

BEFORE THE MINNESOTA OFFICE OF ADMINISTRATIVE HEARINGS
600 North Robert Street
St. Paul, MN 55101

FOR THE MINNESOTA PUBLIC UTILITIES COMMISSION
121 Seventh Place East Suite 350
St. Paul, MN 55101-2147

IN THE MATTER OF THE FURTHER
INVESTIGATION INTO ENVIRONMENTAL
AND SOCIOECONOMIC COSTS UNDER
MINN. STAT. § 216B.2422, SUBD. 3

MPUC DOCKET NO. E999/CI-14-643

OAH DOCKET NO. 80-2500-31888

INITIAL BRIEF ON CO₂
EXTERNALITY VALUES

Pursuant to Minn. Rule 1400.7100 and the Prehearing Orders issued in this matter, the Minnesota Public Health Association, Twin Cities Medical Society, Dr. Bruce Snyder, Dr. Phil Murray and Dr. Michael Menzel (collectively, “Doctors for a Healthy Environment”) hereby submit the following Initial Brief on CO₂ Externality Values.

BACKGROUND

By its order of October 15, 2014, the Public Utilities Commission referred this matter to the Office of Administrative Hearings for a contested case hearing to determine appropriate “externality” values for CO₂, SO₂, NO_x, and PM_{2.5} under Minn. Stat. § 216B.2422, subd. 3. The matter was bifurcated into two phases and an evidentiary hearing on the CO₂ phase was held September 24-30, 2015. At issue in the CO₂ phase is whether the Federal Social Cost of Carbon (SCC) is reasonable and the best available measure to determine the environmental cost of CO₂ under Minn. Stat. § 216B.2422, subd. 3 and, if not, what measure is better supported by the evidence.”

DISCUSSION

DHE's position is two-fold: 1) that the damage functions used by the Integrated Assessment Models (IAMs) contain rudimentary approximations of economic damages attributable to global climate change, and are therefore likely underestimates; and 2) that nonetheless, the SCC remains reasonable and the best available measure of the environmental cost of CO₂. On an issue like the one central to this matter, there is no silver bullet. There is no economic model of climate change that is without criticism, and there is no economic model that enjoys universal consensus among experts. A universally accepted, easily understood estimate of the economic damages of global climate change is a chimera.

But the Legislature's directive in Minn. Stat. § 216B.2422 does not require universality, immunity from criticism, or freedom from uncertainty. The Legislature did not direct the PUC to achieve the impossible. It merely asked the PUC to use a best estimate of the environmental costs of CO₂: an estimate based on sound science and economics. On this issue the legislative intent is made clear by the plain language itself, which directs the commission to quantify and establish a range of environmental costs "*to the extent practicable.*"¹ The language clearly recognizes the complexity of the task and the inherent futility of eliminating *all* artifacts of uncertainty or speculation.

In energy policy generally, but especially so in the regulation of carbon, it is axiomatic that for every PhD, there is an equal and opposite PhD. One researcher may find that renewable wind and solar energy could provide all of society's power needs, while another researcher finds energy returned from renewable energy to be too low to

¹ Minn. Stat. § 216B.2422, subd. 3 (2015) (emphasis added).

support an industrial economy. One study may suggest global wind energy capacities have been overestimated while another claims that they haven't. One economist may value the economic damages of carbon at \$5 a ton (or zero\$/ton), while another might value it at \$100 a ton. In this predicament, the only rational way forward is to look at the overall *weight of the science, as evidenced by the best available consensus*. Rejecting this consensus to adopt the methodologies and conclusions of a particular niche researcher (particularly one hired by an entity with a vested economic interest in the outcome of that research) is not a viable option for policymaking. The estimates contained in the federal SCC are the result of a highly collaborative process building on well-known models that have been studied for decades. These estimates, though not without flaws, represent the best available consensus in a highly disputed field. Rather than representing the views and assumptions of one particular modeler, the SCC represents the collective efforts of a huge number of experts in the fields of climate change and economics.

Perhaps most importantly, the estimates of environmental cost under Minn. Stat. § 216B.2422 are not directives. They do not determine policy by themselves, and they are not dispositive of any particular decision faced by the PUC. Any uncertainty inherent in the SCC estimate ranges, and any criticisms of the underlying assumptions in the IAMs, can be accounted for in the decision making processes of the PUC. The statute itself directs the PUC to use the environmental cost values “in conjunction with other external factors, including socioeconomic costs, when evaluating and selecting resource options.”² The SCC ranges are a quantification *tool*, one among many available to the PUC. To

² Minn. Stat. § 216B.2422, subd. 3 (2015).

discard them in a pursuit for unanimity or illusory precision would be antithetical to both legislative intent and common sense.

