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ETHICAL AND COST-EFFECTIVE POLICY RESPONSE TO GLOBAL WARMING: ENERGY EFFICIENCY AS A FIRST STEP

by
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CERTIFICATION

THE UNIVERSITY OF CALGARY
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The undersigned certify that they have read, and recommend to the Faculty of Environmental Design for acceptance, a Master's Degree Project entitled

Ethical and Cost-Effective Policy Response to Global Warming: Energy Efficiency as a First Step

submitted by Kerri R. Blair in partial fulfillment of the requirements for the degree of Master of Environmental Design.

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ABSTRACT

Ethical and Cost-Effective Policy Response to Global Warming:
Energy Efficiency as a First Step

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Prepared in partial fulfillment of the requirements of the M.E.Des. degree in the Faculty of Environmental Design, The University of Calgary

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Through detailed analysis of recent raw data and careful construction of global mean temperature records dating back to the 1800s, scientists have concluded that a significant warming of the earth's surface has taken place alongside increases in the atmospheric concentration of greenhouse gases emitted from human activities over the past 100 years. Complex general circulation models have been used to predict future climatic conditions should anthropocentric emissions of greenhouse gases (primarily carbon dioxide, methane, chlorofluorocarbons and nitrous oxides) continue in a business-as-usual fashion. Scenarios for the possible effects of rapid climate change include suffering and loss among both human and non-human inhabitants of the planet. Given that some form of policy intervention could serve to avoid such suffering and loss, the application of certain ethical principles implies that intervention is morally imperative.

Among the range of ethical principles that might be applied to global warming policy are those that recognize (in varying degrees) the rights and moral standing of future generations and non-human beings. As the number of beings considered morally relevant (and/or rights possessing) grows, greater investment in intervention measures becomes justifiable.

The two basic types of intervention most often discussed with respect to global warming are adaptation and avoidance. Among the options that fall under either adaptation and avoidance, energy efficiency is one that stands out as being highly cost-effective in the initial stages of implementation. In addition, energy efficiency is attractive as a first step in any global warming policy because it accords with ethical principles that range from those that are anthropocentric and present-oriented to those recognizing intergenerational equity and the moral relevance (and/or rights) of non-humans and whole ecosystems. As the number of beings considered morally relevant (and/or rights possessing) grows, implementation of greenhouse taxes, tradable carbon coupons and other comparable market-based measures become justifiable, which in turn renders energy efficiency even more cost-effective.

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INTRODUCTION

There is growing evidence that the earth is experiencing unprecedented warmth as the result of a phenomenon known as the greenhouse effect (e.g. Hare, 1992). Much like the walls of a greenhouse, gases and other substances emitted from human activities are building up in the atmosphere and enhancing its ability to impede the outward flow of infrared radiation. The result - increased radiative forcing - is responsible for what temperature records suggest has been a significant warming trend since pre-industrial times (e.g. Jones and Wigley, 1991). In the context of current emission rates of greenhouse gases, scientists predict that the global mean temperature is climbing and will continue to do so, possibly increasing by between 1.5 and 4.5 ° C by the end of the next century (International Panel on Climate Change [IPCC], 1990).

The implications of global warming due to the enhanced greenhouse effect are not entirely clear. Uncertainty, particularly with respect to the complex interactions between different elements that influence climate, makes it difficult to predict the rate and magnitude of climate change (IPCC, 1990). If, however, significant climate change occurs at a rapid enough rate (relative to natural climatic fluctuations that have taken place throughout the course of the earth's existence), there is reason to believe that certain harmful consequences for some human and non-human populations could result (e.g. Schneider, 1989; Buckmaster, 1991).

Given that global warming is occuring and that it poses a potential threat to some of the planet's inhabitants, it could be argued that some means of policy intervention is in order. Either through mitigative or adaptive strategies (or a combination of both), there are many different options that might be undertaken in response to the potential threats of global climate change (e.g. National Academy of Sciences [NAS], 1991). Mitigation strategies, on the one hand, would include measures to control global warming (van Kooten, 1991) through reducing or offsetting greenhouse gas emissions (NAS, 1991). An example of mitigative action is governmental restriction of greenhouse gas emissions through the implementation of direct and indirect price controls (such as carbon taxes or tradable carbon permits) (National Economic Research Associates [NERA], 1991). Adaptation policy, on the other hand, is concerned primarily with enhancing the ability of certain human and ecologic systems to adjust or adapt to new climatic conditions or events (NAS, 1991). Examples of adaptation include the development of agricultural crop strains that are less sensitive to warmer climates and precipitation changes (NAS, 1991) and the construction of dikes or bridges to protect coastal areas from the consequences of sea level rise that could occur as the result of global warming (Schneider, 1989).

Objectives

One of the primary objectives of my research is to derive an ethical framework that might assist policy-makers in determining the form, timing and degree of intervention (given that some sort of intervention is desirable) in dealing with the global warming issue. In the following paper, I recommend that, prior to deciding upon a policy strategy, the ethical principles upon which policy will be based should be clearly stated. Specifically, it should be determined to what (if any) extent the interests of future people and non-human beings should be taken into account when assessing the various policy options.

A second objective is to illustrate that, according to ethical principles ranging from those that are anthropocentric and present-oriented in nature to those recognizing the rights of future generations and non-humans, energy efficiency across all sectors of society is desirable as a first step in any global warming response strategy. In many cases, I point out, the marked potential that exists for monetary savings through energy efficiency makes it perhaps the most cost-effective means of dealing with the greenhouse problem.

Finally, I aim to show that no one policy option alone may be sufficient to avoid the effects of human-induced climate change entirely. Despite the cost-effectiveness of energy efficiency as a first step in global warming policy, I suggest that, in order to satisfy certain ethical principles, it may be necessary to implement other more costly measures.

Methodology

As a preliminary step in my research, I reviewed scientific literature dealing with the greenhouse effect. Of concern to me was determining what causes global warming; what evidence exists to suggest that global warming is occurring; and what global warming implies for the future. I also sought information pertaining to the potential impacts of global warming on human populations and their various societal and technical systems as well as on ecosystems and non-human populations.

For the second stage of my research, I consulted philosophical texts and sought input from scholars (especially from Dr. Tom Hurka) to help establish the ethical principles that would be appropriate in assessing global warming policy. This phase of the research involved a review of such ethical principles as the "land ethic", according to which special value is recognized in the health of the biotic community as a whole (Callicott, 1989) and the "sustainability criterion" according to which, it is argued, future generations should, at minimum, be left no worse off than current generations (Tietenberg, 1984).

After gaining an understanding of the relevant techniques and principles of applied ethics, I reviewed the literature on policy options that have been considered in response to global warming. This phase of the research involved an investigation into both adaptive and mitigative strategies.

The economic arguments in favor of conservation constituted an important area of investigation. For this aspect of the project, a literature search was conducted and experts were contacted in order to obtain detailed information on energy savings potential in Canada and abroad. There are a number of reasons for including both developed and developing countries in the analysis. Patterns of energy use during the past decade, for example, suggest that most of the growth in the future will occur in the developing countries. (During the 1970s, energy use in developed countries increased by an annual rate of 6.6 percent which is more than four times the rate observed in developed countries (Sathaye et al, 1987)). References that described the positive and negative impacts of improved energy efficiency in less developed countries were consulted. Also, analysis comparing energy use and economic development was examined in order to determine the relationship between the two.

Developing countries were considered in the analysis for ethical reasons as well. Based on a principle that may be described as international equity (Hurka, 1992), and in recognition of the fact that global warming is by and large attributable to emissions in the developed countries (e.g. Tomalty 1992), it was essential to examine issues of the distribution of costs associated with adaption and mitigation measures. The latter, in turn, required an examination of energy technology transfer, development aid that promotes energy efficiency, and debt forgiveness (International Conference on Global Warming and Sustainable Development, 1991).

Among the sizable literature available on the subject of energy efficiency, recent case studies that illustrate cost savings through conservation were valuable in this phase of the research. I also sought information relating to the externalities (both positive and negative) associated with energy efficiency and alternative fuel usage.

Part of the economics review involved investigating the most substantive costs associated with implementing energy efficiency programs and exploring possible means of meeting these costs. Policy analysis literature dealing specifically with energy alternatives was consulted in order to obtain information on the advantages and disadvantages of carbon and other environmental taxes. In addition, I examined alternative mechanisms for promoting conservation and reduced greenhouse gas emissions.

Much of the literature discussed the proven and potential effectiveness of conservation in dealing with the greenhouse problem. Documents produced by government as well as private industry energy experts proved particularly helpful in this regard. Based on a number of case studies found in the literature, I documented quantitative estimates for the potential reductions in greenhouse gas emissions that might be achieved with improved energy efficiency, conservation and alternative fuel resource use. In addition, using data from the National Academy of Sciences (1991) (projecting temperature increases as the result of various carbon dioxide equivalent reduction scenarios), I attempted to quantify the effect that certain selected energy efficiency programs would have in mitigating global warming.

