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REPORT

Incorporating Carbon Dioxide Emissions Reductions in Benefit Calculations for Energy Efficiency:

Comments on the Department of Energy's Methodology for Analysis of the Proposed Lighting Standard

A Report for the New York Office of Attorney General

By

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1. Executive Summary

The New York Office of the Attorney General has requested that Synapse Energy Economics conduct a review of the Department of Energy (DOE's) methodology for taking into account a monetary benefit of carbon dioxide ("CO_2") emissions reductions associated with proposed energy efficiency standards for general service fluorescent lamps (GSFL) and incandescent reflector lamps (IRL). In its recently published Notice of Proposed Rulemaking ("NOPR") regarding these standards, DOE proposes using values that range from $0 to $20 per metric ton of CO_2.[1]

Our key findings and recommendations with regard to taking into account a monetary value of CO_2 emissions reductions are as follows:

- We commend DOE for tackling the difficult, but necessary, task of determining an appropriate method for taking into account a monetary benefit of CO_2 emissions reductions associated with proposed energy conservation standards. Given the direction of the scientific, policy, and public debate, we anticipate that carbon constraints in the U.S. will soon result in an allowance cost for greenhouse gas emissions. However, it is important for DOE to incorporate a value for CO_2 emissions reductions prior to a Federal carbon constraint, and even in tandem with a carbon constraint since allowance prices (when they exist) may not embody the full cost of greenhouse gas emissions.

- We find that DOE's proposed range of values for CO_2 emissions is not well-founded due in large part to DOE's reliance on estimates of the monetary costs of physical damages associated with climate change. Adopting a single damage-based value belies the uncertain and evolving status of scientific understanding of the physical impacts of climate change; and incorporates myriad assumptions regarding regional and temporal equity and other important policy issues in assigning an economic value to those uncertain physical impacts. The current NOPR focuses on an estimate of the aggregate net economic cost of damages contained in a report from the International Panel on Climate Change.[2] The source document for that value, a 2005 paper authored by Richard Tol, shows considerable range and a large number of high values that should not be ignored. While easy to comprehend, a damage-based dollar per ton value oversimplifies the complex policy and societal choices that must be made in developing policies to address climate change.

[1] "Energy Conservation Program: Energy Conservation Standards for General Service Fluorescent Lamps and Incandescent Reflector Lamps, Proposed Rules" 69 Federal Register 16920-17027 (April 13, 2009).

[2] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

- We also dispute DOE's proposal to restrict its estimate of monetary value to those costs and benefits likely to be experienced in the United States. The impacts of CO_2, and other greenhouse gasses, are global and have significant physical, social, and economic consequences throughout the world. Thus, to the extent that DOE uses a damaged-based approach to value CO_2 emission reductions, the agency should consider the damages inflicted upon the world – not just the United States.

- We find that an estimate of the long-run marginal abatement cost of CO_2 is a practical and conservative measure of the social cost of carbon, and is well-suited for use in DOE's decision-making. In developing our recommendation, we review current literature on emissions reductions necessary to avoid the most dangerous impacts of climate change, as well as analyses of technologies available to achieve those emission reductions. We recommend that DOE uses a marginal abatement cost value, which is based on the cost of controlling emissions instead of monetized estimates of damages.

- We recommend that DOE use a long-run marginal abatement cost (2009$) of $80 per short ton of CO_2. ($88 per metric ton) Our recommendation incorporates findings from a recent meta-analysis of greenhouse gas marginal abatement cost estimates and from recent abatement cost analyses published by both international agencies and multinational consultancies. All of these studies find marginal abatement cost values whose upper range is much higher than the $20 per metric ton of CO_2 ($18.91 per short ton in 2009$) value proposed by DOE in the NOPR.

In this report we summarize DOE's methodology for incorporating CO_2 emissions in the benefits calculations, explain the deficiencies and uncertainties that we find in that approach, and make recommendations for DOE to improve the treatment of CO_2 emissions reduction benefits in its calculations.

2. Background

DOE's Method for Quantifying and Calculating CO_2 Emissions and Benefits

DOE calculated the reduction of CO_2 emissions at different trial standard levels using the National Energy Modeling System (NEMS) model developed by DOE's Energy Information Administration (EIA). DOE estimates CO_2 emissions reductions resulting from the standards ranging up to 679.7 million metric tons of CO_2 for the highest GSFL trial standard level 5 ("GSFL TSL 5").[3] As detailed in Appendix I to this report, we note that the model DOE used to estimate CO_2 emission reductions does not include any allowance prices for CO_2 or other greenhouse gas emissions. The results for DOE's CO_2 calculations are presented on tables VI.39 and VI.40 in the NOPR and summarized here in Table 1.[4]

In response to numerous comments by stakeholders, DOE also analyzed the monetary benefit of the CO_2 emissions reductions associated with the proposed standard. DOE estimated CO_2 emission reductions benefits between zero and $4.0 billion (in 2007 present value dollars) over the study period at a 7% discount rate; and between zero and $7.7 billion (in 2007 present value dollars) at a 3% discount rate.[5] The results for DOE's CO_2 valuation analysis are presented on Tables VI.39 and VI.40 of the NOPR and summarized here in Table 1.[6]

In order to estimate the monetary benefit of CO_2 emission reductions, DOE identified a range of values for the benefits of reducing a ton of CO_2 emissions. DOE chose a value of $0/ton CO_2 as its lower bound. DOE based its upper bound upon an analysis of economic costs of damages contained in a report of the Intergovernmental Panel on Climate Change ("IPCC") [7] that, in turn, incorporated a 2005 paper by Richard Tol – a meta-analysis of marginal damage cost assessments.[8] In Tol's 2005 meta-analysis, the mean value of all estimates is $97 per metric ton of carbon. Tol distinguishes the studies that were subject to peer-review, and calculates the mean for those peer-

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[3] DOE reports carbon dioxide emissions in metric tons. Our analysis will follow the Environmental Protection Agency and US utilities convention of using short tons. For the purposes of converting, one metric ton equals 1.102 short tons. Hence, 679.7 million metric tons of CO_2 would be about 749 million short tons of CO_2.

[4] 74 Fed. Reg. at 17,012-13

[5] In our analysis, we have converted values to 2009$ using a Gross Domestic Product (GDP) chain values. The GDP inflator for 2007$ to 2009$ is 1.105. Therefore, the above values would be approximately 0 to $4.1 billion at a 7% discount rate and $0 and $8.5 billion at a 3% discount rate in 2009$.

[6] 74 Fed. Reg. at 17,012-13.

[7] IPCC. "*IPCC Fourth Assessment Report: Working Group II Report Impacts, Adaptation and Vulnerability"*. Ed. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. Cambridge University Press, 2007.

[8] Tol, R.S.J., "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties," Energy Policy 33 (2005) 2064-2074.

reviewed estimates to be $43 per metric ton of carbon (1995$), which is equal to $14.76 (2009$) per short ton of CO_2.[9] DOE's high value of $20 per metric ton of CO_2 ($18.91 in 2009$ per short ton) is based upon the mean of peer-reviewed estimates reported by Tol and incorporates a 2.4% annual growth rate.[10] In economic literature, estimates of net economic costs of damages from climate change are often referred to as the "social cost of carbon" ("SCC").

The range that DOE examines for the monetized carbon emissions benefits is based "on an assumption of no benefit to an average benefit reported by the IPCC."[11] DOE's low value is zero. Thus, the range used by DOE is from a low of zero to a high of $20 per ton of CO_2 ($18.91 in 2009$ per short ton).

These values as presented in the NOPR are summarized in Table 1.

[9] Tol's 2005 paper identifies 103 estimates of SCC from 28 studies done between 1991 and 2003 expressed in 1995 dollars. As noted in Footnote 80 on page 17,011 of the Fed. Reg., DOE arrives at its upper bound monetary value of CO_2 by converting $43 per metric ton of carbon into CO_2 by dividing by 3.66 (to get from tons of carbon to tons of CO_2). This results in a value of $11.74 dollars in 1995$. That number is then multiplied by 1.33 to convert the value from 1995 dollars to 2007dollars or $15.61 per ton of CO_2 in 2007$. The approximate value of $20 per metric ton is arrived by applying an annual growth rate of 2.4% from 1995 to 2007. .

