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# *The Environmental Value of Reducing Greenhouse Gas Emissions*

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## *1. INTRODUCTION*

*Global warming has become of increasing concern both in the scientific community (Hansen 1988, Schneider 1989) and in the popular press (Begley et al. 1988, Lemonick 1989). Because the utility industry is responsible for a substantial fraction of carbon dioxide emissions in the U.S., this sector is likely to be an important focus of policies to mitigate these emissions. Recently, a variety of options, including energy efficiency and tree planting by utilities have been proposed to mitigate urban heat islands and to offset power plant carbon dioxide releases that contribute to global warming (Akbari et al. 1988, Dudek 1988).*

*This testimony examines methodological questions concerning the value of global warming mitigation. The second section supplies background information about all externalities, including frameworks for discussing energy technologies and their associated external costs. The third section presents the two predominant methods for valuing external costs. The fourth section examines pitfalls in such analyses. The fifth section introduces the concept of Net Cost, which is essential to least-cost analysis of global warming mitigation measures. Finally, the sixth section discusses choosing a number in the face of the many uncertainties.*

## *2. BACKGROUND*

*Exploitation of all energy sources generates societal costs external to market transactions. Figure 1 (Holdren 1981) shows a detailed listing of stages of energy sources, from exploration to end-use. It also shows phases of each stage, from research to dismantling. Any comprehensive analysis of external costs must*

*[1] The opinions expressed do not necessarily represent the opinions of the University of California.*

*treat each and every stage in the process, which indicates one of the difficulties inherent in any such calculations.*

*Figure 2 (Holdren 1981) shows the relationships between insults, pathways, stresses, and costs. Insults are humankind's physical and chemical intrusions into the natural world. Pathways are those mechanisms by which insults are converted to stresses. Stresses, defined as changes in ambient conditions (social, political, or environmental), then lead directly to societal costs.*

*Table 1 lists environmental and social insults attributable to fossil fuel combustion. To illustrate how Figure 2 relates to such insults, consider the case of carbon dioxide.* $CO_2$ *(the insult) is emitted from fossil fuel combustion (a pathway). The altered concentration of* $CO_2$ *in the atmosphere and the consequent rise in global surface temperatures are the stresses. The costs (social, economic, and environmental) involve sea level rise, species extinction, direct damage to crops, possible famine, encouragement of pest species, risk of runaway temperature changes, and other effects (Krause et al. 1989a) .*

*Each stage in such processes leads to significant calculational uncertainties. While we can often quantify the size of the insult, the pathways may be so numerous or complicated that only the crudest approximations are possible. Even if we can confidently predict stresses from a given insult, translating those stresses into societal costs is problematic.*

## *3. METHODS OF CALCULATING EXTERNAL COSTS*

*There are two basic approaches to calculating external costs: one is commonly called "direct damage estimation", while the other is some form of "proxy" method.*[2] *Direct damage estimation involves calculating damages that can be definitively linked to emissions of a particular pollutant. For instance, Shuman and Cavanagh (Cavanagh et al. 1982) tally the human health and environmental effects due to coal consumption in new power plants. These effects include premature human deaths, increased health costs, potential famine induced by global warming, and other effects.*

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[2]*For a more detailed discussion of these two approaches, see Chernick and Caverhill 1989.*

*Direct estimation is extremely difficult, even under the best of circumstances. As already noted, some of the most important effects are impossible to quantify, while others depend on pathways that we do not fully understand. Conservatively calculated direct damage estimates can serve as a useful lower bound to the true externality costs.*

*Proxy approaches use the cost of the least expensive mitigation measure as a proxy for the true externality costs imposed by a pollutant. This approach assumes that the marginal costs of mitigation are known and that these marginal mitigation costs are incurred solely to reduce emissions of a single pollutant (i.e., that there are no other benefits to a pollution reduction investment).*

*Several attempts have been made to quantify the value of global warming mitigation, either through direct cost estimation (Cavanagh et al. 1982) or through proxy methods (CEC Staff 1989, Chernick et al. 1989, Schilberg et al. 1989). Direct damage calculations for this phenomenon are especially difficult because regional forecasts of climate change are even less certain than the global predictions, yet regional forecasts are necessary to estimate damages. Proxy approaches are also difficult since many global warming mitigation measures have multiple benefits (Krause et al. 1989b), and many of these measures await detailed, consistent tabulation.*