The Ethics and Climate Change Project

To explore the ethical issues associated with human induced global warming and rapid climate change, The University of Calgary based Institute for the Humanities has organized an interdisciplinary study team that includes philosophers, economists, environmental scientists and representatives from private industry. This study team met in its first week-long workshop in the summer of 1991. One of the results of that workshop was a statement recognizing ethical responsibility as an important basis for policy development (Ethics and Climate Change: Greenhouse Effect Team Members, 1991). Based on this recognition, each of the team members has been assigned research into areas related to ethics and climate change. Following interdisciplinary discussions at week-long workshops on individual research findings to be held in the summer of 1992, study conclusions will be presented in a book to be published shortly thereafter.

My work on this project constitutes one component of the Humanities Institute study. In conjunction with team member Dr. William Ross (and in consultation with Dr. Tom Hurka), I have prepared an initial draft of a chapter for the book tentatively entitled "Reductions Through Energy Efficiency at Home and Abroad". Dr. Ross will make revisions to the chapter and finalize it for submission to the editors. Chapter four of this document is envisioned as the draft chapter to be submitted. The material that preceeds chapter four consists of background information pertaining to the scientific understanding and potential impacts associated with global warming (chapter one); a review of policy options that have been suggested and some economic and ethical criteria recommended for assessing these options (chapter two); and some general observations about energy efficiency as a cost-effective and ethically acceptable part of global warming policy (chapter three). Chapter five consists of a summary of the findings as well as some recommendations for further consideration.

CHAPTER 1:
GLOBAL WARMING AND ITS IMPACTS

Radiative forcing is the term used to describe the atmosphere's ability to impede the outward flow of a certain amount of infrared radiation (The National Academy of Science [NAS], 1991). Atmospheric concentrations of water vapour and other trace gases, responsible for the majority of the radiative forcing that the planet experiences, keep the temperature of the earth approximately 33° C warmer than it would be without these substances (Hare, 1992). This property of the atmosphere, referred to as the greenhouse effect because it resembles the heat trapping effect of the glass of a greenhouse, is important for the survival of most of the planet's organisms (The International Panel on Climate Change [IPCC], 1990).

It is generally understood that, until the industrial revolution took hold in Europe and North America, global temperature change was almost entirely the result of natural climatic variability. With industrialization, however, began the heavy use of fossil fuels that, over time, has led to an accumulation of significantly greater concentrations of greenhouse gases in the atmosphere than would exist without human activity. Scientists calculate that since pre-industrial times, the level of atmospheric carbon dioxide, the gas responsible for over half of the greenhouse effect, has increased by 25 percent. The concentration of methane, another major greenhouse gas, has more than doubled what it was prior to 1750. Chlorofluorocarbons (CFCs), other contributors to the greenhouse effect, do not occur naturally and their existence in the atmosphere was not evidenced until production began a few decades ago (NAS, 1991).

Evidence that concentrations of carbon dioxide, methane, nitrous oxides, chlorofluorocarbons and other similarly behaving gases (greenhouse gases) are increasing due to human activity has led to the conclusion that human beings are, in effect, contributing to a rise in global mean temperature. The climatic change believed to be related to human activity is referred to as the enhanced greenhouse effect (IPCC, 1990).[1]

Particularly in the past ten years, scientists have been devoting increased attention to the study of global mean temperature. A main purpose of such study is to ascertain whether or not the global mean temperature has in fact been increasing corresponding to increases in the atmospheric concentration of greenhouse gases. Exact measurements prior to 1854 are lacking and there are admittedly numerous problems related to the long-term record of hemispheric and global mean temperatures. The original data are weakened by poor areal coverage in polar, marine and tropical regions, especially prior to 1900; incomplete elimination of urban warming effects; errors of original observation; imperfect calibration of thermometers; and difficulty in combining marine and continental records in global estimates (Hare, 1992). Careful analysis of more recent raw data using different techniques, however, has helped to minimize many of the long-term problems. Based on recent carefully constructed records, it appears that average global temperatures have warmed by roughly 0.5 ° C over the past 100 years (Jones and Wigley, 1991). According to Hare (1992:1), "a warming of the earth's surface is detectably in progress." Jones and Wigley note that the 1980s were a decade of unprecedented warmth (with global mean temperatures 0.2 ° C above those of any other decade) and that 1990 was the warmest year since comparable record-taking was initiated in the middle of the 19th century. The six warmest years in the global record, in descending order, are 1990, 1988, 1987, 1983, 1989 and 1981 (Jones and Wigley, 1991).

1Henceforth, however, the adjective "enhanced" will not be used. Nevertheless, the terms "greenhouse effect" and "global warming" will refer to human induced change.

General circulation models (GCMs) are the principal tools currently being used by scientists to predict what the climate will be like in the future. Commonly, GCMs simulate the equilibrium climatic conditions associated with doubling atmospheric concentrations of carbon dioxide compared to pre-industrial levels (NAS, 1991). Due to a difference of perspective, interpretation of GCM results do vary. The IPCC, for example, uses a temperature range of 2 to 4 ° C to accompany an equivalent doubling of pre-industrial carbon dioxide while the National Research Council's Board on Atmospheric Sciences and Climate uses a range of 1.5 to 4.5 ° (NAS, 1991). There is, nevertheless, a general consensus that, in the absence of changes in human activities and their outputs, there is a reasonable chance that an equivalent doubling of the preindustrial level of carbon dioxide will occur by the middle of the next century.

At present, there are numerous uncertainties associated with GCM predictions, especially with respect to the timing, magnitude and regional patterns of change. Part of the uncertainty is due to an incomplete understanding of the complex interactions between different elements that affect climate. The IPCC (1990:xii) explains that before more reliable predictions can be made, a better understanding of the following will be necessary: sources and sinks of greenhouse gases, which affect predictions of future concentrations; clouds, which strongly influence the magnitude of climate change; oceans, which influence the timing and patterns of climate change; and polar ice sheets, which affect predictions of sea level rise. Different elements act and react to one another, often in a cyclical fashion. The state of the atmosphere, including its temperature, greenhouse gas content, cloud distribution and wind distribution affect the amount of radiation that is transmitted into and out of the earth's and oceans' surface. Changes in any of these features can in turn produce changes in the atmospheric and/or oceanic temperature. These temperature changes can lead to changes in cloud cover and humidity that induce further changes in the state of the atmosphere (NAS, 1991). According to the NAS report, climate modifications are not instantaneous responses to the gas concentration changes that produce them. Rather, there is always a transient period before the equilibrium temperature is reached.

According to scientific understanding, shifts in temperature have been a natural part of the earth's processes throughout the planet's history and significant changes in climate have come about as the result of global mean temperature shifts of less than a degree. These historical shifts have occurred over relatively long periods of time - on the order of thousands of years (Schneider, 1989). Naturally occuring changes in temperature are believed to take place gradually enough for living creatures to adapt in a sort of evolutionary process. As distinct from the gradual change characteristic of natural climatic shifts, climate change associated with the greenhouse effect could occur at an unusually rapid rate. Based on GCM models, many scientists (e.g. IPCC, 1990) predict that the global mean temperature could increase by between 1.5 and 4.5° C in less than a century. Scientists generally agree that the magnitude and abruptness of climate change will ultimately determine the impact of global warming (e.g. Schneider, 1989; IPCC, 1990; NAS, 1991: Hare, 1992;).

Rapidly occuring global climate change could have a variety of effects on the earth and its inhabitants. Schneider (1989:124) stresses that consideration of the effects of climate change will necessarily involve economic, social and political as well as physical and biological questions. Making educated guesses about the consequences of global warming into the next century might best be achieved, says Schneider, through integrated impact assessment and scenario formulation.

The following impact scenarios dealing with water runoff, sea level rise, agriculture and natural ecosystems are meant to illustrate what is possible as the result of global warming. In addition to these, many other concerns have been expressed and a great number and diversity of impacts have been suggested as likely outcomes of rapidly occurring global climate change (e.g. Abrahamson, 1989; Bates, 1990; IPCC, 1990; NAS, 1991).

Water Runoff

One of the first areas of concern is that of water runoff (Schneider, 1989). Though at present levels, the total amount of runoff is sufficient to satisfy global needs, some areas receive a more than an adequate supply of water, while others do not recieve enough water. The global balance is uneven. Any changes in runoff, particularly those that amount to an overall reduction in the flows of interregionally or internationally shared basins, clearly have the potential to generate or intensify conflicts over water. Thus, explains Schneider, there could be a connection between changes in runoff due to global warming and a certain degree of geopolitical instability.

Changes in water runoff due to climate change could have a variety of effects depending upon many different factors. Vulnerability to change is influenced by such factors as reservoir storage capacity relative to average annual water basin flows and the demand for water (for agriculture, industry and residential use) relative to the predictable available supply. Other regional characteristics that determine vulnerability are an area's degree of dependence on hydroelectricity; its reliance on groundwater supplies; and the amount of seasonal runoff variability (in magnitude and rate) of the area (Gleick, 1983).

