PREPARED STATEMENT OF GARY W. YOHE

John E. Andrus Professor of Economics
Wesleyan University
Middletown, CT 06459

gyohe@wesleyan.edu

Thursday, March 30, 2006

Mr. Chairman, Senator Biden, and Members of the Committee on Foreign Relations, thank you for your invitation to present testimony in on "The Hidden (Climate Change) Costs of Oil". It is indeed an honor to be here, today.

The task that I accepted when I agreed to testify involves providing some insight into the economic cost of carbon emissions so that you can "back out the share of oil to get the right order of magnitude". I am afraid, however, that this deceptively complicated question has the same answer as nearly every other question in economics: "It depends." My testimony will therefore be directed at providing insight into the underlying factors upon which these costs depend. I will, however, also offer some thoughts about what the underlying uncertainty means for climate policy and the hidden cost of oil.

I will begin with a brief review of the range of more than 100 published estimates of what is termed the "social cost of carbon"; this is the calculation by which we can attribute a share of cost to oil based on its carbon content (per unit energy). I will highlight why the range of these estimates is so large. I will suggest which of the factors that make the range so large can be influenced by political decision-makers, but I will also focus attention on scientific factors that are beyond their control. Thinking about how we should cope with these scientific factors will lead me to identify two fundamental sources of hidden cost that may not be immediately obvious.

I will, in particular, suggest an alternative way to calculate the hidden climate costs of oil based explicitly on hedging against the potentially *severe economic costs of abrupt changes in policy*. These policy adjustments may be required over the near to moderate term as we come to know more about the impacts and/or likelihoods of climate change (particularly abrupt climate change). It is important to recognize that many of these impacts have not yet been included in the direct calculation of social cost. Adopting a risk-management (hedging) approach to minimize the cost of future policy adjustments is therefore an appropriate, economically rational way to think about the social cost of carbon. Moreover, it makes uncertainty a reason to act immediately rather than a reason to procrastinate.

I will, as well, argue that ignoring social costs calculated by either a tradition direct method or one derived from a risk-management approach systematically undervalues projects and programs that would reduce our consumption of petroleum (like

investment in ethanol as an alternative source of energy) while it produces an symmetric overvaluation of projects and programs that would do just the opposite (like drilling in the Arctic National Wildlife Refuge).

To begin, I recall "burning ember" diagram from the Third Assessment Report (the TAR) of the Intergovernmental Panel on Climate Change (2001) in Figure 1. It duplicates Figure TS-12 from the Technical Summary of the Third Assessment Report where five Lines of Evidence" were identified. These are the five sources of concern, or indicators of vulnerability, that have captured our attention. Two are essentially economic indicators of aggregate impacts at the global and regional levels. They are dominated by estimates of the costs of the climate impacts in market-based sectors like real estate (in response to rising seas), agricultural, energy, and the like. As such, they do include evaluations of how various nations and even communities within nations might adapt to climate-related stress. It is important to recognize, of course, that these impacts are felt unevenly across the globe. Panel A of Figure 2 offers a representative portrait of a possible geographic distribution of vulnerability to climate impacts in 2050 calibrated in terms of aggregate impacts. Developing countries show up as most vulnerable, but developed countries are surely not immune to climate risk *even when their superior capacities to adapt are recognized.*

A third row in Figure 1 focuses attention squarely on ecosystems, although the IPCC did not provide the detailed assessment of ecosystem services that was so thoroughly documented in the recently completed Millennium Ecosystem Assessment. The last two rows reflect vulnerability to two potentially more significant areas concern: "Risks from Future Large-Scale Discontinuities" and "Risks from Extreme Weather Events". Figure 2 illustrates the uneven impact point by displaying a plausible global distribution of vulnerability in 2050 calibrated to the risks of extreme weather events. Developing countries are still most vulnerable, but developed countries also face significant vulnerabilities from a more urgent "source of concern".