[10] 74 Fed .Reg. at 17,012.

[11] *Ibid.* at 17,011..

Table VI.39 Preliminary Estimate of Savings from CO_2 Emissions Reductions for General Service Fluorescent Lights			
Trial Standard Level	Estimated Cumulative CO_2 (MMt) Emission Reductions	Value of Estimated CO_2 Emissions Reductions (Billions 2007$) at 7% discount rate	Value of Estimated CO_2 Emissions Reductions (Billions 2007$) at 3% discount rate
1	85.7 to 236.4	$0 to 1.2	$0 to 2.5
2	103.5 to 233.7	$0 to 1.2	$0 to 2.5
3	184.3 to 395.2	$0 to 2.1	$0 to 4.3
4	239.7 to 597.7	$0 to 3.5	$0 to 6.8
5	312.8 to 679.7	$0 to 4.0	$0 to 7.7

Table VI.40 Preliminary Estimate of Savings from CO_2 Emissions Reductions for Incandescent Reflector Lights			
Trial Standard Level	Estimated Cumulative CO_2 (MMt) Emission Reductions	Value of Estimated CO_2 Emissions Reductions (Billions 2007$) at 7% discount rate	Value of Estimated CO_2 Emissions Reductions (Billions 2007$) at 3% discount rate
1	10.3 to 17.7	$0 to 0.1	$0 to 0.2
2	25.1 to 44.8	$0 to 0.3	$0 to 0.5
3	46.2 to 88.1	$0 to 0.5	$0 to 1.0
4	58.6 to 114.1	$0 to 0.6	$0 to 1.3
5	79.3 to 118.8	$0 to 0.7	$0 to 1.3

Table VI.39 and VI.40 from **Federal Register** (pp.17012 & 17013)
Metric tons to short tons conversion (1.102)
2007$ to 2009$ (1.042 based on GDP chain type price index)

Table 1 Summary of DOE Carbon Dioxide Emission Reduction Benefits

Our analysis of those estimates follows.

3. Addressing CO_2 Emissions

DOE's efforts to take into account in decision-making the benefits of CO_2 emissions reductions are part of a broad context of policy action to address climate change. Although CO_2 emissions are currently not regulated in this country at the Federal level, it is widely and reasonably believed that regulation of CO_2 emissions will happen soon, and that the required reductions in CO_2 emissions will be significant. In the March 23 update of the NOPR, DOE noted:

> The Department of Energy, together with other Federal agencies, is currently reviewing various methodologies for estimating the monetary value of reductions in CO_2 and other greenhouse gas emissions. This review will consider the comments on this subject that are part of the public record for this and other rulemakings, as well as other methodological assumptions and issues, such as whether the appropriate values should represent domestic U.S. or global benefits (and costs). Given the complexity of the many issues involved, this review is ongoing. However, consistent with DOE's legal obligations, and taking into account the uncertainty involved with this particular issue, DOE has included in this rulemaking the values and analyses previously conducted. (p.328)

We commend DOE and the other Federal Agencies and note that the Obama Administration indicated in its recently released federal budget that it would seek to establish a cap-and-trade system to reduce greenhouse gas emissions to 14 percent below 2005 levels by 2020 and to 83 percent below 2005 levels by 2050. There are two likely avenues for federal regulation of greenhouse gases. Congress could pass legislation, or the U.S. Environmental Protection Agency could adopt regulations to limit greenhouse gas emissions. Both paths are currently under active consideration. While the details in terms of timing and form are uncertain, it is widely accepted that power plants in the US will soon be subject to CO_2 emissions regulation. [12] In addition, EPA recently announced that CO_2 and other greenhouse gases "endanger public health" and therefore can be regulated under the Clean Air Act.[13] This finding alone should encourage DOE to reconsider its analysis of CO_2 emissions in the context of its energy modeling and include projections of emissions reductions under federal greenhouse gas emission constraints.

What Others are Doing

Across industry sectors, there is growing consensus that CO_2 legislation is imminent and should be internalized into financial decisions.[14] Private companies are, in their planning

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[12] See, for example, recent articles in the *New York Times* and CNN suggest that the current administration has begun to respond to the Supreme Court's decision in Massachusetts vs. EPA to regulate carbon dioxide as a pollutant under the Clean Air Act. Additional articles suggest that the current administration is beginning to determine if CO_2 should be regulated under the Clean Air Act. http://www.nytimes.com/2009/02/19/science/earth/19epa.html?hp

[13] "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Proposed Rule," 74 Fed. Reg. 18,886 (April 24, 2009)

[14] The Carbon Disclosure Project (http://www.cdproject.net/) has 3,700 companies across the globe providing climate change data. Additional corporate information and reports has also been collected by Ceres (http://www.ceres.org/) to promote corporate responsibility.

and investment decisions, using price forecasts for CO_2 emissions.[15] A number of investment banks are now considering carbon legislation in their capital financing process.[16]

At the regional and state level, there are a variety of agreements and policies that address CO_2 and other greenhouse gas emissions.[17] In the United States, several states have adopted state greenhouse gas reduction targets of 50% or more reduction from a baseline of 1990 levels or then-current levels by 2050 (California, Connecticut, Illinois, Maine, New Hampshire, New Jersey, Oregon, and Vermont). In 2001, the New England states joined with the Eastern Canadian Premiers in also adopting a long-term policy goal of reductions on the order of 75-80% of then-current emission levels.[18] And in 2008, the ten Northeast and Mid-Atlantic States forming the Regional Greenhouse Gas Initiative (RGGI) held its first auctions for CO_2 emission permits.[19]

[15] A number of corporations have announced goals to reduce greenhouse gas emissions. For example, Disney joins a growing number of companies announcing goals to reduce greenhouse gas emissions from fuel usage by 50% by 2013.
http://corporate.disney.go.com/news/corporate/2009/2009_0309_cr_release.html

[16] http://online.wsj.com/article/SB120209079624339759.html

[17] For example, in 2006, Governor Schwarzenegger signed Bill AB32, the California Global Warming Solutions Act of 2006 that commits the state of California to cap greenhouse gas emissions for 2020 based on 1990 emissions (http://gov.ca.gov/press-release/4111/). RGGI commits ten northeastern and mid-Atlantic states to reduce CO_2 from power generation sources by 10% from 2009 levels by 2018 (http://www.rggi.org/about).

[18] New England Governors/Eastern Canadian Premiers, *Climate Change Action Plan 2001*, August 2001. NEG/ECP reiterated this commitment in June 2007 through Resolution 31-1, which states, in part, that the long term reduction goals should be met by 2050.

[19] Another market signal of the price of carbon dioxide emissions is the selling of climate futures on the Chicago Climate Exchange. Current carbon financial instrument (CFI) futures show a big jump in future contracts that expire in December 2010 compared to January 2013. Contracts that expire in 2010 range in the $2 per metric ton range while contracts set to expire in 2013 range much higher in anticipation of future federal regulation of CO_2 emissions. The first RGGI auction on September 25, 2008 cleared all 12.5 million allowances at a price of $3.07. The second auction on December 17, 2008 cleared all 31.5 million allowances at a price of $3.38.

4. Analysis of DOE's Proposed Value for Carbon Dioxide

DOE and other Federal Agencies are in the midst of a difficult and essential task of estimating the monetary value of reductions in CO_2 and other greenhouse gas emissions. In the interim, DOE proposes to use a limited range of values to reflect the monetary cost of physical damages associated with CO_2 emissions. On its face, it makes sense to equate the benefits of avoided emissions with the economic value of damages that would otherwise be incurred.