Within the United States, it has been suggested that some areas are more vulnerable than others. Potential effects of precipitation changes have been studied in detail for the state of California (Gleick, 1983; Smith and Tirpak, 1988). Projections that consider several different scenarios for a doubling of atmospheric carbon dioxide share a common conclusion: the implications for California are, in general, earlier and greater runoff in early winter, followed by reduced runoff by late spring and summer. Overall, the amount and reliability of runoff would decrease by 7 to 16 percent. Current reservoirs would not be able to store the heavy winter runoff and also retain flood control capacities. Problems with demand (that, even without changes in precipitation, cannot forseeably be met according to future estimates) would be exacerbated by flow reductions related to temperature increases. Decreased availability of fresh water would not only affect urban, agricultural and industrial users, but would also be a threat to natural ecosystems. Estuaries where the survival of flora and fauna depends on fresh supplies to repel salty water would be especially threatened (Gleick, 1983; Smith and Tirpak, 1988).

The Great Lakes region is another area determined to be vulnerable to dramatic temperature shifts (Gleick, 1983; Smith and Tirpak, 1988). A significant drop in lake levels (from .5 to 2.5 metres below average historic levels) could take place due to changes in evaporation and precipitation patterns (Marchand et al, 1988). Lower lake levels could result in a need to invest hundreds of millions of dollars along the Illinois shoreline alone to dredge ports and harbors and to make channels deeper to accomodate shipping. Without dredging, reduced cargo loads could increase shipping costs between 2 and 33 percent (Marchand et al, 1988). On the other hand, reduced periods of ice cover due to warmer annual temperatures might lengthen the shipping season, compensating for the lower lake levels. According to Schneider (1989:142),

> If the lake states and countries were willing to make the few hundred million dollars of investment needed to expand port facilities and channels, shipping tonnages could not only be maintained but probably increased, owing to the longer shipping season. This is an example of..(a situation where)..wealthier countries would be in a better position to deal with climatic change than poorer countries. The former have the resources to adapt more effectively, while the latter lack the financial capacity to mitigate the effects of climate change by infrastructure changes.

Another possible effect of global warming would be changes in farming practice in the areas surrounding the lakes that could, in turn, alter the runoff of nutrients and chemicals into the lakes, thus altering water quality.

Schneider stresses repeatedly that the effects of global warming on water runoff are far from certain. Even the most sophisticated climate models cannot with certainty predict whether precipitation will in fact increase or decrease in different areas. In the face of such uncertainty, local planners are quite reluctant to take any precautionary steps. On an international level, however, the potential for changes in water flow is viewed with concern and desire to know more. In general, planners from the local to international levels of decision-making tend to support efforts to reduce the rate of climate change due to the greenhouse effect in order to "buy time" for the study of the relationship between temperature increases, precipitation changes and water runoff. Thus, by slowing the rate of greenhouse gas build-up in the atmosphere, more time would be available to make more accurate forecasts about the eventual impacts (Schneider, 1989).

Sea Level Rise

Sea level rise, which could come about as the result of several temperature-related changes, is another potential result of the greenhouse effect that has generated much discussion and speculation. Most of the rise would probably be due to physical expansion of the oceans. (Like mercury in a thermometer, oceans expand as they warm.) (Wigley and Raper, 1987) Another factor contributing to sea level rise could be a hastened melting of the ice on mountain glaciers in the Alps, Andes, Rockies, Himalayas and in other ranges (Meier, 1984).

The difference in ability to adapt to change between wealthy and relatively poor nations is especially relevant where sea level rise is a threat. For example, the Dutch, as the result of a long history of protecting the sub-sea level country against sea level rises and incorporation of a large margin of safety, have the economic capacity and a considerable technological headstart to avoid ocean water rising over Holland's dikes (Hekstra, 1989). In contrast, a less developed country such as Indonesia may not have the money or the technology to protect its inhabitants against the potentially devastating consequences of a sea level rise as small as one metre per century (the rate typically suggested by scientists for the twenty-first century) (Schneider, 1989).

A variety of physical and political characteristics of Indonesia could serve to worsen the country's chances of avoiding harm due to climate change. Indonesia possesses 15 percent of the world's coastlines, and 40 percent of Indonesia's surface is considered vulnerable to predicted changes in sea level. Both the abundance of diversely speciated wetland ecosystems and the large numbers of people living in vulnerable coastal areas could suffer tremendous losses from flooding (Schneider, 1989).

There are countries other than Indonesia that could be deleteriously affected by sea level rise. In Thailand, for example, coastal recession could displace entire villages and deprive many people of their lands and resources, while existing problems of salt water intrusion would be exacerbated (Hekstra, 1989). Among the many serious problems related to coastal flooding of poorer regions throughout the world are the prospects of migration and the creation of environmental refugees, with major implications for international peace and security (Schneider, 1989).

Agriculture

Projections for the effects of global warming on agriculture tend to be more optimistic than predictions concerning other areas of potential change (e.g. van Kooten, 1991; Schneider, 1989). Particularly in some regions, crop yields and cropping area could increase as the result of global warming. Arable acreage would probably increase, for example, in the northern regions of the Canadian provinces of Alberta and British Columbia where adequate soils are available (van Kooten, 1991).

As with most other predicted impacts, there is a great deal of uncertainty regarding the effects of global warming on agriculture. In addition, it is generally recognized that the effects will vary by geographic region (van Kooten, 1991; Schneider, 1989). It has been suggested that the best approach for assessing potential agricultural changes is to apply GCMs on a crop-by-crop and region-by-region basis (Parry et al, 1988). Even as the result of this technique, the variability of crop production factors and the lack of knowledge pertaining to the effect of carbon dioxide on crops (while temperature and precipitation changes come into play simultaneously) make it difficult to predict with certainty what the effects on production will be (Schneider, 1989).

Some researchers in the U.S. are confident that, even with decreases in yield of up to 36 percent (double the largest of the figures predicted based on GCMs) in the regions with the highest production today, production capacity would still be adequate to meet world food demand. Helping to compensate for decreases in yield due to climate change, according to these researchers, is an expected increase in yield due to technological improvements (van Kooten, 1991).

Application of GCMs suggests, in general, that there will be an overall shift in the centres of agricultural productivity (Parry et al, 1988). For example, though northern parts of Alberta may benefit from the climatic changes, the southern part of the province may become quite a bit warmer and potentially dryer, thereby resulting in increased soil moisture requirements for agriculture (Byrne, 1991). According to Byrne, there could arise a much greater need for water due to notable increases in crop evapotranspiration and the changes in precipitation accompanying global warming are not expected to accomodate this increased need. Schneider cautions that undesirable consequences related to food security and economic equity could result from such shifts. Especially in midlatitude areas, changes in comparative regional advantages could lead to the development of international and domestic conflicts (Easterling et al, 1989).[2]

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[2] In developing countries agriculture assumes a more significant role than its simply being a source of food. A group of Indian specialists stress that the primary difference between developed and developing country agriculture is the technological character, and more specifically the energy intensity, of production. According to Sinha, Rao and Swaminathan (1988), taking into account the energy input of Western-style agriculture, land preparation, on-the-farm work, transport to processing plants and sale in supermarkets with trucking, refrigeration and lighting all factored in, then "more commercial energy (is) being spent than..harvested solar energy through crops. Thus, it would be virtually true to say that ultimately in developed countries, fossil fuels serve as food." In developing countries, where over 50 percent of the population works on farms, it is quite possible that technological improvement of the kind envisioned for agriculture in developed countries would displace many of these people to city slums (Sinha et al, 1988).

Optimistic projections for the impact of global warming on agriculture are further tempered by specialists who caution that the complex interactions between production and the environment are not understood well enough to warrant complacency. Conditions conducive to the flourishing of crop pests, for example, could constitute a significant threat related to climate change (Sinha et al, 1988).

As in the case of water runoff issues, the uncertainty and divergence of opinions associated with the effects of global warming on agriculture give rise to an unwillingness to commit to action on the part of local and regional planners. Schneider again stresses (1989:175) that the

> relative inability to know how to react yet at the local level should not be misconstrued as a lack of need to act at national and international levels to slow down the rates of change and buy time. This strategy will allow scientists to improve their forecasts so that sounder planning can be made at the local level. Extra time will also allow the development of agricultural infrastructure, testing of new seeds, and improvement of irrigation systems. With these efforts made, humanity will be better able to adapt as climate change inevitably unfolds than if it came unknown and in a giant rush.

Natural Ecosystems

Similar to agricultural crops, natural ecosystems would likely undergo regional redistribution as the result of climate change. However, certain species, especially some trees, would be much less capable of adapting to rapid climate change than would agricultural crops. Trees have in fact "moved" thousands of kilometres due to temperature changes occurring over a very long period of time (somewhere on the order of a degree or so per thousand years). Research suggests that, through history, intact forest systems and animal ecosystems did not simply move north with changes in climate. Instead, as species moved they changed their relative abundances and, as a consequence, habitats changed (Emanuel et al, 1988; Botkin and Nisbet, 1986). If climate changes at the unprecedented rates predicted by some models, many species may be unable to migrate quickly enough to new locations appropriate for their flourishing. As a result, these species and many of the animals that rely on them for habitat may go extinct.