I. THE DAMAGE FUNCTIONS OF THE IAMs USED BY THE FEDERAL SOCIAL COST OF CARBON UNDERESTIMATE THE HEALTH IMPACTS OF GLOBAL CLIMATE CHANGE

DHE believes that the Commission should use the SCC as a *conservative* estimate of the environmental costs of CO₂. As explained in the next section, the SCC is reasonable and the best available measure, but it is almost certainly an underestimate, and should be utilized accordingly.

As explained by Dr. Anne Smith, the IAMs used by the SCC follow a similar methodology in calculating the economic damages of global climate change. The models project global GHG emissions into the future and then use those projections to create a forecasted increase in temperatures.³ These future temperatures are then inputted into a damage function that “translates projected changes in climate metrics into monetized societal value or ‘welfare.’”⁴ These damage functions can be in aggregate, by expressing a change in GDP as a function of a change in temperatures,⁵ or they can be specialized by sector. As the Department’s expert Dr. Hanneman explains,

To estimate the marginal cost associated with an additional unit of GHG emissions one needs to estimate, in general terms, (1) how that emission changes the existing accumulation of GHGs in the atmosphere via the carbon cycle; (2) how that, in turn, changes the amount of energy stored in earth’s system (the change in radiative forcing); (3) how the change in radiative forcing leads to changes in the climate worldwide; (4) how those changes in climate affect things that matter to humans, such as water supply and drought, crop production,

³ Ex. 302, Smith Direct Attachment 2 (AES-D-2), at 3

⁴ Ex. 300, Smith Direct at 18.

⁵ Ex. 302, Smith Direct Attachment 2 (AES-D-2), at 24.

disease and human health, outbreaks of wildfire, coastal flooding, and ecosystem functioning etc.; and (5) how humans value the changes in those things.⁶

Of particular concern to DHE are items 4 and 5 in Dr. Hanneman's account of damage modeling. Some models (Dice (2010)) dispense with item 4 entirely, substituting GDP as a crude approximation of "things that matter to humans." Others (FUND (v3.8)) attempt an accounting of public health impacts, but do so in a rudimentary way that leads to underestimation.

DICE (2010)

Of the three models, the damage function in DICE is the most basic, relatively speaking. While PAGE and FUND divide global damages into separate regions, DICE looks at damages globally.⁷ DICE then produces damage estimates in two sectors: sea level rise (SLR) and aggregate non-sea level rise.⁸ The damage estimate is expressed rather directly as a quadratic function of either global SLR (driven by temperature and income, e.g. Damages = α SLR²), or of global temperatures (for non-SLR damages, e.g. Damages = α Temperature²). Although damages are aggregated, they are "calibrated to represent impacts" to, among other things, agriculture, sea-level rise, change in energy use, and human health.⁹

⁶ Ex. 800, Hanneman Direct at 21-22.

⁷ Unless otherwise noted, all characterizations of the damage functions in DICE (2010), FUND (v.3.8), and PAGE (2009) are derived from Ex. 600, Martin Direct Schedule 5C, p. 96-99 of 173.

⁸ As Anne Smith's report demonstrates, an aggregate damage function is one that expresses a change in GDP as a function of a change in temperatures. *See* Ex. 302, Smith Direct Attachment 2 (AES-D-2), at 24.

⁹ Ex. 100, Polasky Direct at 13-14.

FUND (v3.8)

Of the three models, FUND contains the most granular damage estimates, using 16 regions and 14 sectors, including sea level rise, agriculture, forests, heating, cooling, water resources, tropical storms, extratropical storms, biodiversity, cardiovascular respiratory, vector borne diseases, morbidity, diarrhea, and migration. Each sector's damage specification is unique, but is driven by many of the same variables: temperature, CO₂ concentrations, ocean temperature, population, income, per capita income, and technological change.

PAGE (2009)

PAGE occupies a middle ground of granularity by using 8 regions and 4 sectors of damage. Those sectors – sea level rise, economic, non-economic, and discontinuity – express damage as a power function of regional temperature, modified by a regional scaling factor relative to the EU, adaptation capacity and costs, per capita income, and income.

Damage Functions' Basis on Outdated Climate Impacts Literature Results in Underestimation of True Damages

The damage function equations themselves – linking temperatures and change in GDP, for instance – are derived from climate impacts literature. Crucially, much of this literature is outdated, as pointed out by many of the experts testifying in this matter. Mr. Martin notes that “the models draw directly and indirectly on older literature, some dating back to the 1990s.”

Scientific understanding of global climate change impacts, however, has increased considerably in the last twenty years. That new understanding almost invariably produces

ever-higher estimates of damage, but those increasing estimates are not reflected in the three IAMs used in the SCC. Mr. Martin notes that “[s]cientific impacts knowledge has progressed since [the 1990s] . . . [h]owever, this knowledge is not reflected in the current SCC model formulations.”¹⁰ Dr. Hanneman concurred, and described the outdated damage functions for each model.¹¹ The “detailed accounting of individual sectoral impacts” for DICE ended in 2000. For FUND, the damage functions were based on 32 academic studies, only four of which appeared after 2002. The damage functions of PAGE are based on eight studies, seven of which were published in the period 2006-2009. Altogether, the damage functions of the IAMs are based on fewer than 50 studies, a small fraction of the total body of literature on climate change impacts.