Economists have been trying for some time to assign currency values to the impacts of climate change identified in Figure 1 by tracking their potential trajectories along long-term scenarios of how the future might unfold. Not surprisingly, economists do not agree on what that future might hold. They do, however, agree on what measure to use: "the social cost of carbon". What is that? It is the damage caused over time by releasing an addition unit of ton of carbon in the atmosphere discounted back to the year of its emission. That is to say, the social cost of carbon represents the "marginal cost" of emissions; alternatively, it represents the "marginal benefit" of unit of carbon emissions reduction. Most importantly for present purposes, the social cost of carbon, when modified by the carbon content of petroleum, is the hidden (climate change) cost of oil.

Figure 3 displays the range of more than 100 estimates currently available in the published literature; it is derived from Tol (2005). Panel A of Figure 3 displays the social cost in dollars per metric ton of carbon; Panel B tracks the estimate to the hidden cost of oil by expressing social cost in dollars per barrel of oil.

How should the data portrayed in Figure 3 be read? Percentile values are recorded up the vertical axis for cost estimates ordered from lowest to highest. So, for example, point A indicates that 12% of the published estimates were below $0. Point B highlights the median estimate, suggesting that 50% of the estimates were below $13 per ton of carbon ($2 per barrel of oil), and 50% of the estimate were above this benchmark. Point C shows that 20% of the estimates were above $73 per ton of carbon ($9 per barrel of oil). Finally, the average across all of the published estimates is $85 per ton ($11 per barrel of oil).

How should the content of Figure 3 be read, given all of the disagreement that it reveals? Richard Tol, an economist from Germany, read the data to mean that $45 per ton should be interpreted as the upper bound for a reasonable "best" estimate of the social cost of carbon; this is $6 per barrel of oil. Thomas Downing (2005), a geographer from the Stockholm Environment Institute office in the United Kingdom looked at the same distribution through the lens of enormous experience in developing countries where changes in climate produce enormous displacement effects that cannot be quantified in terms of currencies. He read the data to mean that $45 per ton or $6 per barrel of oil should be interpreted as a lower bound to the true social cost of carbon.

I have been told that presenting such a figure in a political environment would allow people who do not think that climate is a problem to focus on the lower part of range and people who think that climate is a large problem to focus on the upper part of the range. Productive conversations between the two sides, I have also been told, would seldom be a product of such readings.

For this, and a few other reasons, I now preach caution to all. To appropriately read Figure 3, we must work to understand what is going on behind the scenes. Why is the range so large? Which of the "Lines of Evidence" do the estimates include, and which do they miss? What combinations of underlying factors produce low or even negative estimates of social cost, and what other combinations support estimates on the high end of the scale? Answers to these questions can be enormously revealing.

The choice of discount rate and the incorporation of equity weights are extremely important, and both lie within the purview of decision-makers. High discount rates sustain low estimates because future damages become insignificant. Conversely, low discount rates produce high estimates because future damages are important. Meanwhile, strong equity weighting across the globe support high estimates because poor developing countries are most vulnerable. Conversely, weak or no equity weighting can produce low estimates because poor developing countries do not factor heavily in the overall calculation.

It turns out, however, that several scientific parameters that decision-makers cannot choose are even more important in explaining the variability depicted in Figure 3. Indeed, climate sensitivity (i.e., the increase in global mean temperature that would result from a doubling of greenhouse gas concentrations from pre-industrial levels) is the largest source of variation. It is possible to derive high estimates for the social cost of

carbon even if you assume low discount rates and almost no equity weighting. All that is required is the assumption that the climate sensitivity lies at the high range of the latest range of estimates. Andronova and Schlesinger (2001), for example, find that the historical record could easily be explained with climate sensitivities as high as 8 or 9 degrees Centigrade (even though the TAR reported an upper bound of 5.5 degrees).

Moreover, none of the estimates from which Figure 3 was drawn include the economic costs of "Risks from Extreme Climate Events" or "Risks from Future Large-Scale Discontinuities".

To offer one glimpse at the role that these sources of concern might play, I can report the results of some more recent work that focuses on what we know about when the Atlantic thermohaline circulation (the Gulf Stream when it flows close to the United States) might weaken or suddenly collapse. Schlesinger, et al. (2006) put the chance of collapse at 50% if the global mean temperature were to climb by another 2 degrees Centigrade. Put another way, Yohe, et al. (2006) show more than a 40% chance of collapse by 2105 along a "middle of the road" emissions scenario. Imposing a *global policy* targeted at a $100 per ton social cost of carbon ($12 per barrel of oil) would reduce that likelihood to 25% if it were initiated immediately; but only to 35% if it were delayed by 30 years.