Conclusion

It is becoming increasingly clear, according to many scientists today, that a marked warming of the earth's surface is in progress. To at least some extent, recent records of unprecedented warmth are attributed to the enhanced greenhouse effect which, predominantly, has been brought about by the emission of greenhouse gases from human activity. In order to predict future climatic conditions, complex and carefully developed general circulation models have been used. Though there are numerous uncertainties associated with these model-generated predictions, especially with respect to the timing and magnitude of change, there is growing consensus that, before the end of the next century, the global mean temperature could increase by between 1.5 and 4.5 ° C. This temperature increase (and other related climatic changes) could have many diverse effects on human societies and natural systems. Though there is no clear indication that all of the effects will be detrimental, many impact scenarios suggest that there may be reason for concern. Possible changes in water run-off and shifts in agricultural productivity, for example, could lead to regional disparity and political tension. Sea level rise could potentially be devastating to some predominantly coastal communities in less developed countries. And climate change might occur too rapidly for certain non-human species and ecosystems in general to adapt, thereby resulting in extinction and significant losses of biodiversity. If the potential exists for these and other harmful impacts as the result of human-induced global warming, then it would appear that policy discussion related to the global warming issue is in order.

CHAPTER 2:
GLOBAL WARMING POLICY OPTIONS

One of the first criteria of relevance to decision-making on global warming policy is cost-effectiveness. Employing cost-effectiveness means choosing options with the lowest cost relative to their level of effectiveness. Policy-makers are responsible for the allocation of resources (most often in the form of financial support) and, in deciding whether or not to invest resources into a project, consideration must be given to alternative projects in order to ensure that the financial and other resources will be used in the most efficient and effective manner possible. In other words, the prospect of investment into any given policy option must be weighed against investment elsewhere (e.g. NAS, 1991; Patton and Sawicki, 1986).

The cheapest solution, however, is not necessarily the one that will become policy. In some situations, a more expensive solution that yields a higher degree of effectiveness in dealing with the issue at hand might be preferable to a cheaper, less effective option. In addition to questions of cost and effectiveness, there are numerous ethical criteria that should be called upon to help determine desirable policy options. Notions such as equity, and the respect of rights and moral obligations can be extremely important with regard to policy making. To a large extent, policy making is an exercise in applied ethics (Hurka, 1992).

Applied Ethics

Philosophers generally distinguish between two different types of ethics: theoretical and applied. Essentially, theoretical ethics is the process of deriving general ethical principles. Applied ethics, on the other hand, is an attempt to apply general moral principles to situations and issues. With the use of general ethical principles, one can attempt to explain judgements one already accepts or to arrive at judgements one could not otherwise arrive at (Hurka, 1992).

Applied ethics requires detailed knowledge of both the ethical principles and the facts around an issue. For example, when assessing the ethical implications of paroling prisoners, it is important to know whether (e.g. statistically) paroling prisoners does or does not lead to increased crime. Similarly, regarding an issue such as taxation, applied ethics would require that decision-makers understand the effects increased taxation will have on the welfare of the less well-off members of society. An understanding of the facts surrounding an issue serves to guide the policy maker in applying ethical principles (Regan, 1986).

In addition to knowledge of the real-world setting in which moral questions arise, there are other features that, ideally, should characterize any exercise in applied ethics. One of these features is conceptual clarity (Regan, 1986). Conceptual differences between certain terms need to be explicit and clear when undertaking an exercise in applied ethics. Some ethicists might claim, for example, that sentience, the ability to feel such things as pain, pleasure, and happiness, is a sufficient condition for a being to possess rights (e.g. Regan, 1986). Others might claim that sentience is a sufficient condition to give a being moral standing but not rights (e.g. Singer, 1973). Whereas possession of rights involves justified constraints upon how others may act, possession of moral standing does not necessarily guarantee such constraints. According to Hurka (1992), recognizing that a being has moral standing implies that that being has interests that count in the calculation of what are the best consequences, but (unlike rights) these interests can be overriden. Moral standing may give a being reason to be considered in issues that might forseeably involve pain or suffering, but does not imply that this being has a right to life, liberty or some other guaranteed state of existence. The difference between moral standing and possession of rights is one of numerous important conceptual differences that need to be made clear when applying ethics to policy issues (Hurka, 1992).

Besides knowledge of facts and conceptual clarity, good judgment in applied ethics requires an element of rationality. Rationality involves the ability to recognize the connection between different ideas and to understand that if some statements are true then some other statements must be true while others must be false. The need to be rational implies the need to observe the rules of logic. The antithesis of rationality, contradiction, according to Regan (1986), renders moral judgement that falls short of the ideal.

Finally, clearly stated ethical principles are critical to good moral judgement. In particular, it is necessary when practicing applied ethics to determine which are the relevantly affected beings, which beings have moral standing and which have rights (Hurka, 1992).

There are many different points on a continuum that might be used to describe the positions one may take with respect to establishing ethical principles. Positions could conceivably range from a very narrow to a relatively broad recognition of which beings have moral standing and/or rights. In determining the relevantly affected, morally considerable and/or rights possessing beings, it is perhaps useful to divide the continuum into sections (Hurka, 1992). Though this sort of division presents an oversimplification of the true diversity of ethical positions possible, it is a practical step in an introductory examination of applied ethics.

The spectrum of ethical positions might be divided according to recognition of interests. The first division of the continuum might occur at a point where only human beings are considered to possess moral standing or rights and where the interests of presently existing human beings are considered to be of greater importance than those of humans that will exist in the future. At this point, moreover, non-humans have neither rights nor moral standing. People now may care about people in the future and about non humans, and it may therefore be proper to say that looking after future and non-human beings is in the interest of presently existing people. Following from this, it is probably true, even at this point on the continuum, that future and non-human beings count in an indirect way. Nevertheless, this arbitrarily chosen point serves to define a first general ethical principle that is, relative to the other positions on the continuum, more anthropocentric (person-centered) and present-oriented in nature (Hurka, 1992).

In turn, points of division might be designated first, where the interests of future generations of people are considered of equal relevance to those of present generations (designating a principle of intergenerational equity); and, second, where the interests of non-humans are considered relevant (designating an environmental ethics principle) (Hurka, 1992).

In this analysis of global warming policy, these three points on the continuum of ethical principles will be used. In assessing policy response options, a present-oriented anthropocentric principle will be applied, followed in turn by a principle of intergenerational equity and environmental ethics.

Ethics and Future Generations

What, if any, ethical bind exists between present and future persons? This question, according to Shrader-Frechette (1981), constitutes a classic conflict in ethical philosophy. In determining how resources will be used, policy makers must commonly consider notions of equity and utility with respect to future persons and, whereas some policy makers might employ a "time-bound" ethical principle that calculates the greatest good for the greatest number of those presently alive, others might base decisions on considerations of equal justice for all generations (Shrader-Frechette, 1981).

The issue of obligations to and rights of future people might be viewed from many different perspectives. Wagner (1981: 64), for example, suggests that it is in people's nature to have a "future focus"; that humans "probe" the future through work and play, basing decisions on conjecture and speculation; and that "modern societies justify themselves in terms of their future". However, Wagner sees no relevance (in a direct dependency sense) for the present in the threats to humankind's existence in the future.

As mentioned above, present people may care about future people; and, therefore, future generations may be said to matter indirectly, even from a relatively present-oriented perspective (Hurka, 1992). While refuting any direct dependence of present people on the welfare of future generations, Wagner asserts that we in the present derive something of importance by altruism toward the future. He believes that concern for the future benefits us in the present by involving us in the "intimacy of empathetic role-taking". Through the process of empathisizing with future peoples, humanity becomes more compassionate. In turn, a compassionate humanity, says Wagner, is necessary for the self-actualization of each presently existing person. In essense, he is arguing that we have a concern for (not necessarily an obligation to) future people because it helps us in the present. In contrast to Wagner, Shrader-Frechette (1981:60) argues that "there is a social contract among all humans and that membership in the moral community need not be limited by considerations of time". She concludes that "we must ascribe the same basic rights to future generations as those we claim for ourselves".

The notion of duties to future generations could be applied on strictly utilitarian grounds (Hurka, 1992). In an effort to maximize the sum-total of all benefits, utilitarians might justify inequalities. The result, says Hurka, could conceivably be rough on present generations (e.g. where present humans are made to forego consumption by some extensive degree with the aim of providing in excess a certain resource for future people). Intergenerational equity, on the other hand, calls for equality between different generations and, as such, would not prescribe actions that require present generations to make significant sacrifices in order to maximize benefits in the future. Illustrating the concept of intergenerational equity, Livingston (1981) describes a duty to future generations as a stewardship. Livingston suggests that present generations have an obligation to hand over to our descendants that which has been in our temporary custodianship in as good a shape as we can manage. We have, he insists, a moral duty not to foreclose options on behalf of those who follow us. Described as the "sustainability criterion" (Tietenberg, 1984), this ethical tenet maintains that as the result of our decisions and actions (or inaction), future generations ought to be at least as well off as us.