However, analysis of the sources underlying DOE's chosen number for its high estimate reveals that adopting a damage-based value belies the uncertain and evolving status of scientific understanding of the physical impacts of climate change; and incorporates myriad assumptions regarding regional and temporal equity and other important policy issues in assigning an economic value to those uncertain physical impacts. DOE relies on the IPCC's Fourth Assessment Report, and in turn, a 2005 paper authored by Richard Tol as its basis for its high estimate for the monetary value of CO_2 emission reductions[20] Even if DOE had considered a range of damage cost studies, including more recent updates from Professor Tol, as the basis for its monetary value of CO_2, damage cost estimates contain too much scientific uncertainty about physical impacts, and too many embedded assumptions about very significant policy issues. In instances where a damage-based estimate is used, selection of the value should acknowledge scientific uncertainties about physical damages, and should include a discussion and explicit consideration of value judgments that are embedded in specific monetized damage estimates.

For its low value, DOE chose to use zero as the monetary value for CO_2. A zero value for the damaged-based cost of carbon implies that the emission of carbon dioxide into the atmosphere is not causing any damages to our society. We believe that the preponderance of scientific evidence is pretty clear that climate change has an associated cost that is greater than zero to society.

The Analysis Underlying DOE's Proposed Value – Tol 2005

The range of the damage-based SCC values in the papers collected and summarized by Tol is tremendous. This range is presented in Tol's paper, and is reported by the IPCC; however, it is not addressed in DOE's NOPR. For the peer-reviewed studies, Tol's mean value of $43/tC in 1995$ ($14.76 in 2009$ per short ton of CO_2) has an "uncertainty range" (the "standard deviation") of $43/tC, which constitutes a high variability in values. The mean value for all 103 estimates is $97/tC ($32.54 in 2009$ per short ton of CO_2) with a standard deviation of $203/tC ($68.10 in 2009$ per short ton

[20] The term "Social Cost of Carbon" is used in economic literature and by the IPCC to denote economic costs of damages from climate change aggregated across the globe and discounted to the present (See IPCC Fourth Assessment Report: Working Group II, 2007). As such the SCC can be considered a proxy of the seriousness of climate change.

of CO_2), suggesting an even larger "uncertainty range" in values. DOE only references the "mean of peer reviewed studies" in its decision to use Tol as the basis of its damage-based value.

Indeed, based on the wide range of values, the IPCC concludes that the damage-based approach may underestimate monetary damages associated with climate change. For example, in its "Summary for Policymakers" from the Fourth Assessment in the same paragraph in which Tol's 2005 study is cited, the IPCC states:

> The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates.

The IPCC further explains:

> It is very likely that globally aggregated figures underestimate the damage costs because they cannot include many non-quantifiable impacts. Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time."[21]

Update of SCC meta-analysis -Tol 2008

To the extent that DOE relies on an damage-based approach, it should adjust its analysis to account for the fact that Tol's 2005 paper has been superseded by a more recent paper in 2008. The newer paper is titled "The Social Cost of Carbon: Trends, Outliers and Catastrophes." It has a larger database of estimates, now up to 211 estimates of SCC from 47 studies in the 2005 paper, done between 1982 and 2006.[22]

We analyzed of the SCC estimates collected by Tol in order to discern the trends over time, the shape of the distribution, and other characteristics of the data set to illustrate the rapid advancement in climate change research. Further discussion of our analysis of the Tol paper may be found in Appendix II to this report.

In the figure below, we show a scatter plot of the estimates over time. The horizontal axis is the year of the estimate of the specific study. The vertical axis is the SCC estimate that we have converted in 2009 dollars per short ton of CO_2, expressed in log terms because of the wide range of the distribution.[23] As shown, the reported SCC estimates appear to vary widely across time with no particular pattern emerging associated with when individual studies were performed.

[21] IPCC. *Summary for Policymakers* in "*IPCC Fourth Assessment Report: Working Group II Report Impacts, Adaptation and Vulnerability"*. 2007. Page 17.
[22] It should be noted that many of the studies in Tol's database were authored or co-authored by Tol himself.
[23] $100 in 1995 dollars is equal to $135.6 in 2009 dollars.

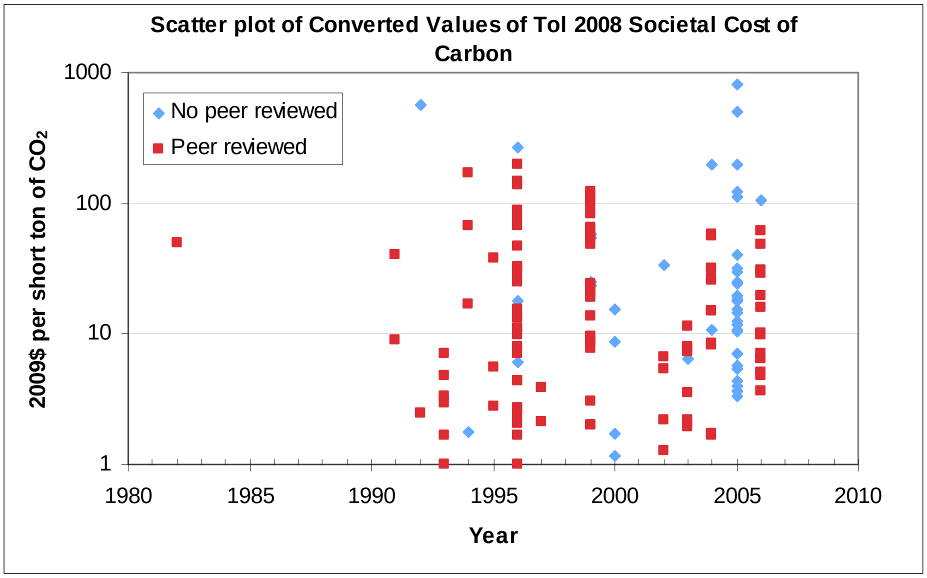

Figure 1 Tol 2008 SCC Scatter plot

In Figure 2, below, we show a frequency distribution of the SCC observations. Note that the higher estimates from the paper are not shown in the figure since they would be far beyond the right edge of the figure. The depicted data in the figure show the highly skewed or asymmetrical shape of the distribution. This skewed distribution highlights the conundrum facing policy makers dealing with climate change. While the median or 50th percentile value may represent serious damages resulting from climate change, the outlying values represent damages of relatively low probability, but potentially catastrophic impact.

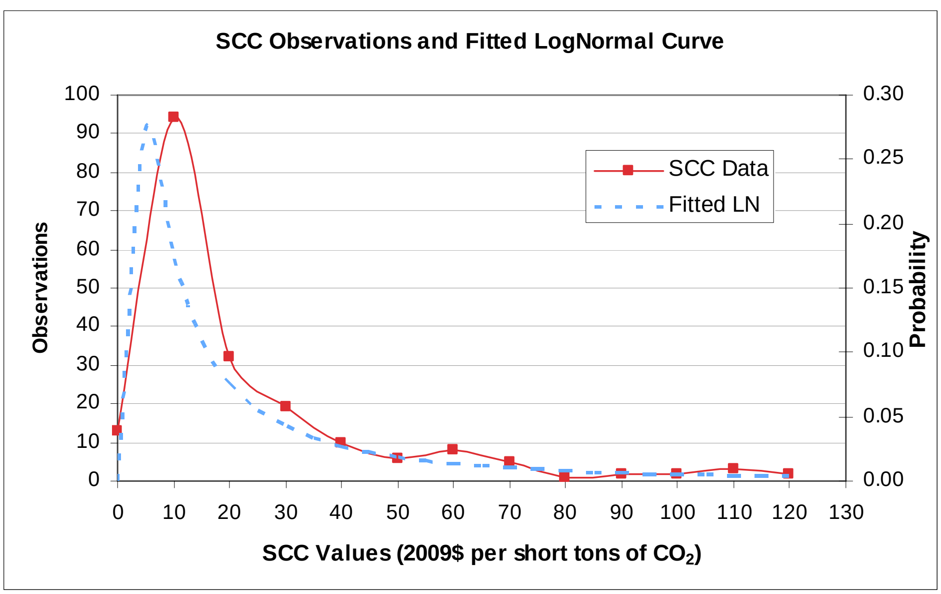

Figure 2 Frequency Distribution of SCC values

In general terms, we can draw parallels between climate policy and insurance. Insurance is not purchased because it is cost effective in the most likely future scenario, or even because it is cost-effective in many future scenarios. One purchases insurance to address the high consequence, but low probability scenario. How these consequences are reflected in a damage-based value is discussed in the next section.