## *4. PITFALLS IN EXTERNALITY ANALYSIS*

### *Indirect Emissions Factors*

*To facilitate least-cost analysis, the CEC needs a consistent, comprehensive database of emissions factors of all pollutants for new and existing power plants, as well as for direct combustion. This database should include indirect emissions from extraction, transport, and processing of the fuel. While some analysts have calculated indirect emissions of* $CO_2$ *and several other pollutants from fossil fuels (DeLuchi et al. 1987a, DeLuchi et al. 1987b, Gleick et al. 1989, Meridian Corp. 1989, Unnasch et al. 1989), none treat all the relevant pollutants for each stage[3] of a large number of technologies.*

*[3]For a description of the various stages of energy technologies, see Figure 1.*

*Consistent Treatment of Greenhouse Gases*

*All emissions that contribute to global warming should be treated equivalently. Carbon, which is the most important contributor to the global warming problem, is by no means the only one. Radiatively active trace gases like methane ($CH_4$), nitrous oxide ($N_2O$), and chloroflourocarbons (CFCs) should all be assigned the same externality cost per unit of global warming contribution.*

*Distinction Between Saving and Sequestering Carbon*

*A ton of carbon dioxide saved by a more efficient air conditioner is not the same as a ton of $CO_2$ sequestered by rural trees. If the house in which the air conditioner resides burns down, the house will be replaced by a new one that is likely to be better insulated and have more efficient space conditioning equipment. If rural trees burn down, the sequestered carbon will be released to the atmosphere and society will have to start over again. Carbon savings from efficiency investments are thus less easily reversed than those from planting rural trees.*

*Distinction Between Mitigation Value and Mitigation Cost*

*As described below, the cost of mitigating global warming from the societal perspective could in principle be less than zero (given sufficient quantities of energy conservation and other resources that have multiple benefits). Even in this most fortunate case, the value of mitigating global warming is still greater than zero, as long as the risk analyses indicating a greenhouse threat are accurate. The net benefit to society of investing in these negative cost resources is even greater than it would have been without the greenhouse threat.*

*Defining Cost Perspectives: The Importance of Multiple Benefits*

*The cost of global warming mitigation measures may depend upon the cost perspective used. For instance, from the utility perspective, rural trees always have positive cost and deliver only carbon sequestration. Energy conservation, on the other hand, both saves the utility money (by avoiding power plants) and reduces* *carbon emissions (Krause et al. 1989b).*[4] *Society may garner benefits from rural tree planting that are irrelevant to the utility (such as wood products, wildlife habitat, erosion control, etc), so planting trees may be beneficial to society while not being the most cost effective carbon mitigation measure for the utility.*

*Proxy approaches should be based on estimates of theSocietal Cost of mitigation measures. Such analysis is difficult because of the wide range of benefits that investments like trees and energy conservation offer. However, ignoring these benefits may be misleading.*

## *5. NET COST*

*Krause and Koomey (1989b) present a consistent methodology for incorporating multiple benefits when comparing saved carbon from energy efficiency to sequestered carbon in rural trees. This methodology is based on Net Cost, which is defined as:*

$$\text{Net Cost}\left(\frac{\$}{ton}\right) = \frac{\text{Cost - Other Benefits}}{\text{Carbon Savings}}$$

*The net cost of a carbon saving resource can be negative, in which case mitigation is better than free. If the cost of the power plant avoided by efficient electric appliances is equal to 5¢/kWh, and the cost of the conservation measure is 3¢/kWh, the net cost of this resource to the utility is -2¢/kWh (this net cost of conserved energy can be converted to a cost of conserved carbon using the carbon savings per kWh). If the cost to society of air pollutant emissions from the power plant is equal to 1¢/kWh, then the net cost of efficiency is -3¢/kWh from the societal perspective, and the cost of conserved carbon would be reduced correspondingly. As noted above, the existence of negative cost resources does not imply that the risk from global warming is zero.*

*Wider application of this methodology awaits further research. In the longer term, the Commission should consider multiple benefits of global warming mitigation measures in their least-cost analysis of these options.*

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[4] *This conclusion presupposes the existence of a mechanism to eliminate the utility's short-run disincentive to conserve, such as California's Electric Revenue Adjustment Mechanism.*

## 6. CHOOSING A NUMBER

*CEC Staff have chosen a value of $7/ton of $CO_2$, based on a proxy approach. Other parties in this proceeding (eg, Nahigian et al (1990)) have examined the assumptions supporting this value. The following comments focus on general approach and not on specific assumptions.*