Sustainable development, a concept made popular by the Brundtland report (WCED, 1987), implies a certain degree of concern about the future as expressed by present generations of people. The Brundtland Commission explains that, in travelling the world for nearly three years and listening to government leaders, scientists, experts, citizens' groups and thousands of individuals, it found

> grounds for hope: that people can cooperate to build a future that is more prosperous, more just, and more secure; that a new era of economic growth can be attained, one based on policies that sustain and expand the Earth's resource base; and that the progress that some have known over the last century can be experienced by all in the years ahead. (WCED, 1987:28)

In principle, present persons may indeed regard themselves as having a moral duty to respect the rights of future generations. In situations where decisions favour the maximization of benefits in the present, however, persons tend to (either consciously or subconsciously) apply high discount rates. The discount rate is the term used to refer to the rate at which currency (or another valued entity) is perceived to decrease in value with time. In economic terms, the discount rate is the return on foregone present consumption that is sacrificed to secure future consumption. A temporal discount rate gives progressively less weight to goods in more remote generations (Norgaard and Howarth, 1991). Use of a proper discount rate is important when dealing with integenerational resource use - a discount rate that is too high may imply that not enough attention is being paid to future generations and a rate that is too low may mean that inadequate attention is being paid to present generations (Ross, 1992).

According to Norgaard and Howarth (1991), (traditional) economic theory rationalizes discounting the future.

> Economists heretofore have not distinguished between decisions concerning the efficient use of this generation's resources and decisions concerning the reassignment of resource rights to future generations. All decisions over time have been simply treated by economists as investment questions, as if all resources were always this generation's resources. (Norgaard and Howarth, 1991)

Cost-benefit analysis, assert Howarth and Norgaard (1991), should be treated as one criterion of many in policy formulation and should be used only in conjunction with ethical principles that define the proper distribution of welfare between present and future generations.

Ethics and People in Distant Lands

According to Regan (1986), in discussing questions about rights and moral standing, people in distant lands should be treated with impartiality. Singer (1972) argues that (by assumption) suffering is bad and that, if it is in our power to prevent something bad from happening (without sacrificing anything of comparable moral importance), we ought, morally, to do it. According to Singer (1972:232), the above takes no account of proximity or distance:

> The fact that a person is physically near to us, so that we have personal contact with him, may make it more likely that we *shall* assist him, but this does not show that we *ought* to help him rather than another who happens to be further away. If we accept any principle of impartiality, universalizability, equality, or whatever, we cannot discriminate against someone merely because he is far away from us (or we are far away from him).

Throughout this paper, a principle of international equity is recognized. In essense, this principle states that, once determined, rights, moral standing and/or other aspects of ethical relevance are applicable to all individuals in all countries of the world (e.g. Regan, 1986).

In the context of global warming, international equity is of special relevance. It has been noted that most of the responsibility for the release of carbon dioxide and other greenhouse gases and therefore the escalation of the greenhouse effect belongs to the developed countries of the world (Tomalty, 1992). The threats associated with the greenhouse effect, however, are global in nature, and (as noted in Chapter 1) it is the less developed countries that are likely to sustain the most harm from predicted climate changes (e.g. Schneider, 1989).

Given that all people of the world have equal rights to life and freedom from suffering, we in the more affluent countries have a moral obligation to do what it is in our power to do in order to avoid the harm to individuals in less developed countries that has been associated with global warming scenarios.

Ethics and Human Versus Non-Human Beings

Perceptions about the relationship between humans and nature are undoubtedly shaped by cultural and religious beliefs. Lynn White, for example, argues that, especially in its Western form, Christianity is one of the most anthropocentric religions that has been practiced in the world (White, 1973). According to White, Christianity, in contrast to paganism and most Asian religions, established a dualism of human beings and nature and insisted that it is God's will that human beings exploit nature for their own purposes. Some scholars point to spiritual thinkers such as St. Francis of Assisi to demonstrate that Christianity is not entirely anthropocentric. St. Francis proposed that the idea of the equality of all creatures be substituted for the idea of humankind's limitless rule over creation. White asserts, however, that St. Francis's alternative view of the human to nature relationship failed to take hold.

In contrast to White's insistence on the "orthodox Christian arrogance toward nature" (1973:30), Lewis Moncrief (1973) suggests that there has been a certain degree of egoism on the part of human beings from the beginning of humankind's existence. Moncrief explains that intervention in natural processes, such as redirection of the waters of the Nile, occurred long before Christianity developed.

There are others who disagree with White's interpretation of the effect Christianity has had on humans' view of nature. According to Howard Coward (1992:5), for example, though the Bible may place humans in a position superior to nature, it also establishes the dominion of the human as that of "*a responsible co-worker with God* rather than that of a selfish and arrogant despot." The message of Genesis, says Coward, is that humans should strive for harmony between all aspects of God's creation. Coward argues (1992:8) that, rather than from the Bible, rationale for domination and exploitation of nature resulted from the rise of a scientific worldview in the seventeenth century which was "highlighted by Francis Bacon's proposition that the conquest of nature is the goal of science."

Though it may be the result of a long period of religious, cultural and/ or scientific thought development, a human-centered ethic is nevertheless echoed in myriad ways in contemporary society. In the treatment of issues concerning environmental degradation, a dualism of human beings and nature is very often assumed. Stein and Harper (1983) argue that the environmental scientist's client is humanity and that his or her role is not to save the environment per se but to protect the rights of persons to an environment which allows them to pursue their goals. Our Common Future (The World Commission on Environment and Development [WCED], 1987), a widely discussed report (commonly referred to as the Brundtland report) recommending implementation of a concept known as sustainable development, is notably anthropocentric in its treatment of the environment. Throughout the Brundtland report, priority rests on the fulfillment of human goals. Preservation of the environment in this context is only important because it serves to fulfill basic human needs.

Anthropocentric ethical principles are perhaps more common and less controversial than ethical principles recognizing the moral standing and/or rights of non-humans. Nevertheless, principles that are less person-centered have been explored increasingly with the recent upsurge of the environmental movement. In the relatively nascent field of environmental ethics, attention is focused on determining whether or not (and/or to what degree) non-humans may be said to possess morally relevant interests and rights, and on determining the duties (if any) that are owed by humans to non-human beings (Regan, 1986).

Aldo Leopold (1966) describes an ethical relationship between human beings and the environment as a natural progression in ethical thinking. Leopold urges the expansion of ethical thinking from religion (a "man-to-man ethic") and democracy ("a man-to-society ethic") to include a third major ethic, a "land ethic" emphasizing obligations rather than economic privleges. In 1971 Eugene Odum called environmental ethics an "attitude revolution" and emphasized the need for a stepwise expansion of ethical thinking to include Leopold's "third ethic":

> ...it matters not whether one takes the cynical viewpoint that man becomes ethical only when he has to or whether one believes that the goodness and wiseness in human behaviour eventually surfaces. We can confidently expect that the decade of 1970 to 1980 will bring greater acceptance of the third ethic, because it must. (Odum, 1971:12)

As is true for many other areas within the study of ethics, much discussion in the field of environmental ethics is devoted to establishing the criteria for ascribing moral relevance (e.g. Singer, 1973; Stein and Harper, 1983; Regan, 1986). As mentioned above, sentience is one example of such criteria (Singer, 1973). Other possible criteria of, for example, the possession of rights, include all and only free rational beings; all and only conscious beings; all and only beings who are able to use a language; and all and only beings who have a concept of themselves as an enduring entity (as a self) (Regan, 1986). The potential for consciousness, as a criterion for rights possession (or moral standing), for example, would imply that animals and fetuses have rights (or moral standing) but that plants do not.

Within the field of environmental ethics, different explanations are used to justify (in some cases) the moral standing and (in other cases) the rights accorded to non-humans. According to Callicott (1989), one of these explanations ascribes moral standing to all sentient beings. Because of a being's ability to feel pain and pleasure, according to this idea, it should not be subjected to unnecessary suffering (Singer, 1973). This code of behaviour would discourage decisions that might cause unnecessary pain to any creatures with the capacity to feel pain. "Humane moralists" or animal liberationists (as advocates of this "sentience argument" are commonly referred to) employ an "atomistic" vision of the world and its inhabitants. The landscape, as humane moralists see it, is a plurality of separate individuals (Callicott, 1989). In issues involving sentient non-humans, therefore, decisions might follow from a strictly utilitarian approach (where the objective is to maximize the sum-total of pleasure and minimize the sum-total of pain). Accordingly, for example, the killing of one whooping crane might be deemed preferrable to the killing of twenty rabbits, despite the fact that the former is endangered and the latter are not (Hurka, 1992).

Another approach to decision-making is one where special value is recognized in biodiversity or the existence of a wide variety of species. Leopold's land ethic (1966) most clearly defines this type of approach. According to Leopold (1966:224-25), "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise." In contrast to the humane moralist approach, the land ethic encourages a more holistic vision of the world (Callicott, 1989). Whereas animal liberationists are concerned about the suffering of domestic animals, proponents of the land ethic are generally indifferent toward domestic animals or the plight of animals used in scientific experiments. Emphasis, according to the land ethic, is not so much on animals as individuals, as on the biotic community as a whole. Where Singer (1973) expresses concern for sentient beings only, Leopold (1966) expresses concern over such occurrences as the disappearance of plant and animal species, soil erosion and the pollution of streams.

In the global warming policy arena, arguments espousing the moral standing or rights of individual sentient beings and those calling for preservation of a healthy biotic community might imply different decisions. For the most part, however, the implications for global warming policy of different versions of a non-anthropocentric ethical principle will differ more in degree than in kind. In general, any ethical principle recognizing the moral relevance of non-humans will call for greater investment and perhaps more expedience in response to the potential threats of climate change than a more anthropocentric ethical principle.