Dr. Polasky also agrees, concluding that the SCC is a “conservative value that likely errs on the side of underestimating the damage from climate change.”¹² Dr. Polasky observed that the SCC underestimates damages in four key ways: by not giving sufficient weight to catastrophic consequences of climate change, by using relatively high discount rates, by failing to adequately account for the impacts of climate change on economic growth, and by failing to include several potentially important types of damages from climate change.¹³ On this last point, Dr. Polasky pointed out that several experts have identified entire categories of impact that are not accounted for in the IAMs’ damage functions, including biodiversity losses, impacts on long-term economic growth, increased political instability, increased migration, extreme weather events, irreversible climate

¹⁰ Ex. 600, Martin Direct Schedule 5C, p. 98 of 173.

¹¹ Ex. 801, Hanneman Rebuttal at 47.

¹² Ex. 100, Polasky Direct at 18.

¹³ *Id.*

change, and increases in wildfires.¹⁴ The view that the SCC is a conservative estimate, Dr. Polasky concludes, is a prevalent view among economists.¹⁵

Underestimation of Public Health Impacts of Climate Change

DHE's own expert, Dr. Rom, elaborated on several ways in which a full accounting of the public health impacts of climate change is not included in the IAMs' damage functions. Dr. Rom observed that one of the models (FUND) contains arbitrary limitations on the extent to which public health impacts are included in its damage function. The model limits mortality and morbidity to urban areas, even though rural areas will be impacted as well.¹⁶ The damage function also limits the total change in mortality to a maximum of 5% of baseline mortality.¹⁷ It is unclear why this limitation was chosen, but it is clear that mortality increases may be much higher than 5%.¹⁸

But aside from these arbitrary limits, all three of the IAMs exclude entire categories of public health impact, thereby producing damage functions that are certain underestimates. The federal government acknowledges these exclusions, noting that "Current integrated assessment models do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature."¹⁹ None of the models, for instance, account for wildfires, droughts,

¹⁴ *Id.* at 23.

¹⁵ *Id.*

¹⁶ Ex. 500, Rom Rebuttal at 9.

¹⁷ *Id.*

¹⁸ *Id.* at 18 (citing study that warmer temperatures will increase PM2.5 mortality by 8%).

¹⁹ *Id.* at 9 (quoting U.S. EPA, Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants, June 2, 2014, at 409, available at <http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule-regulatory-impact-analysis>).

flood, reduced drinking water quality and harmful aquatic blooms, and perhaps most significantly, the exacerbation of exposure to ozone and PM2.5.²⁰

There are two important considerations that arise from these notable omissions: 1) the inescapable conclusion that the damage functions of the SCC models contain at best a bare minimum of accounting for the full extent of the public health impacts of climate change, and 2) the observation that these omissions are not insignificant. PM2.5 and ozone are deadly air pollutants with well-known morbidities. Exposure to ozone causes a range of health outcomes, beginning with increased susceptibility to lung infection and ending with fatalities.²¹ These outcomes show a linear dose-response relationship, meaning more ozone, more damage to the lungs.²² PM2.5 is even deadlier, and exposure to it drastically increases the risks of dying from cardiovascular and respiratory disease.²³ Both of these mortality rates are heightened by warmer temperatures from climate change, yet none of the IAMs have accounted for this impact.²⁴ Warmer temperatures increase atmospheric concentrations of ozone and PM2.5, but they also affect how the body responds to these pollutants.²⁵ Heat stresses the body's systems, even at small increments like one or two degrees, leaving the body more vulnerable to the destructive actions of lung irritants.²⁶

The EPA quantified these effects and found that reductions in GHG emissions would avoid 13,000 premature deaths in 2050 and 57,000 deaths in 2100, all from

²⁰ *Id.* at 12, 19.

²¹ *Id.* at 13.

²² *Id.* at 14.

²³ *Id.*

²⁴ *Id.* 15-16.

²⁵ *Id.*

²⁶ *Id.* at 15-17.

improvements in air quality (reduced temperatures from mitigating climate change reduces exposures to ozone and PM2.5).²⁷ The economic value of these premature deaths was estimated as \$160 billion in 2050 and \$930 billion in 2100.²⁸ Other studies found these estimates to be low, and it appears that once again the federal estimates of damage are unnecessarily conservative.²⁹ Even if they are not overly conservative, however, these estimates encompass only one sector of health impact excluded from the IAMs. Other sectors – the impacts of wildfires, droughts, flood, non-fatal illnesses, and reductions in drinking water quality - are to date unquantified by the literature cited in this docket. The SCC, in other words, underestimates public health impacts by a *minimum* of \$930 billion in 2100, but almost certainly much more than that.