Shortcomings of Damage-based CO_2 Valuation

We have referred to Tol's SCC estimates as "data" but it is important to note that this data is the construct of economic modeling, and not simply observations of physical phenomena. These SCC or damage-based studies are the result of human researchers grappling with a very complex task (some might say impossible) of estimating all of the significant damages from climate change, attaching economic values to them, and then aggregating them over all of the countries and over long periods of time.

There are various methods available for monetizing environmental externalities such as air pollution from power plants. These include various "damage costing" approaches that seek to value the damages associated with a particular externality, and various "control cost" approaches that seek to quantify the marginal cost of controlling a particular pollutant (thus internalizing a portion or all of the externality).

The "damage costing" methods generally rely on travel costs, hedonic pricing, and contingent valuation techniques to value non-market impacts or damages. These are forms of "implied" valuation, asking complex and hypothetical survey questions, or extrapolating from observed behavior. For example, travel cost valuation utilizes data such as how much people spend on travel to go on a fishing trip. That information can be then used to quantify the value of the fish, or more accurately, the associated value of *not* killing fish via air pollution. However, this methodology ignores the existence value of the fish. Human lives are sometimes valued based upon wage differentials for jobs that expose workers to different risks of mortality. In other words, comparing two jobs, one with higher hourly pay rate and higher risk than the other can serve as a measure of the compensation that someone is "willing to accept" in order to be exposed to the risk.

To monetize the avoided damages from GHG emissions, economists make significant assumptions to deal with tremendous uncertainties and value judgments.[24] Reducing the monetized damage values into a single value incorporates determinations made with respect to the impact and value of each of the following:

- **Heating and cooling energy requirements**: Assumes lower heating requirements and increasing cooling requirements if global temperatures rise.

- **Agriculture and Forestry**: Using a simple regression and limited data, models estimate if higher temperatures will result in higher or lower crop yields.

[24] A detailed discussion of this issue is found in Ackerman, F. *Can We Afford the Future?: The Economics of a Warming World.* Zed Books, 2009.

- **Water Resources**: The impact on water availability or unavailability will have a significant impact on a local and regional level. Scaling this into a single number is difficult.

- **Sea Level Rise**: Rising sea levels inundate drylands and wetlands. Individuals who are forced to leave flooded areas will face infrastructure losses, lost commerce, the opportunity costs of using the land, or more complex costs such as the value of existing buffers against storm surge, reduction in fish nurseries in coastal wetlands, or lost coastal groundwater resources, much less the social unrest of displaced persons.

- **Ecosystem Impacts**: The value of species, biodiversity, and landscapes are difficult to monetize, the services provided by natural ecosystems (such as clean air and water, moisture, temperature, and dust regulation, and buffers against natural disasters) cannot be denied and may be quickly lost in a highly uncertain single valuation.

- **Human Morbidity and Mortality**: Increasing evidence suggests that climate change may impact human health across a wide range of factors, from the increasing range of malaria, dengue, and plague, to malnutrition, water shortages leading to cholera, diarrhea, and schistosomiasis, amongst others (Khasnis and Nettleman, 2005).[25] In a social cost model, all of these debilitating and deadly factors simply result in a loss of economic productivity.

- **Human migration**: The impacts of global climate change including sea level rise, water shortages, increasing aridity, and spreading diseases may result in significant forced human migration. Social cost models represent these events as a shifting population with less disposable income.

It is understandable that for the purpose of decision-making, DOE would strive to select a single number that could reflect the vast array of damages from carbon emissions. However, because the impacts of climate change are so varied, spread out geographically, affect such a wide swath of economic activities, and continue to be the subject of scientific analysis, it is important to also understand the projected physical impacts that are being combined into that single dollar value.

Once physical damages have been identified, a damage-based estimate requires making numerous and challenging value judgments in assigning a monetary value to these physical impacts.

One such value judgment that influences the damage-based valuation but is not of a scientific nature is the equity or country weighting across different economic conditions throughout the world. In other words, is the value of an individual life greater in a

[25] Khasnis, A. A. and M.D. Nettleman. 2005. Global Warming and Infectious Disease. *Archives of Medical Research*. **36**:689-696

developed country or an undeveloped country? Sometimes, for example, lost earnings are used as a metric for human life. How this value judgment is incorporated into the development of a damage-based valuation has a profound influence on the modeled output.

Another value judgment arises during the final step in damage-based cost aggregation. Economists typically choose a discount rate, or a time value of money that represents how much should be paid today to avoid a future damages..[26] For short term capital investments, these rates can be quantified relatively easily. But, for long-term cost streams (on the order of centuries), standard discount rates are inappropriate.

With regard specifically to the selection of an appropriate discount rate, we recommend that DOE uses a method for valuing CO_2 that does not discount future impacts to the point that they are effectively ignored. It should be noted that the discount rate applied to near term costs (e.g., manufacturing costs for appliances, or electricity prices for consumers) need not be the same discount rate used for long-term climate change damages. These are fundamentally different impacts.

DOE's Focus on Damages in the United States

DOE's valuation of CO_2 emission benefits is restricted to those costs likely to be experienced in the United States (US). DOE surmises that the costs will likely be a small fraction of the total damages from CO_2 emissions.[27] According to DOE's reasoning, this approach justifies using a low CO_2 value of zero and a high CO_2 value based on the "mean" of the damage-based values estimated in the Tol (2005) article.

While we do not recommend using a damage cost estimate, it is informative to consider damages to get a sense of the scale of the problem. For example, one important recent report by the Stern Review on the Economics of Climate Change, concluded that "the benefits of strong and early action far outweigh the economic costs of not acting." Based on a review of results from formal economic models, the Stern Review estimated that, in the absence of efforts to curb climate change, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever, and could be as much as 20% of GDP or more. In contrast, the Stern Review concluded that the costs of action – the cost of implementing actions to curb climate change – can be limited to around 1% of global GDP each year.[28]

In our view, DOE's decision to exclude the cost of damages which occur outside of the US is unreasonable. US emissions have impacts on others in the world, as other

[26] A more detailed discussion of discount rates, specific to the 2005 Tol article is presented in Appendix II.

[27] This is discussed on page 17012 of the **Federal Register**: "DOE also believes that it is reasonable to allow for the possibility that the U.S. portion of the global cost of carbon dioxide emissions may be quite low. In fact, some of the studies looked at in Tol (2005) reported negative values for the SCC. DOE is using U.S. benefit values, and not world benefit values, in its analysis, and future, DOE believes that the U.S. domestic values will be lower than the global values."

[28] Stern, Sir Nicholas; *Stern Review of the Economics of Climate Change*; Cambridge University Press, 2007.

countries' emissions have an impact on us. As climate change affects the global environment, regional disasters have and will continue to impact the US both domestically and internationally. In terms of cost, the Office of Foreign Disaster Assistance of United States Agency of International Development reported for Fiscal Year 2007 that it had spent $573.4 million to respond to approximately 77 disasters affecting 94 million people in 57 countries.[29] It is impossible to apportion these damages to climate change but the US is clearly spending resources to address natural disaster outside of the US. Within this country, the FY 2007 budget for the Federal Emergency Management Administration (FEMA) was $5.2 billion.[30]

We believe that any monetized CO_2 value should be supplemented by estimating and presenting ranges for the tangible non-monetized impacts (i.e., human morbidity and mortality, number of people displaced by flooded coastlines and water shortages, number of species lost, and so on). Such information would be based in science and would not incorporate the ethical considerations of analysts. The numerous assumptions entailed in consolidating a wide range of impacts into a single value render the dollar value less meaningful than a full representation of physical impacts.

[29] USFDA. Annual Report for FY 2007 Office of US Foreign Disaster Assistance at p. 8.
[30] Department of Homeland Security. Budget-in-Brief FY 2008.