At this point, it is essential to re-emphasize the point that none of these critical scientific factors can be decided by committee deliberation and popular elections. Their values are up to nature to decide, and we simply do not know what she has in the cards for us. The bottom line is that the planet faces significant risks whose economic impacts have not yet been quantified. We have some idea of their likelihood, though, and so it is impossible to claim with certainty that they will not materialize as the future unfolds.

What should we do? We should recognize that the climate policy will be adjusted over time as we learn more, especially if all (or even one) of the really bad news scenarios begin to materialize. We should also recognize that these adjustments could significantly and immediately change the economic environment in which we will be living. Moreover, we should recognize that these adjustments might be required sooner rather than later.

All of this risk in the policy realm suggests an alternative method for estimating the social cost of carbon. Yohe, et al. (2004) conducted a simple "act-then-learn" experiment which showed that the expected discounted *cost of global policy adjustment* in 2035 could be minimized if a modest hedging policy were begun now. Their work suggests a risk-based social cost of carbon in 2005 equal to about $10 per ton ($1.50 per barrel of oil). And their approach makes uncertainty is THE reason to act in the near term rather than a reason to delay.

To be clear, tacking on $1.50 to the price of a barrel of oil will not do the trick. This risk based social cost would increase over time at the rate of interest. So it would be $3 per barrel in 2020 and $5 per barrel just after 2030. The critical component of the

policy, and this estimate of social cost, is not the starting point. Consistent with the observation by Watkiss, et al. (2005) that the traditionally computed social cost of carbon increases over time, *it is the persistent and predictable ratcheting-up of the effective price of carbon* that would give the hedging strategy any traction at all.

This observation brings me to my last point – identifying a second potentially expensive consequence of ignoring the hidden climate cost of oil. Failing to include estimates of the social cost of the carbon content of oil simply makes projects that use more oil or provide more oil more likely to go forward. Why? Because the calculations upon which the investment decisions would be made would inappropriately underestimate true costs. They would, in other words, show exaggerated benefit-cost ratios because the denominators would be too low. Conversely, failing to include the social cost of the carbon content of oil makes projects that conserve oil or provide alternative sources of energy less likely to go forward. They would simply show deflated benefit-cost ratios because the numerators would be too low.

So, what if I had to pick a number? What would I say if asked to estimate place the hidden social cost of oil in perspective? I think that my $1.50 per barrel risk-based estimate is too low, since our analysis assumed immediate global participation in any policy response 2005 and it captured only a very limited set of possible sources of uncertainty. Given all of the impacts that are not yet part of the more traditional approaches, though, I do not think that the $6 per barrel estimate that separated Tol from Downing is too high. If pressed, I would probably say $5 per barrel for 2006, but I could be just as comfortable with $10. Indeed, I would insist only that the social cost attributed to oil for its climate impacts increase over time at the real rate of interest.

Again, thank you for the opportunity to be here today, and thank you for your attention.

References

Andronova, N.G. and M.E. Schlesinger, 2001, "Objective estimates of the probability density function for climate sensitivity", *Journal of Geophysical Research* **106** (D19): 22605.

Downing, T., et al, 2005, "Social Cost of Carbon: A Closer Look at Uncertainty, Final Report", Stockholm Environment Institute for the United Kingdom Department for Environment, Food, and Rural Affairs.

Intergovernmental Panel on Climate Change (IPCC), 2001, *Climate Change 2001: Impacts, Adaptation and Vulnerability,* Cambridge University Press, Cambridge.

Schlesinger, M.E., J. Yin, G.W. Yohe, N.G. Andronova, S. Malyshev, and B. Li, 2006, "Assessing the risk of a collapse of the Atlantic thermohaline circulation in *Avoiding Dangerous Climate Change*, Cambridge University Press, Cambridge, Chapter 5.

Tol, R.S.J., 2005, "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties", *Energy Policy* **33**: 2064–2074.

Watkiss, P., et al, 2005, "The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment, Final Report" for the United Kingdom Department for Environment, Food, and Rural Affairs.