New Literature on Climate Change Impacts Almost Invariably Produces Damage Estimates That Are Revised *Upwards*

What is of particular importance is not just that the damage functions are outdated, which is undisputed, but that the additional studies on climate change impacts almost invariably *skew upwards*. The new data coming in, in other words, just keeps *raising* the damage estimates. This was made clear by Dr. Rom’s testimony, but also by the testimony of Dr. Hanneman, who stated that “My assessment of the newer literature is that these studies generally indicate more severe damages than the earlier literature and thus, if anything, the damage estimates in the IWG SCC are too low.”³⁰ Because of what

²⁷ *Id.* at 18 (citing U.S. EPA, Climate Change in the United States: Benefits of Global Action, June 22, 2015, Health Sector at 26, available at <http://www2.epa.gov/cira/downloads-cira-report>).

²⁸ *Id.*

²⁹ *Id.*

³⁰ Ex. 801, Hanneman Rebuttal at 48.

he calls the “convexity of the damage functions,” this trend can be expected to continue in the future, and damage estimates will continue to climb higher.³¹

The IWG itself acknowledges this limitation, noting that the “SCC estimates may be biased downwards” (meaning they are underestimates) because of the inherent limitations in “quantifying and monetizing the full array of potential catastrophic and non-catastrophic damages.”³² As new peer-reviewed literature becomes available, the new studies confirm this finding,³³ suggesting that the SCC should be viewed as a floor, a best-case scenario.

Peabody’s Response to Dr. Rom’s Testimony

Dr. Rom’s analysis on the human health impacts of climate change and the economic value of those impacts is essentially undisputed in this matter. Dr. Bezdek and Dr. Happer offered some response to Dr. Rom’s testimony, but their responses illustrate only a deep confusion concerning the medical literature on climate change and human health. Their responses starkly demonstrate the very same analytical confusion and torpidity that pervades their testimonies denying the overwhelming scientific consensus on climate change. Dr. Happer, for instance, first responds that CO₂ does not cause asthma.³⁴ This is a non-sequitur. Dr. Rom made no argument in this regard, and does not deny that inhalation of CO₂ at atmospheric concentrations is relatively harmless. Dr. Happer then responds by citing studies that quite clearly do not conclude what he believes they conclude, and in many cases, conclude exactly the opposite of what he

³¹ *Id.*

³² *Id.* at 58 (quoting IWG *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (July 2015, p. 27)).

³³ *Id.*

³⁴ Ex. 206, Happer Surrebuttal at 22.

believes they conclude. He has either not read these studies or he has deeply misunderstood them.

Dr. Happer's attempt to distort the medical literature to make it appear as if global warming will reduce temperature related mortality is a *tour de force* in misdirection and bias in reporting scientific data. The first study he cites indicates a relationship between cold temperatures and asthma-related hospital admissions in Shanghai.³⁵ This study *does not* conclude, however, that global warming will produce a net decrease in temperature related mortality, as Dr. Happer seems to believe. Indeed, that study concluded that "climate change . . . may relate to the *increased burden* of asthma."³⁶ That study also noted that the relationship between temperature and asthma is not a one-sided interaction: while cold temperatures are associated with acute asthma *attacks*, warmer temperatures are associated with increased *prevalence* of asthma, due to increased exposure to allergens such as pollens, air pollutants, and mold spores.³⁷ The study confirms,

Climate warming can produce longer pollen seasons, whereas additional hot sunny summer days can generate ozone, with the two together increasing the symptoms in individuals at risk for asthma and breathing difficulties. In addition, climate change can influence the concentrations of airborne pollutants, which either alone or, in conjunction with aeroallergens, can exacerbate asthma and other respiratory illnesses.³⁸

Dr. Happer then cites another study with the exact same conclusions, and he again draws unsupported conclusions from that study. What Dr. Happer does not seem to understand is that a planet warmed by global climate change will not of a sudden *eliminate* deaths due

³⁵ *Id.*

³⁶ *See id.* (citing study available at <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0102475>) (emphasis added).

³⁷ *Id.*

³⁸ *Id.*

to cold. Winter will still continue to exist, even if it is less severe in places. As Dr. Rom testified, there *will* be some reduction in cold-related mortality, but that reduction is overwhelmed by the drastic increase in heat-related mortality.³⁹ In reviewing the medical literature on this point, the EPA came to the conclusion that “the projected increase in deaths due to more frequent extremely hot days is much larger than the projected decrease in deaths due to fewer extremely cold days, a finding that is consistent with the conclusions of the assessment literature.”⁴⁰

That Dr. Happer either does not understand this or does not want to address it is not surprising, as his expertise is in physics, not medicine (although his misunderstanding of the statistics indicates a worrying inability to interpret scientific data). Indeed, it seems as though Dr. Happer has taken a cursory look at a few papers in order to find “support” for a preconceived idea. One paper he cites does not relate to health at all. It is entitled: “Spatiotemporal change of diurnal temperature range and its relationship with sunshine duration and precipitation in China.”⁴¹ Like all the other papers he cited, this paper makes no conclusions about net changes in temperature-related mortality in a world warmed by climate change.

