The SCC and the MAC are applicable to different types of policy-making decisions.

In general, policy-makers use the SCC to assess the economic benefits of climate (and other related) policy options by looking at the cost of climate change-related damages. Some policy-makers believe the benefits of using this tool, despite its limitations, includes improved policy-making, since it helps create consistency and transparency across policies in different departments.[66] Policy-makers who are convinced of the SCC's utility must decide which parameters and model to use to calculate it, and then how it will be used. Theoretically, a carbon price (e.g. a carbon tax) should be set to the value of the SCC as the price would then force emitters to internalize the cost of damages arising from their emissions.[67] In terms of calculation methods for the SCC, experts tend to suggest using a declining discount rate, as well as an equity weighting, and using the mean, not median, values.[68]

However, there are many who oppose the use of the SCC in policymaking. The UK government, an early adopter of the SCC, has replaced it with the MAC. The main objection to the use of the SCC is that it is flawed as a tool to measure carbon damages, given that it likely underestimates the potential damages, especially of catastrophic climate change. The

65 Ibid.

66 Price, Richard, Thornton, Simeon and Stephen Nelson. (December 2007). *The Social Cost of Carbon and the Shadow Price of Carbon: What they are, and how to use them in economic appraisal in the UK.* Department for Environment, Food and Rural Affairs (UK).

67 Pearce, David. (2002). *The Social Cost of Carbon and Its Policy Implications.* Environmental Policy Seminar, Oxford University.

68 Watkiss, Paul. (July 6, 2006). *The Social Cost of Carbon: Use of the Values in Policy.* http://www.oecd.org/dataoecd/42/56/37116988.pdf.

climate science suggests a considerable likelihood of a high-impact but low-probability event (i.e. global collapse) arising from rising temperatures, which most of the models that calculate the SCC do not reflect.[69] The assumptions and parameters underlying it and choice of model are subjective, further limiting its usefulness in cost-benefit analysis.[70] Its opponents believe that climate policies should instead be focused on avoiding the worst case scenarios, by establishing a target "safe" level of emissions and implementing the least cost strategies to meet it.[71] Climate change is a unique phenomenon with "effectively unlimited downside liability"[72], and standard economic models may not be up to the task of measuring its potential costs.

On the other hand, the MAC allows policy-makers to set an emission reduction target, and the associated costs of meeting it. The MAC enables the estimate of the costs of compliance for various sectors, which can help predict the likely response of specific sectors to a carbon pricing policy, or to regulations. It also therefore allows the estimation of the total economic cost of achieving a specific emission reduction target. It can inform decisions about which sectors to include in a climate policy, and the emission reductions they may be expected to achieve. It is imperative to know the MACs of various sectors for setting the emissions cap in an emissions trading system. It is not necessary for a tax (because no upper limit on emissions is being set), though it is still useful to know, because it will give an indication of how firms in different sectors may react to the tax.

At the federal level, Canadian policy-makers have decided to regulate carbon emissions sector by sector. The MAC is a critical tool in designing these policies, in order to target which sectors to regulate, and what their emission reductions targets should be. The MAC is necessary to assess the cost of emission abatement for each sector, and how it can be expected to change with reductions.

The MAC also has its limitations, but despite these, it has recently gained some momentum, because it is seen to be a more reliable number, as technology costs are relatively well-understood and easier to predict. Studies have shown that while the SCC estimates can vary by three orders of magnitude, the MAC estimates differ only by one.[73]

Use of the SCC in business

Corporate leaders can use the SCC to inform their long-term investments and strategic decisions. Puma recently used a SCC value of USD$87 (€66) t/$CO_2e$ in valuing the damages caused by its greenhouse gas emissions.[75]

69 Weitzman, Martin L. (February 2009). On modelling and interpreting the economics of catastrophic climate change. *The Review of Economics and Statistics* XCI(1), http://www.economics.harvard.edu/faculty/weitzman/files/REStatFINAL.pdf.

70 Masur, Jonathan S. and Eric A. Posner. (August 2010). *Climate Regulation and the Limits of Cost-Benefit Analysis.* John M. Olin Law & Econ., Working Paper Nº. 525, Public Law and Legal Theory, Working Paper Nº. 315. http://www.law.uchicago.edu/files/file/525-315-jm-eap-climate.pdf.

71 Ackerman, Frank and Elizabeth A. Stanton. (April 2010). *The Social Cost of Carbon: A Report for the Economics for Equity and the Environment Network.* Stockholm Environment Institute – US Center.

72 Weitzman, Martin L. (February 23, 2011). *Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change.* REEP Symposium on Fat Tails. http://www.economics.harvard.edu/faculty/weitzman/files/REEP2011%2Bfat-tail.pdf.

73 Dietz, Simon. (2007). Review of DEFRA paper: *The Social Cost of Carbon and the Shadow Price of Carbon: what they are, and how to use them in Economic Appraisal in the UK.* London School of Economics and Political Science (LSE).

74 Puma. (2011). *Greenhouse Gas Emissions Valuation Method.* http://about.puma.com/wp-content/themes/aboutPUMA_theme/media/pdf/2011/en/PRESS_KIT_GHG_Valuation.pdf.

Implications for Policy-Makers

This Brief is meant as an overview of the theory and experience on various techniques that can be used to estimate the value of carbon. Based on the overview, Sustainable Prosperity believes that the following conclusions are of direct relevance to policy-makers engaged in the development of carbon policy in Canada:

1. The SCC and the MAC are both valuable, but imperfect, tools and therefore must be used prudently by policy-makers. If the SCC is used, a range of values should be used in a sensitivity analysis. The SCC numbers should be complemented by other information, such as the latest climate science, when formulating climate policy.

2. At the same time, the challenges associated with making future cost estimates should not undermine the need to implement aggressive policies to curb greenhouse gas emissions. An underestimate for the SCC will not spur the necessary stringency of regulations and decisions to shift towards a low-carbon economy and cut emissions. Using a low SCC, while a good first step, will not induce transformational change in the economy, since it encourages weak climate policy.

3. The SCC and the MAC are complementary, and are used to inform different policy-making decisions. The SCC is useful when estimating the benefits of any policy involving the potential reduction of greenhouse gases. The MAC is a valuable tool for setting an achievable emission reduction target, and calculating the costs associated with meeting it, both on an aggregate economic level and for specific sectors.

4. The actual damages from climate change are likely to exceed the cost of addressing it.[75] Government action on climate change is justified, since it is likely to be cheaper to reduce greenhouse gas emissions in the present than to suffer future damages.[76] As long as there is a chance that the SCC could be higher than the MAC, as would be the case with climatic changes that are irreversible and catastrophic, it is worth pursuing all possible greenhouse gas reductions.

75 Stern, Nicholas. (2007). *The Stern Review: The Economics of Climate Change.* Cambridge University Press.

76 Ackerman, Frank and Elizabeth Stanton. (2011). *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon.* Economics for Equity and the Environment. http://www.e3network.org/papers/Climate_Risks_and_Carbon_Prices_executive_summary+full_report+comments.pdf.