Yohe, G.W., N. Andronova, N.G., and M.E. Schlesinger, 2004, "To Hedge or Not Against an Uncertain Climate Future", *Science* **306**: 416-417.

Yohe, G.W., M.E. Schlesinger and N.G. Andronova, 2006, "Reducing the risk of a collapse of the Atlantic thermohaline circulation", *Integrated Assessment Journal* **XX**: 1-17.

Figure 1: Sources of Concern and Color-Coded Indications of Vulnerability [Source: the "Burning Embers" of Figure TS-12 in IPCC (2001)]. Relative levels of vulnerability along five "Lines of Evidence" or "Sources of Concerned" and their sensitivity to increases in global mean temperature were assessed based on the literature available through the middle of 2000. Low vulnerability was indicated by a white or very pale yellow coloration. High vulnerability was highlighted by red coloration; and intermediate vulnerabilities by various shades of yellow and orange.

Figure 19-8-1: Summary of Lines of Evidence
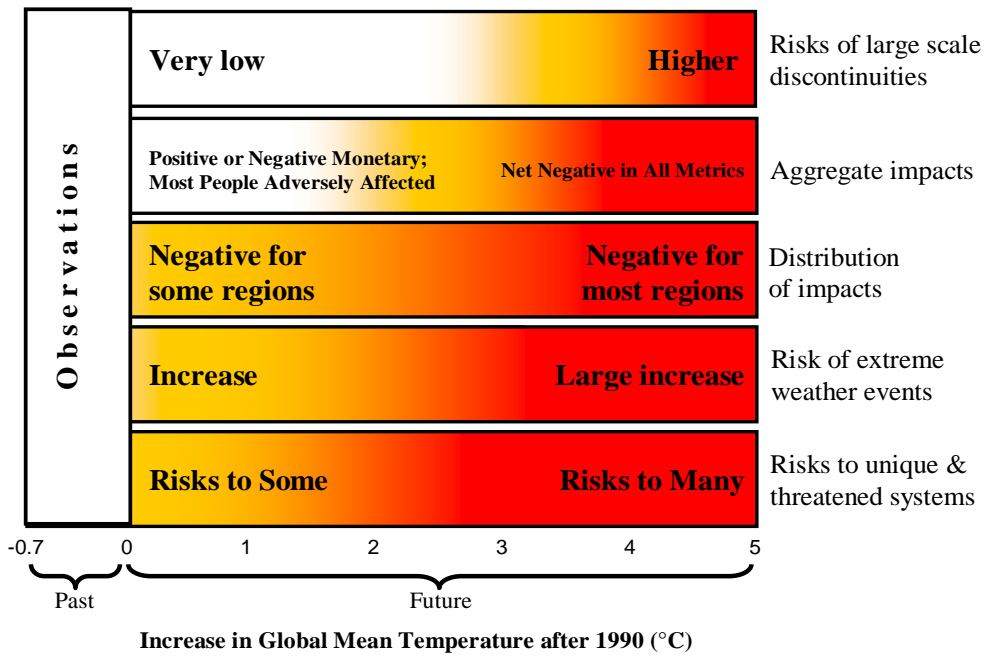
Figure 2 – Panel A: Geographical distribution of vulnerability in 2050 calibrated to "Aggregate Impacts" along an A2 emissions scenario with a climate sensitivity of 5.5°C. The color scale reflects relative vulnerability as suggested by the "Aggregate Impacts" row of the "burning embers" depicted in Figure 1.
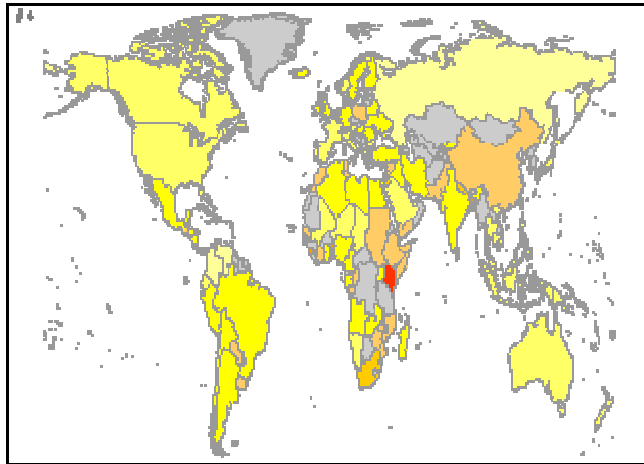
.