Dr. Happer then for some reason cites two studies demonstrating that living on a farm is associated with lower incidence of asthma.⁴² Needless to say, neither of these studies draws any conclusions about climate change. He then returns to the previous idea, that since cold weather can cause health problems, it must necessarily follow that a

³⁹ Ex. 500, Rom Rebuttal at 4 (citing U.S. EPA, Climate Change in the United States: Benefits of Global Action, June 22, 2015, Health Sector at 26, available at <http://www2.epa.gov/cira/downloads-cira-report>).

⁴⁰ *Id.*

⁴¹ Ex. 206, Happer Surrebuttal at 23, fn 40.

⁴² *Id.* at 23, fn 37.

warmer world would improve overall health. One study comes closest to supporting his thesis, and found that in situations where humans were able to adapt to warmer temperatures, then the overall effect on temperature-related mortality was beneficial.⁴³ This study concerned England and Wales, economically developed areas where adaptation to heat is widespread in the form of air conditioning.⁴⁴ In this very limited circumstance, some warming may be beneficial in that one particular aspect of human health. But as the study's authors noted,

The numerous other impacts of climate change on human health, like those already mentioned earlier, are almost invariably detrimental. Moreover even if the synergy between adaptation and milder winters decreases the total mortality related to cold and heat, extreme events like heatwaves may still exert a stress beyond the adaptation limits on the population.⁴⁵

In short, the study found that *in those countries* where adaptation to heat is viable, warmer temperatures *may* decrease mortality, but even this effect can be overwhelmed by extreme heat events with “sharp increases in daily mortality.”⁴⁶ But more importantly, the study says nothing about those poorer countries that are likely to bear the brunt of climate change, and that have drastically lower adaptation ability than the rich areas of England and Wales. The study is not indicative of *global impacts*, in other words.

Similarly, the next study Dr. Happer cites looked at the UK and Australia and found that cold-related deaths outnumbered heat-related deaths.⁴⁷ Just as with the previous studies he cited, this study also did not conclude that warmer temperatures

⁴³ *Id.* at 23, fn 38.

⁴⁴ *Id.*

⁴⁵ See N. Christidis, GC Donaldson, & P Stott, Cause for the recent changes in cold- and heat-related mortality in England and Wales. *Climatic Change* 102: 539-553, 540 (2010), cited in Ex. 206, Happer Surrebuttal at 23.

⁴⁶ *Id.*

⁴⁷ Ex. 206, Happer Surrebuttal at 23, fn 39.

would produce a *net* decrease in temperature related mortality. Rather the opposite. The authors explain:

In the absence of any planned, spontaneous behavioral or physiological adaptation of the population to climate change, heat-related mortality is projected to rise steeply (e.g., by approximately 90% and 70% between the 2020s and 2050s in the United Kingdom and Australia, respectively, for constant populations) by mid-century and beyond in both countries because of rising mean temperatures as well as population growth and aging. Over the same period, cold-related mortality estimates show a relatively smaller decline (e.g., by approximately 16% and 17% between the 2020s and 2050s in the United Kingdom and Australia, respectively, for constant populations) that will be largely offset by demographic changes, as suggested by the differences in mortality estimates based on constant versus projected populations.⁴⁸

Just as noted above, the heat-related mortality skyrockets while cold-related mortality experiences a modest decline. The overall effect is a net increase, even if the cold-related deaths outnumber heat-related deaths in those particular rich, well-adapted countries.⁴⁹

This point is so important in understanding Dr. Happer's deep misunderstanding of the medical literature that some elaboration is helpful. Some of the studies cited by Dr. Happer *do* concern places where cold-related deaths currently outnumber heat-related deaths. This is bound to be true given the planet's huge variety of combinations of climate, geography, economic development and population demographics. In rich areas,

⁴⁸ Vardoulakis, S, Dear, K, Hajat, S, Heaviside, C, Eggen, B and McMichael, AJ. Comparative assessment of the effects of climate change on heat- and cold-related mortality in the United Kingdom and Australia. *Environmental Health Perspectives* 2014; 122: 1285-1292, cited in Ex. 206, Happer Surrebuttal at 23, fn 39.