*In the face of the uncertainties alluded to above, the CEC should choose a conservative number for the value of global warming mitigation, and apply it in resource planning. As Figure 3 shows, CEC Staff's value is lower than several other estimates of rural tree sequestering costs, which indicates that it is conservative. As more information and research accumulates, the number and the methodology can be modified to better correspond with the state-of-the-art.*

*Not assigning a value to global warming implies that this value is zero. However, the current best estimates of risks associated with global warming (Krause et al. 1989a) indicate that this risk is substantial. A conservative choice for the value of global warming mitigation will incorporate these risks into planning and lead to a more efficient outcome from society's perspective.*

## 7. CONCLUSIONS

*To minimize risk, society must act to mitigate global warming without complete knowledge of its potential consequences. The California Energy Commission should choose a conservative number as the value of global warming mitigation to society, use it in resource planning, and modify it as further research indicates. In the longer term, the CEC and staff should incorporate Net Cost into their analysis and planning.*

*Emissions from extraction, processing, and transport of all fuels can be important and should be added to estimates of carbon emissions at the point of end use. All greenhouse gases should be assigned the same costs per unit of contribution to global warming.*

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*Table 1: Environmental Insults From Fossil Fuels*

| | All Fuels | Natural Gas | Oil | Coal |
|---|---|---|---|---|
| Exploration/ Harvesting | $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, ROG, HCs, particulates, trace metals, thermal pollution | drilling accidents, drilling sludge disposal | drilling accidents, $SO_2$, drilling sludge disposal | mining injuries, land degradation, $SO_2$ |
| Processing/ Refining | $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, ROG, HCs, particulates, trace metals, thermal pollution | refinery accidents, refinery waste disposal | $SO_2$, refinery accidents, refinery waste disposal | $SO_2$ |
| Transport/ Distribution | $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, ROG, HCs, particulates, trace metals, thermal pollution | pipeline accidents, LNG explosions | pipeline and tanker accidents, oil spills, $SO_2$ | train accidents, $SO_2$ |
| Conversion/ Marketing/ End Use | $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, ROG, HCs, particulates, trace metals, thermal pollution | | ash disposal, $SO_2$ | ash disposal, $SO_2$ |

*ROG = Reactive Organic Gases, HC = hydrocarbons, LNG = Liquified Natural Gas*

*Stages of Energy Sources*

- Exploration/Evaluation
- Harvesting
- Processing/Refining
- Transportation/Distribution
- Storage
- Conversion  (Elect. Generation)
- Marketing
- End Use

*Phases within a Stage*

- Research
- Development/Demonstration
- Commercial Construction
- Operation and Maintenance
- Dismantling
- Management of Long-Lived Wastes
- Environmental Controls*
- Regulation and Monitoring*

## Figure 1:  Steps in Energy Production, Processing, and Use

*Occurs simultaneously with other phases but may have its own effects

Source:  Holdren, John P. 1981. "Chapter V.  Energy and Human Environment: The Generation and Definition of Environmental Problems." In *The European Transition from Oil:  Societal Impacts and Constraints on Energy Policy*. Edited by G. T. Goodman, L. A. Kristoferson and J. M. Hollander.  London: Academic Press.

***Insults*** *to Physical and Human Environment*

Resources Used (land, water, energy)
Material Effluents ($NO_x$, $SO_2$, $CO_2$)
Non-Material Effluents (noise, radiation, E&M)
Other Physical Transformations (dredging)
Socio-political Influences (politics, employment)

***Pathways*** *(Convert Insults to Stresses)*

Media (air, water, ice, soil, rock, biota)
Processes (evaporation, diffusion, conduction)

***Stresses*** *(Physical or Social Consequences of Insults)*

Altered ambient conditions (temperature, humidity, concentrations, EM fields)
Altered physical or social processes

***Environmental and Social Costs*** *of Insults*

Magnitudes of Consequences
Temporal Distribution of Harm
Spatial Distribution of Harm
Coincidence of Risks and Benefits
Scaling (linear or nonlinear)
Resistance to Remedy
Irreversibility
Visibility of Harm
Quality of Evidence of Harm

## Figure 2: Insults, Pathways, Stresses, and Environmental Costs

Source: Holdren, John P. 1981. "Chapter V. Energy and Human Environment: The Generation and Definition of Environmental Problems." In *The European Transition from Oil: Societal Impacts and Constraints on Energy Policy*. Edited by G. T. Goodman, L. A. Kristoferson and J. M. Hollander. London: Academic Press.

**Figure 3: Carbon Dioxide Mitigation Costs ($/ton of $CO_2$)**