5. Synapse's Recommended Cost of Carbon for Use in Proposed Energy Conservation Standards

The other approach for assigning a monetary value to CO_2 emissions is to estimate the marginal cost of achieving a given emissions target through emissions abatement. The marginal abatement cost approach requires identifying an emissions reduction target for the purpose of the analysis. In this case, we rely on current scientific understanding of the level of atmospheric greenhouse gas concentration (and the associated emissions level) that could avoid the most dangerous climate change impacts. For ease of reference we call this a "sustainability target," though we understand that scientific knowledge continues to evolve and that the use of the term "sustainable" applied to climate change is almost an oxymoron. We then review estimates of the marginal cost of achieving that target through emissions abatement. It is important to note that, at this stage in our collective understanding of the science of climate change, as well as its social, economic, and physical impacts, the notion of a "sustainability target" is a construct useful for discussion, but not yet numerically definitive.

The "sustainability target" approach relies on the assumption that the nations of the world will not tolerate unlimited damages. It also relies partly on an expectation that policy leaders will realize that emission reduction will be cheaper now than the cost of addressing climate change at a future date.[31] It is worth noting that, in theory, a cost estimate based on a sustainability target will likely be a bit lower than a comprehensive damage cost estimate because the choice of a "sustainability target" reflects an assessment of the relative costs of damages and costs that will be incurred to avoid those damages.

Estimating the Long-Run Marginal Abatement Cost of CO_2

We recommend that an estimate of the long-run marginal abatement cost of CO_2 is a practical and conservative measure of the social cost of carbon, and is well-suited for use in DOE's decision-making. To develop that estimate, we reviewed the most recent science regarding the level of emissions that is likely to avoid the most dangerous climate change impacts, as well as the literature on costs of controlling emissions at that level.

Given the daunting challenge of valuing climate damages in economic terms as noted in the previous section, Synapse takes a practical approach consistent with the concepts of "sustainability" and "avoidance of undue risk." Specifically, the carbon externality can be valued by looking at the marginal costs associated with controlling total carbon

[31] A more thorough examination of this issue has been presented in the Stern Review. (Stern, N.H. et al. 2006. *Stern Review: The Economics of Climate Change.* Cambridge University Press, Cambridge). A detailed introduction of strategies to address the idea of stabilizing atmospheric concentrations of carbon dioxide can be found in Socolow and Pacala, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science (*vol. 305) August 13, 2004 (pp. 968-72).

emissions at, or below, the levels that is currently thought to avoid the major climate change risks.

Because the environmental costs of energy production and use are so significant, and because the climate change impacts associated with power plant CO_2 emissions are urgently important, it is worthwhile to attempt to estimate the externality price and to put it in dollar terms that can be incorporated into electric system planning.

What is the Current Understanding of an Appropriate Target Level of CO_2 Emissions?

In order to determine what is currently deemed a reasonable "sustainability target", we reviewed current science and policy regarding the avoidance of dangerous climate change. In 1992, over 160 nations (including the United States) agreed to "to achieve stabilization of atmospheric concentrations of greenhouse gases at levels that would prevent dangerous anthropogenic (human-induced) interference with the climate system…." (United Nations Framework Convention on Climate Change or UNFCCC).[32] Achieving this commitment requires determining the maximum temperature increase above which impacts are anticipated to be dangerous, the atmospheric emissions concentration that is likely to lead to that temperature increase, and the emissions pathway that is likely to limit atmospheric concentrations and temperature increase to the desired levels.

The determination of an acceptable level of temperature change will ultimately be established by politicians, as it requires value judgments about what impacts are tolerable regionally, globally, and over time.[33] We expect that such a determination will be based upon what climate science tells us about expected impacts and mitigation opportunities.

While uncertainty and research continue, a growing number of studies identify a global average temperature increase of 2^{o}C above pre-industrial levels as the temperature above which dangerous climate impacts are likely to occur.[34] Temperature increases greater than 2^{o}C above pre-industrial levels are associated with multiple impacts, including sea level rise of many meters, drought, increasing hurricane intensity, stress on and possible destruction of unique ecosystems (e.g., coral reefs, the Arctic, alpine regions), and increasing risk of extreme events.[35] The European Union has adopted a

[32] There are currently over 180 signatories.
[33] For multiple discussions of the issues surrounding dangerous climate change, *see* Schnellnhuber, Cramer, Nakicenovic, Wigley and Yohe, editors; *Avoiding Dangerous Climate Change*; Cambridge University Press, 2006. This book contains the research presented at The International Symposium on Stabilization of Greenhouse Gas Concentrations, Avoiding Dangerous Climate Change, which took place in the U.K. in 2005.
[34] Mastrandrea, M. and Schneider, S.; *Probabilistic Assessment of "Dangerous" Climate Change and Emissions Scenarios: Stakeholder Metrics and Overshoot Pathways;* Chapter 27 in *Avoiding Dangerous Climate Change*; Cambridge University Press, 2006.
[35] Schnellnhuber, 2006.

long-term policy goal of limiting the increase in global average temperature to 2°C above pre-industrial levels.[36]

Because of multiple uncertainties, it is difficult to define with certainty what future emissions pathway is likely to avoid exceeding a 2°C temperature increase. We reviewed several sources to determine reasonable assumptions about what level of concentrations are deemed likely to achieve the sustainability target, and what emission reductions are necessary to reach appropriate emissions levels. The IPCC's most recent Assessment Report indicates that concentrations of 445-490 ppm CO_2 equivalent correspond to 2° – 2.4°C increases above pre-industrial levels.[37] A comprehensive assessment of the economics of climate change, the Stern Review, proposes a long-term goal to stabilize greenhouse gases at between the equivalent of 450 and 550 ppm CO_2.[38] Recent research indicates that achieving the 2°C goal likely requires stabilizing atmospheric concentrations of CO_2 and other heat-trapping gases near 400 ppm CO_2 equivalent (CO_2-eq).[39]

The IPCC indicates that reaching concentrations of 450-490 ppm CO_2-eq requires reduction in global CO_2 emissions in 2050 of 50-85 below 2000 emissions levels.[40] The Stern Review indicates that global emissions would have to be 70% below current levels by 2050 for stabilization at 450ppm CO_2-eq.[41] To accomplish such stabilization, the United States and other industrialized countries would have to reduce greenhouse gas emissions on the order of 80 – 90% below 1990 levels, and developing countries would have to achieve reductions from their baseline trajectory as soon as possible.[42]

But even this relationship between emissions and atmospheric abundance is fraught with uncertainty because scientists are still working to understand factors. For example, scientist do not know the ultimate GHG absorption capacity of the oceans, how the oceans will change with increasing acidity or altered circulation patterns, and what system feedback loops might be affected. Modeling studies suggest that (1) the slow and predictable impacts increase with increasing CO_2 abundance in the atmosphere, and (2) the likelihood of catastrophic impacts (i.e., hitting thresholds) is lower with lower CO_2 in the atmosphere. On this second point, the IPCC has determined that a 2°C

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[36] The European Union first adopted this goal in 1996 in "Communication of the Community Strategy on Climate Change." Council conclusions. European Council. Brussels, Council of the EU. The EU has since reiterated its long-term commitment in 2004 and 2005 (see, e.g. Council of the European Union, Presidency conclusions, March 22-23.)
[37] IPCC AR4, WGIII Summary for Policy Makers, 2007. Table SPM5.
[38] Stern, Sir Nicholas; *Stern Review of the Economics of Climate Change*; Cambridge University Press, 2007.
[39] Meinshausen, M.; *What Does a 2°C Target Mean for Greenhouse Gases? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates;* Chapter 28 in *Avoiding Dangerous Climate Change*; Cambridge University Press, 2006.
[40] IPCC AR4, WGIII Summary for Policy Makers, 2007. Table SPM5.
[41] Stern Review, Long Executive Summary, 2007. Page xi.
[42] den Elzen, M., Meinshausen, M; *Multi-Gas Emission Pathways for Meeting the EU 2°C Climate Target;* Chapter 31 in *Avoiding Dangerous Climate Change*; Cambridge University Press, 2006. Page 306.

temperature increase is the level at which we are unlikely to hit the thresholds and the impacts will be more manageable.