Ethically Correct Action

According to Hurka (1992), an ethically correct action is one which brings about the best consequences without violating any rights. Two questions, therefore, must be answered in order to decide what is ethically correct. First, it must be decided what determines "the best consequences". From a utilitarian point of view (a point of view quite commonly taken), the best consequences are those that maximize the benefits of those for whom benefits count (Hurka, 1992). Second, it must be determined who has rights. Because rights imply constraints, there are some actions that must not be taken , even if they have the best consequences (Hurka, 1992). For example, though five dying individuals might be saved by the killing of one person and distribution of his or her organs, such action is not just. As this example illustrates, the right to life (of even one individual) overrides other (utilitarian) objectives. (In a situation where one person might be sacrificed to save a population of thousands, the decision becomes more problematic.) (Hurka, 1992).

Determining the ethically correct action(s) with respect to global warming policy will require an examination of both the overall consequences of each action (in terms of enhancing adaptation to change or avoiding change) and the ethical principles that each action satisfies (or, alternatively, violates). In summary, I propose the following guides for decision-making in the global warming policy debate:

•Any action (or inaction) that violates the right to life and/or the right to be spared unnecessary suffering (once it has been determined which beings possess such rights) is unacceptable.

•If a humane moralist (or animal liberationist) stance is adopted, then any action that results in an overall reduction in the sum-total of pleasure or an increase in the sum-total of pain among individual sentient beings is unacceptable.

•If the land ethic is adopted by policy makers, then any action leading to loss of biodiversity or to a lessening of the overall well-being of the environment is seriously objectionable.

•If it is determined that future generations matter only indirectly, then actions that maximize benefits to present generations, though they may in some way disadvantage future people, are acceptable.

•If maximizing the sum-total of benefits to present and future generations is taken as desirable, then some actions that are detrimental to present generations may be justified if they contribute to an overall maximization of benefits in the long-run.

•If intergenerational equity is accepted as an ethical principle, then decisions and actions must result in future generations being at least as well off as present generations.

Examples of Greenhouse Warming Policy Response

Policy response to the scientific evidence that temperatures are warming and that significant shifts in regional climate may occur within the next century, might consist of essentially two types of options: adaptation and/or mitigation (e.g. Coward, 1992). Both adaptation and mitigation measures require evaluation from ethical, economic, social and cultural perspectives as well as according to the effectiveness each might have in avoiding harm related to global warming.

Even a brief overview of global warming policy options reveals that there are a great many choices available (e.g. NAS, 1991). The process of narrowing down the choices to those that are most appropriate for immediate or near-term action involves a careful analysis not only of initial costs, but of discount rates (and subsequent estimates for rates of return), effectiveness in enhancing adaption to or avoidance of global warming, external costs and costs across generations and species.

Adaptation

In the context of global warming, adaptation generally refers to actions that enable organisms and systems to carry on when climate change occurs. Adaptation options would exclude any actions meant to slow the rate of global climate change or otherwise alter the physical characteristics of the earth's atmosphere that have been determined responsible for the greenhouse effect.

As part of the decision-making process associated with greenhouse warming policy, examining the ability of people, systems and institutions to adapt to the predicted changes is an important first step. The NAS panel (1991:34) describes five alternative ways in which humans might adapt to future climatic changes: modify the hazard, as by channeling rivers that are prone to flooding; prevent or limit impacts, as by building dikes; move or avoid the loss, as by implementing flood plain zoning; share the loss, as by providing insurance; and bear the loss, as by losing all or part of a crop. There are thus numerous types of adaptation that could serve to assist human beings in dealing with global warming, some of which might be undertaken before climate change occurs and some after.

As the NAS panel points out, humans throughout history have utilized innovation to adapt to environmental conditions. Technological "hardware" such as fans, refrigerators, antifreeze and special farm equipment, and "software", including information and rules such as weather forecasts and insurance restrictions, make up the vast selection of means through which humans have coped with less than optimal weather conditions in the past. Many of these innovations have been developed rapidly in comparison to the 40 or 50 years predicted for the equivalent doubling of carbon dioxide.

The NAS panel makes a number of recommendations for adaptive action that might help make human and natural systems less vulnerable to future climate change. For the most part, the recommended actions are intended to make the affected systems more robust with respect to the events predicted to accompany greenhouse warming. In summary, these recommendations include the following:

•Maintain basic, applied and experimental agricultural research to help farmers and commerce adapt to climate change and thus ensure ample food.

•Make water supply more robust by coping with present variability by increasing efficiency of use through water markets and by better management of present systems of supply.

•Plan margins of safety for long-lived structures to take into consideration possible climate change.

•Move to slow present losses in biodiversity.

Evaluating the cost-effectiveness of adaptation options is difficult given the many uncertainties associated with the global warming issue. As an example, the NAS panel offers the option of constructing a hypothetical bridge over an estuary (1991:41):

> An added meter of height above sea level might add $100,000 to current construction costs. If that additional clearance were not included at the time of construction, and the sea level rose enough to require it after 50 years, the retrofit raising of the bridge might cost $5 million. Discounted at 6 percent per year, the present value of that $5 million is $271,000. If we were certain the sea would rise, we could realize a benefit of $171,000 in this example by adding the meter of clearance today rather than waiting.

Some adaptation measures, such as the development of drought resistant food crops or dike-building, may require significant costs to present generations while offering benefits almost exclusively to future generations. If intergenerational equity is accepted as an applicable ethical principle, then measures such as these would be easier to justify than if the applied principle is decidedly present-oriented.

If an ethical principle recognizing the value of biodiversity is taken into account, then even the most costly adaptation measures may not be adequate as a response to the threats of global warming. Though such things as agricultural and industrial systems may be characterized by a relatively low sensitivity and high adaptability to climate change, others, such as unmanaged forests and marine ecosystems may be unable to adjust if the change occurs rapidly enough (see chapter 1). If, in a holistic sense, the integrity of an ecosystem is threatened by the implications of global warming, then, through application of the land ethic, there are moral grounds for favoring avoidance over adaptation measures.

Animals whose habitat is lost as the result of climate change may experience suffering and death. Applying the animal liberationist point of view, if suffering as the result of climate change is avoidable, then investment should be concentrated in avoidance efforts. More controversially, from the perspective of those who uphold the rights of non-humans, allowing climate change to occur to the point where the right to life of any individual (human, animal or plant) is violated is morally unacceptable.

Society in general, and affluent societies, in particular, appear to be moving toward a state of less sensitivity to natural phenomena, including climatic fluctuations (NAS, 1991). However, some scenarios (e.g. Schneider, 1989), suggest that relatively poor countries may not have the necessary resources to adapt sufficiently to global warming, particularly if the magnitude and rate of change are great. Recognizing a principle of international equity, the welfare of people in all lands is of equal importance in the global warming issue. Therefore, suffering that people in less developed countries (for example, those in coastal regions of Thailand and Indonesia (see Chapter 1), might experience as the result of climate change is unacceptable and we (in developed countries) have a moral obligation to see that effort is made to avoid such suffering.

Thus, on the one hand, there is clearly a risk of extinction for some species due to an inability to adapt; and, on the other, there is some possibility that the people of many developing countries may be subjected to conditions to which they cannot readily adapt. These two factors (depending upon the ethical criteria used) provide justification for considering mitigation strategies.

Mitigation

The main focus of a mitigation strategy is to reduce or offset greenhouse gas emissions and thus avoid (or mitigate) the resulting climatic change. As part of such a strategy, a combination of regulatory and economic instruments might be utilized. Regulatory instruments, according to Alberta Energy (1991a) are "legislative and administrative rules established by government to provide clear directives concerning behaviour to industry or individuals operating within its jurisdiction". Regulations might, for example, require a company to obtain a permit or license before operating a plant. Such a permit could specify location and capacity of the plant, equipment and technological processes to be used and requirements for source and ambient monitoring and reporting of information on plant operations. Performance, product and equipment standards (such as energy efficiency standards that are incorporated into building codes) are another type of regulatory device (Alberta Energy, 1991a).

A major shortcoming associated with regulatory instruments is the difficulty of enforcement. With respect to improved performance standards, there is also some debate over effectiveness. One example of this concerns the issue of fuel efficiency standards for vehicles in Canada. On one side of the debate are lobby groups such as Friends of the Earth who press for tighter standards under the federal government's Corporate Average Fuel Consumption (CAFC) guidelines (Broadbent, 1991). On the other side are automobile manufacturers who argue that the CAFC efficiency standards are not practical without the support of high gasoline prices to give consumers an incentive to buy more efficient vehicles.