Figure 2 – Panel B: Geographical distribution of vulnerability in 2050 calibrated to "Risk to Extreme Weather Events" along an A2 emissions scenario with a climate sensitivity of 5.5°C. The color scale reflects relative vulnerability as suggested by the "Risk of Extreme Weather Events" row of the "burning embers" depicted in Figure 1.
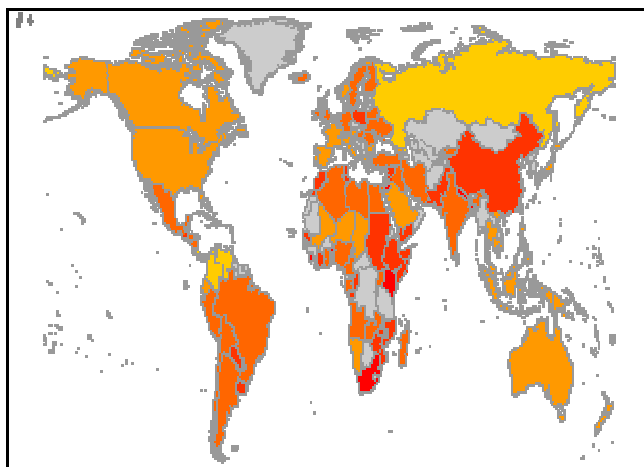
Figure 3 – Panel A: The Distribution of Published Estimates of the Social Cost of Carbon Emitted in 2005 (expressed in 2005$ per ton of carbon emitted). Source: Tol (2005)
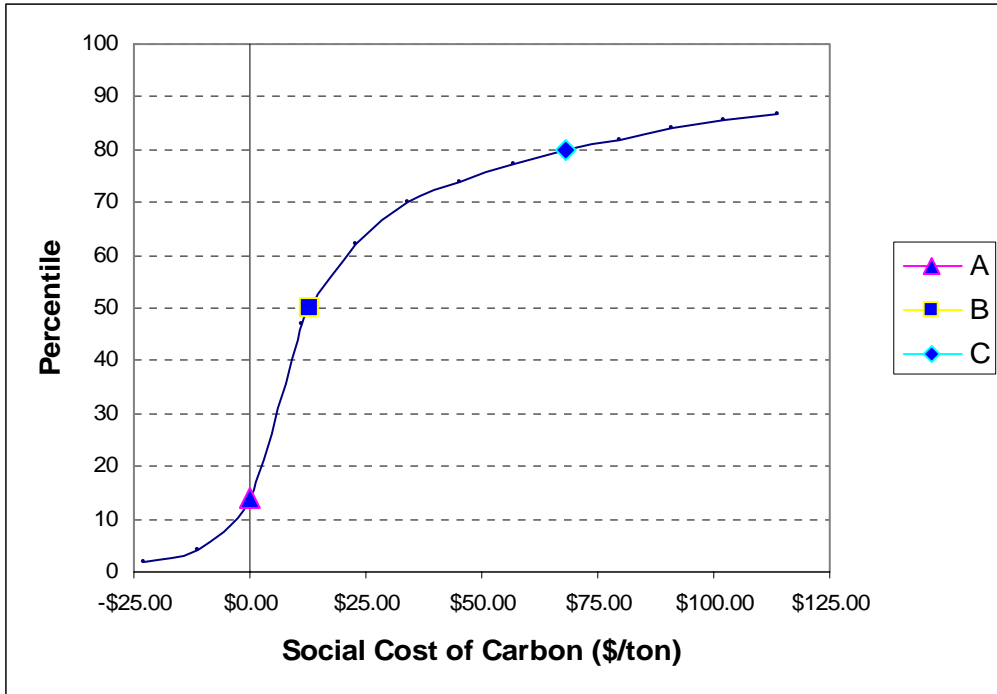

Figure 3 – Panel B: The Distribution of Published Estimates of the Social Cost of Carbon Emitted in 2005 (expressed in 2005$ per barrel of oil). Source: Tol (2005)