⁴⁹ An additional study cited by Dr. Happer found that in the countries studies, cold-related deaths outnumbered heat-related deaths for the period 1985-2012. *See* Gasparrini, A et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet* 2015; 386: 369-375, 25, cited in Ex. 206, Happer Surrebuttal at 24, fn 41. This study, as noted, addressed past mortality, not forecasted mortality in a world warmed by climate change. It also entirely excluded Africa and the Middle East regions, two areas notable for their lack of cold weather. But most importantly, this study also - like all the others cited by Dr. Happer - did not draw any conclusions about the *net* effect of climate change on temperature-related mortality rates. It is not the *relative* comparison of heat-related and cold-related deaths that is important. It is the *net* effect that determines overall mortality.

air conditioning alleviates a large brunt of the health impacts of warmer temperatures. But it simply does not follow that a warmed planet will produce a net decrease in temperature related mortality. The *net* effect is an *increase* in temperature-related mortality, not a decrease. A simplification makes the point quite clear. Assume that in present temperatures, 5 people out of 100 die from the cold, and 1 dies from the heat. In this hypothetical, cold-related deaths are higher. Then in a world warmed by climate change, only 4 people die from the cold, but 3 people die from the heat. So the total temperature related mortality is 6% in present temperatures, and 7% in warmer temperatures. Global warming has saved some lives, but killed more than enough to make up for those lives saved, and then some. Cold-related deaths still outnumber heat-related deaths, but since the heat-related deaths have increased faster than the cold-related deaths have decreased, the overall mortality rate has increased.

This scenario, of course, is the best-case scenario: rich countries where adapting to the heat is readily achievable with air conditioning. In poorer countries heat-related deaths will outnumber cold-related deaths to begin with, followed by skyrocketing heat mortality in a warmed world.⁵⁰ This is exactly what all of the comprehensive, peer-reviewed analyses have concluded about the weather related mortality effects of global climate change.⁵¹ A recent international, multidisciplinary collaborative commission report published in *The Lancet* concluded that although “there may be modest reductions in cold-related deaths . . . these reductions will be largely outweighed at the global scale by heat-related mortality.”⁵² Dr. Happer’s attempts to dispute this rely on misdirection,

⁵⁰ Ex. 500, Rom Rebuttal at 4-5.

⁵¹ *See, e.g., id.* at 11.

⁵² *Id.* at 5 (quoting Watts, N et al. Health and Climate Change: Policy Responses to Protect Public Health. *The Lancet*, June 23, 2015. [http://dx.doi.org/10.1016/S0140-6736\(15\)60854-6](http://dx.doi.org/10.1016/S0140-6736(15)60854-6), at p. 8).

obfuscation, and an outright misunderstanding of the science and statistics. Either Dr. Happer did not actually read the studies he cited, or he does not understand the dangers of attempting to draw broad conclusions from a small effect taken out of context. As demonstrated by many experts in this matter, these techniques are ubiquitous among Peabody's experts.

Dr. Bezdek's response was less substantive, but equally unsupported. He first replies that Dr. Rom is simply wrong, pointing to his list of references that he believes supports the notion that humans will flourish in a warming world.⁵³ Dr. Bezdek does not address Dr. Rom's observation that these references simply do not say what he thinks they say. What Dr. Bezdek has done is to pick out studies addressing cold-related mortality, and then offer *his own extrapolation* of those studies, even though that extrapolation has been expressly rejected by the literature. If cold weather is associated with temperature related mortality, then surely warmer weather would be better, he believes. This baseless theorizing is why it is dangerous for an economist to attempt to draw conclusions about the literature outside of his field.⁵⁴ As explained above, the

⁵³ Ex. 235, Bezdek Surrebuttal at 20.

⁵⁴ Dr. Bezdek's reply on this point is hardly worth addressing, but DHE feels compelled to do so. Dr. Bezdek's replies that although he is not a medical expert, he has "extensively researched and documented any statements I have made concerning potential health impacts." It is of course absurd to believe that one can become an expert in environmental health without the requisite education, training and experience undergone by truly qualified experts in the field. Dr. Bezdek's second response is to characteristically misdirect attention by observing that Dr. Rom also indicated in his testimony that there are areas in which his expertise does not extend. Dr. Rom did so for the sake of intellectual honesty and for the benefit of the ALJs in this case, so that they may know what conclusions are drawn from Dr. Rom's particular expertise and what conclusions are drawn from other sources. Although he is an expert in environmental health and is intimately familiar with the process of valuing health impacts, Dr. Rom is not an expert in Integrated Assessment Modeling, and indicated as much in his testimony. Dr. Bezdek mystifyingly understands this concession to mean that he himself is qualified to opine about any subject that he has read an article on. Dr. Rom's point, obviously, is that his conclusions about the health impacts of climate change are based on his extensive expertise in environmental health, whereas his conclusions about the valuation of those impacts are based on sources in the field of

overwhelming consensus of medical experts concludes that yes, global warming will slightly reduce cold-related mortality, but that overall the net effect will be a positive increase in mortality from skyrocketing rates of heat-related mortality.⁵⁵

II. DESPITE THE TENDENCY TO UNDERESTIMATE DAMAGES, THE FEDERAL SOCIAL COST OF CARBON REMAINS REASONABLE AND IS THE BEST AVAILABLE MEASURE OF THE ENVIRONMENTAL COSTS OF CO₂

Despite these limitations, the SCC remains the best available measure of the environmental costs of carbon. It is the only measure that:

1. Is the result of collaborative efforts by objective parties, rather than an individualized effort of a party with a vested interest in the outcome of the modeling;
2. Is widely used in regulatory proceedings at the federal and state levels; and
3. Uses multiple Integrated Assessment Models, thereby providing some compensation for biases in individual models.