Requiring a certain degree of regulatory control, one mitigative option with the potential for global application is the elimination of halocarbon emissions. Halocarbons, including chlorofuorocarbons (CFCs), contribute a significant portion of the radiative forcing due to human activities. International phaseout of CFC manufacture and emissions was established as a goal at the 1987 Montreal Protocol to the Vienna Convention (Alberta Energy, 1991a). Though goals set at the Montreal Protocol were derived mainly in response to the role of CFCs in the depletion of stratospheric ozone, fulfillment of these same goals makes especially good sense given the additional role CFCs are understood to have with respect to global warming (e.g. Hare, 1992; IPCC, 1990). The need to continue the aggressive phaseout of halocarbon emissions could thus be an important contribution in the short run. As with other regulatory measures, successful elemination of halocarbon emissions depends upon enforcement.[1]

Though regulations provide a uniform level of control, they can be an inflexible means of achieving emission targets. Another type of mitigative policy instrument, referred to as an economic or incentive instrument (Alberta Energy, 1991a; NAS, 1991) might serve to address the deficiencies associated with regulatory policies. Economic instruments

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[1] Along with the phaseout of CFCs, effort could be directed toward the development of economical substitutes (i.e. means of providing the insulative and other useful properties that characterize CFCs) that do not contribute to the greenhouse effect.

include taxes, fees, subsidies and tradable permits. With regard to the global warming issue, economic instruments that affect greenhouse gas emissions directly would be most effective (Alberta Energy, 1991a). Thus in choosing between the option of taxing fuel-inefficient equipment and taxing the fuel itself, the latter would probably be more effective because it is closer to the thing meant to be discouraged (i.e. greenhouse gas emissions, specifically carbon dioxide which is created through the combustion of fossil fuels).

There are a host of options that have been suggested as global warming mitigation strategies. Many of these might be implemented using a combination of regulation and economic incentives. Table 2.1 provides a number of these strategies as summarized by the NAS panel.

The use of economic instruments is based on the belief that the costs of mitigation should be reflected in the cost of goods, especially in the cost of energy and energy intensive technologies (Alberta Energy, 1991a). Full cost accounting would require policy-makers to assess environmental, social and other costs when determining energy prices. At present, prices for energy and energy using devices do not generally reflect the ecological costs resulting from their production, use and/or disposal (Alberta Energy, 1991a). If, as the result of full cost accounting, energy prices were higher than they are currently, producers and consumers might have more incentive to reduce their use of fossil fuels and hence their greenhouse gas emissions through changes in fuel mix, new investments in energy efficiency and/or behavioral changes.

TABLE 2.1 BRIEF DESCRIPTIONS OF MITIGATION OPTIONS (FOR THE UNITED STATES) CONSIDERED IN NAS STUDY

RESIDENTIAL AND COMMERCIAL ENERGY MANAGEMENT

Electricity Efficiency Measures

White Surfaces/Vegetation	Reduce air conditioning use and the urban heat island effect by 25% through planting vegetation and painting roofs white at 50% of U.S. residences.
Residential Lighting	Reduce lighting energy consumption by 50% in all U.S. residences through replacement of incandescent lighting (2.5 inside and 1 outside light bulb per residence) with compact fluorescents.
Residential Water Heating	Improve efficiency by 40 to 70% through efficient tanks, increased insulation, low-flow devices, and alternative water heating systems.
Commercial Water Heating	Improve efficiency by 40 to 60% through residential measures mentioned above, heat pumps, and heat recovery systems.
Commercial Lighting	Reduce lighting energy consumption by 30 to 60% by replacing 100% of commercial light fixtures with compact fluorescent lighting, reflectors, occupancy sensors, and daylighting.
Commercial Cooking	Use additional insulation, seals, improved heating elements, reflective pans, and other measures to increase efficiency 20 to 30%.
Commercial Cooling	Use improved heat pumps, chillers, window treatments, and other measures to reduce commercial cooling energy use by 30 to 70%.
Commercial Refrigeration	Improve efficiency 20 to 40% through improved compressors, air barriers and food case enclosures, and other measures.
Residential Appliances	Improve efficiency of refrigeration and dishwashers by 10 to 30% through implementation of new appliance standards for refrigeration, and use of no-heat drying cycles in dishwashers.

Residential Space Heating	Reduce energy consumption by 40 to 60% through improved and increased insulation, window glazing, and weather stripping along with increased use of heat pumps and solar heating.
Commercial and Industrial Space Heating	Reduce energy consumption by 20 to 30% using measures similar to that for the residential sector.
Commercial Ventilation	Improve efficiency 30 to 50% through improved distribution systems, energy-efficient motors, and various other measures.
Oil and Gas Efficiency	Reduce residential and commercial building fossil fuel energy use by 50% through improved efficiency measures similar to the ones listed under electricity efficiency.
Fuel Switching	Improve overall efficiency by 60 to 70% through switching 10% of building electricity use from electric resistance heat to natural gas heating.

INDUSTRIAL ENERGY MANAGEMENT

Co-generation	Replace existing industrial energy systems with an additional 25 000 MW of co-generation plants to produce heat and power simultaneously.
Electricity Efficiency	Improve electricity efficiency up to 30% through use of more efficient motors, electrical drive systems, lighting, and industrial process modifications.
Fuel Efficiency	Reduce fuel consumption up to 30% by improving energy management, wast heat recovery, boiler modifications, and other industrial process enhancements.
Fuel Switching	Switch 0.6 quads[a] of current coal consumption in industrial plants to natural gas or oil.
New Process Technology	Increase recycling and reduce energy consumption primarily in the primary metals, pulp and paper, chemicals, and petroleum refining industries through new, less energy intensive process innovations.

TABLE 2.1 (continued)

TRANSPORTATION ENERGY MANAGEMENT	
Vehicle Efficiency	
Light Vehicles	Use technology to improve on-road fuel economy to 9.4 litres [L]/100 km (7.3 L/100 km in CAFE[b] terms) with no changes in the existing fleet.
	Improve on-road fuel economy to 6.6 L/100 km (5.0 L/100 km CAFE) with measures that require changes in the existing fleet such as downsizing.
Heavy Trucks	Use measures similar to that for light vehicles to improve heavy truck efficiency up to 7.6 L/100 km (5.9 L/100 km CAFE).
Aircraft	Implement improved fanjet and other technologies to improve fuel efficiency by 20% to 130 to 140 seat-miles per gallon.
Alternative Fuels	
Methanol from Biomass	Replace all existing gasoline vehicles with those that use methanol produced from biomass.
Hydrogen from Nonfossil Fuels	Replace gasoline with hydrogen created from electricity generated from nonfossil fuel sources.
Electricity from Nonfossil Fuels	Use electricity from nonfossil fuel sources such as nuclear and solar energy directly in transportation vehicles.
Transportation Demand Management	Reduce solo commuting by eliminating 25% of the employer provided parking spaces and placing a tax on the remaining spaces to reduce solo commuting by an additional 1.5%.
ELECTRICITY AND FUEL SUPPLY	
Heat Rate Improvements	Improve heat rates (efficiency) of existing plants by up to 4% through improved plant operation and maintenance.

Advanced Coal	Improve overall thermal efficiency of coal plants by 10% through use of integrated gasification combined cycle, pressurized fluidized-bed, and advanced pulverized coal combustion systems.
Natural Gas	Replace all existing fossil-fuel-fired plants with gas turbine combined cycle systems to both improve thermal efficiency of current natural gas combustion systems and replace fossil fuels such as coal and oil that generate more carbon dioxide than natural gas.
Nuclear	Replace all existing fossil-fuel-fired plants with nuclear power plants such as advanced light-water reactors.
Hydroelectric	Replace fossil-fuel-fired plants with remaining hydroelectric generation capability of 2 quads[a].
Geothermal	Replace fossil-fuel-fired plants with remaining hydroelectric generation capability of 2 quads[a].
Biomass	Replace fossil-fuel-fired plants with biomass generation potential of 2.4 quads[a].
Solar Photovoltaics	Replace fossil-fuel-fired plants with solar photovoltaics generation potential of 2.5 quads[a].
Solar Thermal	Replace fossil-fuel-fired plants with solar thermal generation potential of 2.6 quads[a].
Wind	Replace fossil-fuel-fired plants with wind generation potential of 5.3 quads[a].
Carbon Dioxide Disposal	Collect and dispose of all carbon dioxide generated by fossil-fuel-fired plants into the deep ocean or depleted gas and oil fields.
NONENERGY EMISSION REDUCTION	
Halocarbons	
Not-in-kind	Modify or replace existing equipment to use non-CFC materials as cleaning and blowing agents, aerosols, and refrigerants.
Conservation	Upgrade equipment and retrain personnel to improve conservation and recycling of CFC materials.
HCFC/HFC-Aerosols, etc.	Substitute cleaning and blowing agents and aerosols with fluorocarbon substitutes.

TABLE 2.1 (continued)

HFC-Chillers	Retrofit or replace existing chillers to use fluorocarbon substitutes.
HFC-Auto Air Conditioning	Replace existing automobile air conditioners with equipment that utilizes fluorocarbon substitutes.
HFC-Appliance	Replace all domestic refrigerators with those using fluorocarbon substitues.
HCFC-Other Refrigeration	Replace commercial refrigeration equipment such as that used in supermarkets and transportation with that using fluorocarbon substitues.
HCFC/HFC-Appliance Insulation	Replace domestic refrigerator insulation with fluorocarbon substitutes.
Agriculture (domestic)	
Paddy Rice	Eliminate all paddy rice production.
Ruminant Animals	Reduce ruminant animal production by 25%.
Nitrogenous Fertilizers	Reduce nitrogenous fertilizer use by 5%.
Landfill Gas Collection	Reduce landfill gas generation by 60 to 65% by collecting and burning in a flare or energy recovery system.
GEOENGINEERING	
Reforestation	Reforest 28.7 Mha of economically or environmentally marginal crop and pasture lands and nonfederal forest lands to sequester 10% of U.S. carbon dioxide emissions.
Sunlight Screening	
Space Mirrors	Place 50 000 100-km^2 mirrors in the earth's orbit to reflect incoming sunlight.
Stratospheric Dust[c]	Use guns or balloons to maintain a dust cloud in the stratosphere to increase the sunlight reflection.
Stratospheric Bubbles	Place billions of aluminized, hydrogen-filled balloons in the stratosphere to provide a reflective screen.