The sobering news is that a long term stabilization goal of even 400 ppm might not be sufficient. One 2006 study concludes, for example, that “while very rapid reductions can greatly reduce the level of risk, it nevertheless remains the case that, even with the strictest measures we model, the risk of exceeding the 2ºC threshold is in the order of 10 to 25 per cent.”[43] Similarly, a 2009 analysis estimates that if global emissions in 2050 are half 1990 levels, there is a 12–45% probability of exceeding 2^{o}C.[44] Further, the 2ºC threshold may not be sufficient to avoid severe impacts.[45] Nevertheless, the goal of policymakers seems to be coalescing around maintaining global temperatures increases at or below 2°C above pre-industrial levels.

What is the Cost of Stabilizing CO_2 Emissions at this Target Level?
There have been several efforts to estimate the costs of achieving a variety of atmospheric concentration targets. The IPCC has undertaken the most comprehensive effort in this area, as DOE recognizes. In its fourth Assessment Report, the IPCC indicates that annual reductions on the order of 34 metric gigatonnes (Gt) would be necessary to achieve an 80% reduction below current emission levels. [46] That report estimates that up to 31 Gt in reductions are available for $97 per short ton of CO_2 in 2009$ or less (Working Group III Summary for Policy Makers).[47] Other recent studies on the costs of achieving stabilization targets include the following:

- The International Energy Agency (IEA) has modeled the implications and results of two international policy framework scenarios: (1) achieving 550 ppm (to limit temperature increases to 3oC), and (2) achieving 450 ppm (to limit temperature increase to 2^{o}C).[48] IEA projects that a cap and trade program would result in

[43] Bauer and Mastrandrea; *High Stakes: Designing emissions pathways to reduce the risk of dangerous climate change;* Institute for Public Policy Research, U.K.; November 2006.
[44] Meinshausen et. al.; *Greenhouse-gas emission targets for limiting global warming to 2^{o}C*; Nature, Volume 458, April 30, 2009.
[45] See recent research by James Hansen, Goddard Space Flight Institute – NASA’s top climate scientist.
[46] 2000 emissions levels were 43Gt CO_2-eq. IPCC AR4, WGIII, Summary for Policy Makers, 2007, at p. 11.
[47] Original value of $100 per metric ton of $CO_{2\text{-eq}}$ in 2006 dollars.
[48] IEA *World Energy* Outlook 2008. WEO 2008 demonstrates how an energy revolution, to achieve a low carbon efficient and environmentally benign system of energy supply, can be achieved through decisive policy action and at what cost. The choice of appropriate global emissions trajectory will have to take into account technological requirements and costs in the energy sector. The WEO-2008 provides analysis to help policy makers around the world assess and address the challenges posed by worsening oil supply prospects, higher energy prices and rising emissions of greenhouse gases. WEO-2008 takes a detailed look at the prospects for oil and gas production. It also analyzes policy options for tackling climate change after 2012 when a new global agreement – to be negotiated at the U.N. Conference of the Parties in Copenhagen next year – is due to take effect. The analysis assumes a hybrid policy approach, comprising a plausible combination of cap-and-trade systems, sectoral agreements and national measures.

carbon prices of \$85 per short ton CO_2 in 2030 under the 550 ppm scenario, and \$170 per short ton CO_2 in 2030 under the 450 ppm scenario.[49]

- The IEA has also performed an intensive analysis of technologies available to achieve significant greenhouse gas emissions reductions. In its Technology Perspectives 2008, IEA projects that the marginal cost of technologies necessary to reduce emissions in 2050 to current levels (the ACT Map Scenario) would be \$50.10 per short ton CO_2 in 2009\$.[50] The marginal cost of technologies necessary to reduce emissions in 2050 to 50% below current levels (the Blue Map Scenario, and the low end of what IPCC projects is necessary for a 2°C temperature increase) would be up to \$200 (2009\$) per short ton CO_2 when fully commercialized. If technological progress fails to meet expectations, marginal costs could be as high as \$501 (2009\$) per short ton of CO_2.[51] IEA notes that its marginal cost figure for the ACT Map Scenario is nearly twice that in the *Energy Technology Perspective* 2006, primarily due to accelerated trends in CO_2 emissions and an approximate doubling of engineering costs.[52]

- McKinsey has produced a second version of its Global Greenhouse Gas Abatement Cost Curve.[53] In this analysis, McKinsey determines that only what it defines as the "Global Action" and "Green World" scenarios are consistent with a sustainability goal of avoiding more than a 2°C temperature increase. In the most aggressive scenario, the "Green World" scenario, all countries would capture one hundred percent of abatement options that cost approximately \$75 per short ton or less, all technical potential options costing up to approximately \$125 per short ton CO_2, and all behavioral change potential would be captured. McKinsey states that transaction and program costs, that are not part of the abatement cost curve, are often estimated at an average between one and eight percent per ton of CO_2 abated.

Prior to these most recent studies, the IPCC Working Group III Summary for Policy Makers states that "An effective carbon-price signal could realize significant mitigation

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[49] The WEO-2008 values are reported in \$2007 per metric ton. Original values of \$90 per metric ton for the 500 ppm scenario and \$180 per metric ton for the 450 ppm scenario.
[50] Original costs are in real 2005 US dollars of \$50 per metric ton of CO_2.
[51] Original values of \$200 and \$500 per metric ton in 2005\$.
[52] IEA *Technology Perspectives 2008*. The introduction to the ETP states that its purpose is to explain how the global energy economy can be transformed over the coming decades to avoid "unsustainable pressure on natural resources and on the environment." ETP 2008 presents "an in depth review of the status and outlook for existing and advanced clean energy technologies, offering scenario analysis of how a mix of these technologies can make the difference."
[53] McKinsey & Company; *Pathways to a Low-Carbon Economy- Version 2 of the Global Greenhouse Gas Abatement Cost Curve*; 2009. McKinsey has developed a global greenhouse gas abatement database to provide a quantitative basis for international discussions of greenhouse gas emissions reduction targets. The current version builds on an earlier version published in 2007 and incorporates updated and more sophisticated assessment of low-carbon technologies, regional and industry-specific abatement opportunities, and investment and financing needs, as well as review of implementation scenarios and how abatement could develop.

potential in all sectors."[54] IPCC explains that modeling studies show that, to achieve stabilization at around 550 ppm CO_2-eq by 2100, carbon prices would rise to between $19-$78 per short ton of CO_2-eq by 2030 and $29-$151 per short ton of CO_2-eq by 2050.ppm CO_2-eq by 2100.[55] IPCC notes for the same stabilization level, studies since the Third Assessment Report, that take into account induced technological change, lower these price ranges to between $5-$63 per short ton of CO_2-eq in 2030 and $15-$126 per short ton of CO_2-eq in 2050.

IPCC finds that most top-down, as well as some 2050 bottom-up assessments, suggest that real or implicit carbon prices of $19 to $49 per short ton of CO_2-eq, sustained or increased over decades, could lead to a power generation sector with low-greenhouse gas emissions by 2050 and make many mitigation options in the end-use sectors economically attractive.

A summary of the aforementioned study findings are presented in the table below, in both their original values and units and converted to 2009$ per short ton of CO_2 values.

Study Source	Study	Analysis End Year	Scenario	Value	Units	Value (2009$/short ton CO2)
McKinsey & Company	Version 2 of the Global Greenhouse Gas Abatement Cost Curve	2030	Global Action	€ 60.00	2005 Euro/metric ton CO2	$74.87
		2030	Greenworld	€ 100.00	2005 Euro/metric ton CO2	$124.78
Internation Energy Administration	World Energy Outlook 2008	2030	550 ppm	$90.00	$2007/metric ton CO2	$85.07
		2030	450 ppm	$180.00	$2007/metric ton CO2	$170.14
Internation Energy Administration	Energy Technology Perspective 2008	2050	ACT Map	$50.00	$2005/metric ton CO2	$50.10
		2050	Blue Map	$200.00	$2005/metric ton CO2	$200.38
			Average			$117.56

Notes

2005 Euros converted to 2005 US dollars based on average exchange rate of 1:1.245 Euro to Dollars from www.oanda.com

2007$ converted to 2009$ based on GDP chain type values for 2007(119.82) and 2009 (124.86) from http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=13&FirstYear=2002&LastYear=2004&Freq=Qtr
One metric ton equals 1.102 short tons

Table 2 Carbon Emission Studies Summary

A Recent Meta-analysis of Marginal Abatement Costs - Kuik et al.