Of these features, perhaps the most important is the fact that the SCC is the result of a collaboration. The IWG was convened by the Council of Economic Advisers and the Office of Management and Budget, with participation by the Council on Environmental Quality, the National Economic Council, the Office of Energy and Climate Change, the Office of Science and Technology Policy, the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and the Treasury.⁵⁶ It does not represent the views of one particular researcher, or one particular industry. The

environmental economics. By contrast, Dr. Bezdek has no expertise in environmental health, and is unqualified to draw conclusions from the literature in that field.

⁵⁵ Ex. 500, Rom Rebuttal at 5.

⁵⁶ Ex. 800, Hanneman Direct at 45.

involvement of a multitude of federal agencies ensured that the resulting product was suitable for a wide range of regulatory activities.

The U.S. Government Accountability Office evaluated the IWG's process in developing the SCC, and found that "the working group used a consensus-based approach for making key decisions on developing the social cost of carbon estimates."⁵⁷ In its evaluation, the GAO interviewed participants in the IWG proceedings and corresponded with researchers "who developed key academic materials the working group used."⁵⁸ Based on the directive of Executive Order 13563, which directs the federal agencies to conduct regulatory actions based on the best available science, the GAO concluded that the IWG processes "relied on existing academic literature and models,"⁵⁹ and noted that the IAMs used by the SCC were "three of the most widely used models of their kind."⁶⁰

The particular models chosen for use in the SCC are clearly the best available models for estimating the environmental costs of carbon dioxide. They are well known and well used, having been the subject of a large number of peer-reviewed publications. The three models used in the SCC first appeared in 1993, 1994, and 1995,⁶¹ and "have been used and repeatedly revised since, with results of analyses that have been done using them described in peer-reviewed articles."⁶² They were also cited by Working Groups II

⁵⁷ Ex. 100, Polasky Direct at 7.

⁵⁸ *Id.* at Schedule 4, p. 3.

⁵⁹ *Id.* at Schedule 4, p. 13.

⁶⁰ *Id.*

⁶¹ Ex. 800, Hanneman Direct at 30.

⁶² Ex. 302, Smith Direct Attachment 2 (AES-D-2), at 20.

and II in the Second, Fourth and Fifth Assessment Reports of the IPCC, an organization internationally recognized as authoritative on the issue of climate change.⁶³

When it comes to estimating the particular values at issue in this docket, it appears that these three IAMs are indeed the *only* models appropriate for the task. As Dr. Smith explained, the three IAMs used by the SCC are the only appropriate models to be used in a process like the one in this docket, as the other models “are not designed to compute a monetized estimate of the damages from GHG emissions and thus are not relevant to this discussion.”⁶⁴ The three models chosen are the “best known and most widely cited IAMs in the literature.”⁶⁵ Dr. Polasky concurred, testifying that the “IWG averaged estimates from the three most reputable and widely used IAMs and relied on the collective judgment of a group of experts from a range of federal agencies.”⁶⁶

Dr. Hanneman concurs, adding that computational requirements make DICE, PAGE and FUND the only IAMs appropriate for use in this matter. Dr. Hanneman explains:

While the strength of IAMs like DICE, FUND and PAGE is that they combine economic models, climate models and impact models within one integrated framework, their constraint is that they provide a simplified representation of each of those model types. Their climate model is a simplified representation of General Circulation Models. Their model of economic activity and the generation of emissions is a simplified version of what is found in models like IMAGE and other economic models. Their representation of impacts is a simplified version of what is found in more detailed models of individual types of impact.”⁶⁷

⁶³ Ex. 800, Hanneman Direct at 34.

⁶⁴ Ex. 302, Smith Direct Attachment 2 (AES-D-2), at 3.

⁶⁵ Ex. 800, Hanneman Direct at 46.

⁶⁶ Ex. 100, Polasky Direct at 17.

⁶⁷ Ex. 800, Hanneman Direct at 30.

The virtue of using Integrated Assessment Models in policymaking is that they contain simplified economic models, climate models and impact models within one integrated framework.⁶⁸ Because of this integration, the IAMs can be easily revised or updated, and rerun with a minimum of computing time.⁶⁹ They allow a policymaker to easily look at the same spatial and temporal scales for every aspect of the model, rather than going through the incredibly laborious and time consuming process of integrating more detailed and computationally dense Earth System models with economic emissions models. As Dr. Hanneman notes, “[i]t is simply not feasible to run the climate model and the economic emissions model in tandem: the climate model has to be greatly simplified in order to combine it with the emissions model.”⁷⁰ This is exactly what IAMs do, and why they are so well suited to the policymaking arena. The numbers can be updated annually using the GDP deflator index, and as the federal government updates the SCC with newer versions of the IAMs, the Commission could adopt those new estimates.⁷¹ The current iteration of the SCC, for instance, incorporates revisions to the 2010 estimates that included newer versions of the IAMs.⁷² Future revisions are readily transferable to use by the Commission.