A recent meta-study authored by Onno Kuik, Luke Brander, and Richard Tol takes a slightly different approach to develop (through regression modeling) a marginal

[54] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[55] Data originally presented as 20 to 80 US$/tCO2-eq by 2030 and 30 to 155 US$/tCO2-eq by 2050 in 2006$.

abatement cost for greenhouse gas emissions.[56] This paper investigates the marginal abatement costs derived from 26 studies necessary to achieve long-term stabilization of greenhouse gases in the atmosphere. The "control cost" methods generally look at the *marginal* cost of control; i.e., the cost of control valuations look at the last (or most expensive) unit of emissions reduction required to comply with regulations. The cost of control approach can be based upon a "regulators' revealed preference" concept. In other words, if "air regulators" are requiring a particular technology with a certain cost per ton to be installed at power plants, then this can be taken as an indication that the value of those reductions is perceived to be at or above the cost of the controls.

To be clear, unlike the studies at issue in Tol 2005, these studies do not look at the cost of damages, but instead focus on the control cost (marginal abatement cost) associated with meeting a specific target concentration. Kuik et al. investigated a range of atmospheric concentration targets of 450 to 650 parts per million of $CO_{2\ eq}$. This approach sidesteps some of the issues associated with the damage-based valuation, in that it is not necessary to estimate the cost of damages resulting from climate change in each study.

In our analysis we present the marginal abatement costs for 2050 summarized by Kuik et al. in their analysis. A frequency distribution of the 2050 marginal abatement costs converted to 2009$ per short ton of CO_2 is presented in Figure 3.[57]

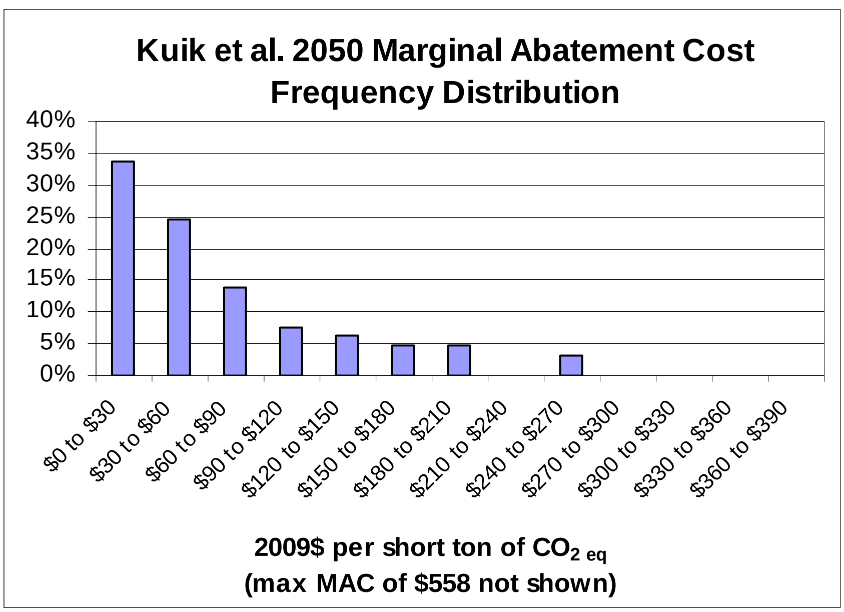

Figure 3 2050 MAC Frequency Distribution

[56] Kuik, O., Brander, L., Tol, R.S.J. 2009. Marginal abatement costs of greenhouse gas emissions: A meta-analysis. *Energy Policy,* **37:**1395-1403.
[57] Raw data provided in $ per metric ton of carbon via personal correspondence with Onno Kuik. Data converted to 2009$ and short tons by Synapse Energy Economics.

Like the damage-based studies at issue in Tol 2005, the studies analyzed by Kuik et al. show a right skewed distribution, meaning that there is a high cost associated with uncertainty. However, the uncertainty associated with the approach applied by Kuik et al. results from the uncertainty of costs in addressing climate change (e.g., effectiveness of carbon capture and sequestration is still unknown), not with the uncertainty of the cost of damages associated with the damage-based approach..

Based on a review of these different sources, we recommend that DOE adopt an estimated marginal abatement cost of \$80/tCO_2-eq (\$88/metric ton CO_2) in evaluating its proposed energy conservation standards. This value is comfortably within the range of current estimates of the marginal abatement costs for achieving a stabilization target that is likely to avoid temperature increases higher than 2^{o}C above pre-industrial levels. We believe that applying this number is a practical and conservative approach to incorporating the Societal Cost of Carbon in benefit/cost analysis. Nevertheless, we recognize that there is a wide range of uncertainty and there are numerous unresolved matters including an appropriate atmospheric concentration, and emissions reduction target. Nevertheless, our recommended value provides a reasonable method for taking the benefits of GHG emission reductions into account in evaluating energy efficiency measures. Clearly, some estimates are lower, and some estimates are much higher, reflecting a variety of effects including assumptions about technological innovation, emission reduction targets, technical potential of certain technologies, international and national policy initiatives, and the list goes on. Of course, selection of this value requires multiple assumptions and cannot be definitive given the quickly evolving combination of scientific understanding of the causes, effects and scale of climate change, international policy initiatives, and technological advances. It will be necessary to continuously review available information, and determine what value is reasonable given information available at the time of reviews.

6. Conclusion

Based on our analysis of DOE NOPR and research, Synapse concludes the following:

- DOE's effort to take into account a monetary benefit of CO_2 emissions reductions associated with its proposed conservation standards is both timely and essential.

- DOE's monetary value of CO_2 emissions reductions should not incorporate a damage-based estimate of a social cost of carbon. The range of the damage-based values in the papers collected and summarized by Tol 2005 is tremendous, and is in our view more important than the specific "mean of peer reviewed studies" that DOE relies upon. Additionally, the studies that are analyzed by Tol, and relied upon indirectly by DOE, are highly dependant upon not just scientific uncertainties (e.g., the climate models) but also upon a number of ethical assumptions, most importantly the assumed discount rate and the equity weighting.

- Using a damage-based estimate of the social cost of carbon reduces all of the species impact, health impacts and societal impacts of climate change into a single number. While easy to comprehend, this number oversimplifies the complex policy and societal choices that need to be made to address the climate change issue.

- DOE's proposal to restrict its consideration to U.S. damages only is inappropriate. DOE puts considerable emphasis on its intention to count only the US portion of the global cost of CO_2 emissions, and points out that this is likely to be a small fraction of the total damages from CO_2 emissions. This becomes the justification given for using a low value of zero and for picking a high value of $20 per ton based on the "mean" values estimated from damage-based models.

- A long-run international marginal abatement cost of carbon is a practical and conservative measure of social costs of carbon, and should be incorporated into DOE's conservation standard analyses. We recommend that DOE use a marginal abatement cost (2009$) of $80 per short ton of CO_2 ($88 per metric ton CO_2) that incorporates findings from a recent meta-analysis of marginal abatement costs and from recent abatement cost analyses published by both international agencies and multinational consultancies. These studies all find marginal abatement cost values that are much higher than the $20 per metric ton of CO_2 currently proposed by DOE.

Appendix I Allowance Pricing for CO_2 in DOE's Electricity Price Projections

We note that the NEMS-BT model used to estimate CO_2 emission benefits resulting from the proposed TSLs does not include a CO_2 price in determining electricity usage and impacts of CO_2 regulation upon the energy markets. This practice is consistent with DOE's treatment of policies in its Annual Energy Outlook reference case where it only models existing policies in an effort to remain policy neutral, However given the current status of actions taken by corporations, states, and regions, and the likelihood of federal carbon constraints; we believe it is warranted for DOE to incorporate some level of CO_2 pricing in its electricity consumption model in evaluating energy efficiency standards.

From a technical standpoint, the value of CO_2 emissions could easily be included as part of the electricity modeling. We recognize that the AEO 2009 reference case does incorporate some acknowledgement of a cost associated with greenhouse gas emissions., *AEO* 2009 states that the reference case includes "a 3-percentage-point cost of capital penalty has been added when evaluating investments in GHG intensive technologies. "[58] However, we believe this approach is inadequate. A three percentage point change translates to approximately $10 to 15 per MWh or $10 to $15 per ton of CO_2, based on capital cost estimate of $4,000/kW for a coal-fired plant.[59] The risk premium is added "to GHG-intensive projects to account for the risk that they may have to purchase allowances or make other investments in the future to offset GHG emissions."[60]

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We believe a preferable approach would be for DOE, for its benefits calculation, to use an electricity price forecast that includes the reasonably expected emission allowance prices for CO_2[61] or, alternatively, add this price in at the end recognizing that it is an expected market cost for emitting CO_2.

We recommend that DOE use as a starting point a NEMS model case that includes either some estimate of federal CO_2 regulation or some allowance price for CO_2 emissions.

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[58] http://www.eia.doe.gov/oiaf/aeo/pdf/aeo2009_presentation.pdf (p. 22)

[59] EIA *AEO 2008* estimates for overnight capital costs are $1,534/kw as noted in http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/tbl38.pdf. Rationale for higher coal capital costs are documented in "Coal Fired Construction Costs" July 30, 2008. http://www.synapse-energy.com/Downloads/SynapsePaper.2008-07.0.Coal-Plant-Construction-Costs.A0021.pdf

[60] http://www.eia.doe.gov/oiaf/aeo/pdf/aeo2009_presentation.pdf (p. 22)

[61] We use the term "allowance price" here, but this could also be a carbon tax or other form of internalized market cost. This is different from the "societal cost of carbon," which gets to the external costs, or "externalities." These include the damages from CO_2 emissions that are not "internalized" in the costs borne by entities in the energy markets.

Appendix II Review of Tol 2008 Paper on the Societal Cost of Carbon

Of the 47 separate studies cited in the Tol (2008) metastudy, less than half have an "independent estimate" of the cost according to Tol's criteria, and half of those are by three prolific authors (including Tol). A majority of these were published before the year 2000. Many of the studies that publish damage figures are derivations and theoretical exercises, exploring different discount rates, damage functions, or interesting scenarios, and cannot be considered independently derived datasets. While the studies all raise important questions there is a nearly universal acknowledgement that "a cost-benefit analysis cannot be the whole argument for abatement. Uncertainty, equity, and responsibility are other, perhaps better reasons to act."[62]

Reasons for and Implications of the Wide Range in SCC Estimates

The distribution of SCC estimates has many causes. These include methodological variations, and differences in what is excluded from the analysis. They also include differences in the underlying models for what the quantitative physical impacts of climate change are. Perhaps most importantly, however, the differences in SCC result from differences in how the various impacts are aggregated across individuals in different parts of the world (this includes the "equity weighting" issue) and differences in how the impacts are valued over time.

The published values for the social costs of climate change range from negative values (a net benefit) to $2,400 per ton of carbon in 1995$. According to the Tol (2008) meta-study, the average value of all studies ranges from $88 to $127 per ton carbon in 1995$, but the standard deviation (indicating the range of values proposed by researchers) is much greater than the average, suggesting significant uncertainty even among researchers. Further, the combined metastudy indicates that an unusually large number of studies estimate very high damage costs.[63] As noted in Guo et al. (2006), "the enormous range of estimates in the damage-based estimates reflects both the sheer size of the uncertainties in our understanding of future climate change, future socioeconomic variables, and also the particular ethical parameters adopted in each model."[64] The Stern Review on the Economics of Climate Change (2006), a report commissioned by the British government, derived a cost of approximately $314 per ton of CO_2 eq.[65]

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[62] Tol, R.S.J. and G.W. Yohe. 2007. A Stern Reply to the Reply to the Review of the Stern Review. World Economics. **8**:2:153-159

[63] The distribution in the Tol (2008) meta-study is non-normal and has a "fat-tail", indicating that there are more studies which suggest a high damage cost than would be expected in a normal distribution of the data.

[64] Guo, J., C.J. Hepburn, R.S.J. Tol, D Anthoff. 2006. Discounting and the social cost of carbon: a closer look at uncertainty. *Environmental Science and Policy*. **9**:205-216.

[65] Stern (2006)

Discount Rate Implications

Global climate damages from a ton of CO_2 emissions today will occur over many decades. The economic models used to estimate damages generally contain a "discount rate" assumption which specifies how much future damages are worth relative to near term damages. Figure 4, below shows a scatter plot of the SCC estimates according to the assumed consumer discount rate (CDR).[66] The CDRs range from zero to 10 percent, with many of the estimates in the 2 to 5 percent range. A 3 percent discount rate would imply, for example, that an impact valued at $100 dollars fifty years from now, would be worth only $23 today. Or, looking out further, and impact valued at $100 dollars one hundred years from now would be worth only $5 today. Impacts out beyond 100 years are effectively discounted to insignificance.

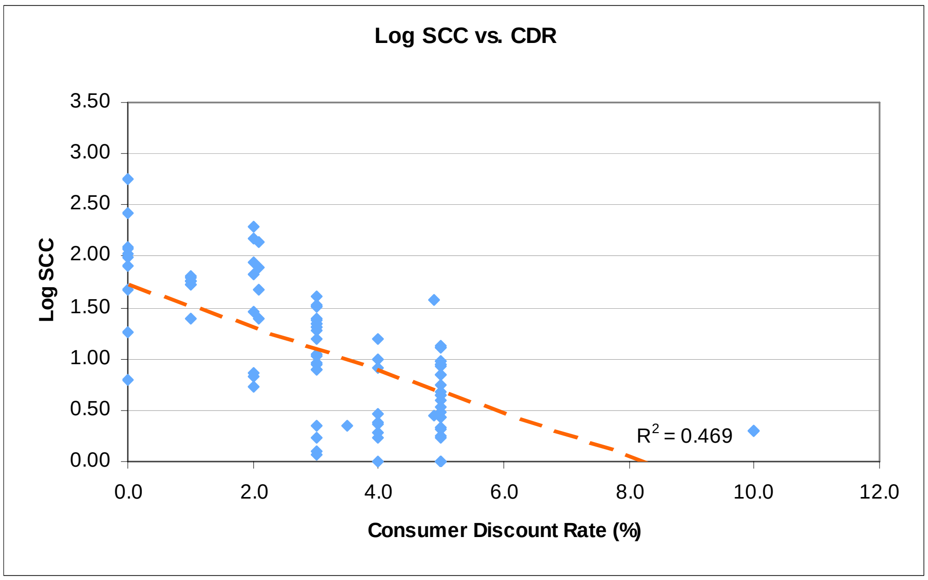

Figure 4 Scatter plot of Log SCC versus CDR

As illustrated in Figure 4, there is a wide range of Log SCC values at any given discount rate; however the assumed discount rate is one of the key factors in explaining the variation in the estimates.[67] The r-squared value of 0.469 suggests that about 46.9% of the variability of the Log SCC values may be attributed by changes in the consumer discount rate. There are arguments for discounting, and for evaluating financial investment decisions over reasonably short time periods, even several decades, are compelling. For public policy questions, however, involving very long time periods or

[66] The Tol SCC values have been converted from 1995 dollars per metric tons of Carbon to 2009 dollars per short ton of CO_2.

[67] Since the distribution of SCC values is skewed by very high values; transforming the data with a log function normalizes the distribution to assist in the analysis.

very large impacts (such as climate policy) economic discounting becomes a more important topic of discussion.[68]

[68] The Office of Management and Budget has very specific guidelines on the use of discount rates and public policy (http://www.whitehouse.gov/omb/circulars/a094/a094.html). Discussion of appropriate discount rates to assess climate change policy impacts is the subject of much scholarly debate. Participants include many of the authors cited throughout this paper. A detailed discussion of the discounting issue with regards to climate change may be found at Ackerman, F. *Can We Afford the Future?: The Economics of a Warming World.* Zed Books, 2009.