SCC Is Best Available Measure of Costs of Carbon Despite Tendency to Underestimate Impacts

At first impression, it may appear problematic to identify the ways in which the SCC underestimates climate change impacts, and yet still recommend its use as reasonable and the best available measure of the cost of carbon. This tension is an

⁶⁸ *Id.*

⁶⁹ *Id.* at 42-43.

⁷⁰ *Id.* at 43.

⁷¹ *Id.* at 61.

⁷² Ex. 100, Polasky Direct at 17.

reflection of the tension between two competing principles: the desire to render economic models as precise as possible and the need to use *some* estimate of the cost of carbon in regulatory proceedings, even if that estimate is evolving. The project of internalizing the externalities of carbon is so vital to combating global climate change that it would be a grave mistake to let the perfect be the enemy of the good. As many of the witnesses in this matter have testified, it is appropriate to utilize the SCC in a regulatory context *even though* damage functions may need to be updated. This is the opinion of Drs. Rom, Hanneman, and Polasky, but also of outside researchers like Dr. Pindyck, around whom much controversy has arisen in this case.

Opponents of the SCC in this case have repeatedly cited Dr. Robert Pindyck for the notion that the damage functions of the SCC are so uncertain and speculative as to be useless.⁷³ But as Dr. Hanneman clarifies, Dr. Pindyck's criticisms have been very much taken out of context. While Dr. Pindyck acknowledges the complexities and uncertainties of calculating something as vast as the global damages of climate change, he also believes that the exercise is so vital that SCC estimates should be used *despite their limitations*, not rejected because of them.⁷⁴ Dr. Pindyck describes the SCC estimates as "a rough and politically acceptable starting point."⁷⁵ This accords exactly with the testimony in this case from Dr. Polasky, Dr. Hanneman and Dr. Rom, who argue that *even though the SCC is likely to be an underestimate*, it should nevertheless be used by the Commission as the best available estimate, and can always be revised upwards later. It is also in accordance with the position of the federal agencies that developed the SCC, who observed that the IAMs

⁷³ Ex. 801, Hanneman Rebuttal at 34-36 (quoting Pindyck's use by the witnesses in this case, including Mr. Martin, Dr. Smith, and Dr. Bezdek).

⁷⁴ *Id.* at 36-38.

⁷⁵ *Id.* at 37.

do not fully capture “all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature.”⁷⁶ Although these impacts are not uniformly positive or negative, overall they “suggest that the SCC estimates are likely conservative [underestimates]”. This position is perhaps best summed by Dr. Hanneman, who testifies:

The damage functions in DICE, FUND and PAGE do not well reflect the current empirical literature on climate change impacts. In addition, the theoretical literature has developed mathematical modifications of the damage function formula that can account for the considerations just discussed above and has demonstrated their application to DICE. My assessment of these newer literatures is that they generally indicate more severe damages than the earlier literature. However at present the damage functions in DICE, FUND and PAGE are the only damage functions currently available for use in a model inter-comparison exercise. The decision by the IWG to use those models was reasonable at the time and is still reasonable today. But, it is important to recognize that these damage functions are likely to understate the social cost of carbon.⁷⁷

This statement reflects the position of DHE as well.

CONCLUSION

Although they are likely to underestimate the environmental costs of carbon dioxide, the three IAMs used by the SCC are the best available estimates of those costs. Alternatives to the IWG’s SCC methodology, including the alternatives offered by witnesses in this matter, do not offer the same flexibility, comprehensiveness and computational simplicity of the SCC. The alternatives offered in this case are either limited to variations on one particular IAM, thus limiting their useful scope (*see* Dr. Mendelsohn’s variant of DICE, Dr. Tol’s variant of FUND) or they are proposals that have not been peer-reviewed (*see* Dr. Smith’s proposal for the average ton, Mr. Martin’s

⁷⁶ Ex. 500, Rom Rebuttal at 9 (quoting EPA Regulatory Impact Analysis for Clean Power Plan).

⁷⁷ Ex. 801, Hanneman Rebuttal at 63.

multi-point proposal, Dr. Bezdek's proposal). Still other alternatives attempt to relitigate scoping decisions already established in this matter (*see* Dr. Gayer's attempt to limit the SCC to only the U.S. derived share of damages). The IWG's development of the SCC remains the only methodology that incorporates peer-review, multi-agency and multi-disciplinary collaboration, and the use of three of the most widely used, well respected IAMs in the field. The SCC is clearly reasonable, and the best available measure of the environmental costs of carbon dioxide.

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Respectfully submitted

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