Low Stratospheric Dust[c]	Use aircraft to maintain a cloud of dust in the low stratosphere to reflect sunlight.
Low Stratospheric Soot[c]	Decrease efficiency of burning in engines of aircraft flying in the low stratosphere to maintain a thin cloud of soot to intercept sunlight.
Cloud Stimulation[c]	Burn sulfur in ships or power plants to form sulfate aeroson in order to stimulate additional low marine clouds to reflect sunlight.
Ocean Biomass Stimulation	Place iron in the oceans to stimulate generation of carbon dioxide-absorbing phytoplankton.
Atmospheric CFC Removal	Use lasers to break up CFC's in the atmpsphere.

[a]a quad = 1 quadrillion Btu= 10^{15} Btu = 1.055 x 10^{18} Joules
[b]Corporate average fuel economy
[c]These options cause or alter chemical reactions in the atmosphere and should not be implemented without careful assessment of their direct and indirect consequences.

SOURCE: Chapter 11 of the Mitigation Panel report in NAS, 1991.

In addition to regulatory and economic instruments, mitigation policy may involve more general directives related to research, technology development and transfer and international cooperation. Investment into improving knowledge for future decisions is a strategy option that would likely yield a high return. Among the information needed to better understand global warming is that pertaining to the evolving climate and that which is necessary for the testing of climate models. Improvements in weather forecasting, identification of mechanisms that play a role in global warming and increased research into the reaction of ecosystems to climate change could all be extremely useful as part of a strategy to reduce the uncertainties of global warming (NAS, 1991).

With respect to global cooperation, participants at the International Conference on Global Warming and Sustainable Development (ICGWSD Conference Statement,1991:6) recommended that funding be made available on a bilateral, regional and/or multilateral basis to ensure that developing countries can afford certain technologies with an initially high cost. All conference participants agreed that industrialized nations and international funding agencies have an obligation not to burden developing countries with obsolete, inefficient, polluting technologies, but to make appropriate technology available on favorable terms. It might be argued that such funding (by, for example, reducing global greenhouse gas emissions and thereby reducing the potential harm of warming worldwide) is in the best interests of all people - those in both developed and developing countries.

Other aspects of policy that fall under the category of international cooperation are debt reduction agreements (which could increase the capital available for investment in energy efficient technologies) and assistance in population control programs (as population growth has been designated a significant factor in the scenarios for future greenhouse gas emissions) (NAS, 1991).

Under the heading of mitigative options, different measures would entail quite different costs. Tables 2.2 and 2.3, adapted from the NAS report, illustrate some of the estimated costs and degrees of effectiveness for different mitigativive measures that might be undertaken in the United States.

Cost calculations given in the tables are not intended to be globally applicable. What has been estimated to be of moderate or high cost to the United States could in fact be prohibitively expensive in some developing countries. Also, especially with respect to certain geoengineering options, many underdeveloped countries may not have the available technology to render some mitigative measures feasible. Still, the effectiveness of implementing any of these measures would be as great in less developed countries because of the global nature of the greenhouse warming problem. For this reason, international agreements regarding assistance to developing countries make sense. Through them, developed countries can make (what is for them) low or moderate cost investments to avoid the potential problem of global warming before they turn to high cost investments.

Some of the options determined to be implementable at a net benefit or low cost, namely those involving energy efficiency, could offer cost savings (or incur relatively low costs) in developing countries as well as in countries like the United States. Especially relevant to developing countries is the potential for energy and cost savings as the result of efficiency that is built into the system during the initial stages of development. Compared to already industrialized countries, developing nations have greater room for efficiency improvements other than those requiring retrofit costs.

TABLE 2.2 COMPARISON OF MITIGATION OPTIONS FOR THE UNITED STATES SELECTED BY THE NAS PANEL

Mitigation Option	Net Implementation Cost[a]	Potential Emission[b] Reduction (tonnes CO_2 equivalent/year)
Building energy efficiency	Net benefit	900 million[c]
Vehicle efficiency (no fleet change)	Net benefit	300 million
Industrial energy management	Net benefit to low cost	500 million
Transportation system management	Net benefit to low cost	50 million
Power plant heat rate improvements	Net benefit to low cost	50 million
Landfill gas collection	Low cost	200 million
Halocarbon-CFC usage reduction	Low cost	1400 million
Agriculture	Low cost	200 million
Reforestation	Low to moderate cost[d]	200 million
Electricity supply	Low to moderate cost[d]	1000 million[e]

[a] Net benefit=cost less than or equal to zero
Low cost =cost between $1 and $9 (U.S.) per tonne of carbon dioxide equivalent
Moderate cost=cost between $10 and $99 per tonne of carbon dioxide equivalent
High cost=cost of $100 or more per tonne of carbon dioxide equivalent

[b] This "maximum feasible" potential emission reduction assumes 100 % implementation of each option in reasonable applications and is an optimistic "upper bound" on emission reductions.

[c] This depends on the actual implementation level and is controversial. This represents a middle value of possible rates.

[d] Some portions do fall in low cost, but it is not possible to determine the amount of reductions obtainable at that cost.

[e] The potential emission reduction for electricity supply options is actually 1700 Mt carbon dioxide equivalent per year, but 1000 Mt is shown here to remove the double-counting effect. The NAS panel provides the following to illustrate double-counting: Implementation of both the nuclear and the natural gas energy options assumes replacement of the same coal-fired power plants. Thus, simply summing up the emission reductions of all options to give total reduction in emissions would overstate the actual potential.

SOURCE: Chapter 11 of the Mitigation Panel report (NAS, 1991).

TABLE 2.3 COST-EFFECTIVENESS ORDERING OF GEOENGINEERING MITIGATION OPTIONS

Mitigation Option	Net Implementation Cost	Potential Emission Mitigation (tonnes CO_2 equivalent/year)
Low stratospheric soot	Low	8 billion to 25 billion
Low stratospheric dust, aircraft delivery	Low	8 billion to 80 billion
Stratospheric dust (guns or baloon lift)	Low	4 trillion or amount desired
Cloud stimulated by provision of cloud condensation nuclei	Low	4 trillion or amount desired
Stimulation of ocean biomass with iron	Low to moderate	7 billion or amount desired
Stratospheric bubbles (multiple balloons)	Low to moderate	4 trillion or amount desired
Space mirrors	Low to moderate	4 trillion or amount desired
Atmospheric CFC removal	Unknown	Unknown

NOTE: The feasibility and possible side-effects of these geoengineering options are poorly understood. Their possible effects on the climate system and its chemistry need considerably more study and research. They should not be implemented without careful assessment of their direct and indirect consequences.

Cost-effectiveness estimates are categorized as either savings (for less than 0); low (0 to \$9 (U.S.)/tonne carbon dioxide equivalent), moderate (\$19 to \$99/tonne carbon dioxide equivalent), or high (>\$100/tonne carbon dioxide equivalent). Potential emission savings (which in some cases include not only the annual emissions, but also changes in atmospheric concentrations already in the atmosphere-stock) for the geoengineering options are also shown. These options do not reduce the flow of emissions into the atmosphere but rather alter the amount of warming resulting from those emissions. Mitigation options are placed in order of cost-effectiveness.

The carbon dioxide-equivalent reductions are determined by calculating the equivalent reduction in radiative forcing.

SOURCE: Chapter 11 of the Mitigation Panel report (NAS, 1991).

Conclusion

Ethical criteria, including international equity and the respect of basic moral rights, as well as economic criteria, such as cost-effectiveness, should be taken into account when making decisions about global warming policy. In addition, response options should accord with the ethical principles determined by policy makers to apply to the climate change issue. These principles may be of an anthropocentric and present oriented nature. Alternatively, policy makers might employ the concept of integenerational equity and/or various non-anthropocentric ethical principles.

There are basically two types of policy response: adaptation and mitigation. Enhancing adaptability to climate change, while perhaps practical for some relatively affluent societies, may be inadequate to avoid suffering and loss in some less developed countries and in certain natural ecological systems. Therefore, consideration of mitigation strategies is justified. There are a great number of options that have been suggested as global warming mitigation strategies, many of which might be implemented using a combination of regulation and economic incentives.

Of the many available options, reducing emissions through energy efficiency is one that should appeal to even the most hesitant decision-makers. Energy efficiency has the potential to offer net savings to organizations of all sizes as well as to society as a whole in both developing and industrialized countries. It has a relatively short pay-back period (especially if energy prices reflect the true lifecycle costs of production through to disposal) and it can be highly effective in reducing not only greenhouse gas emissions, but harmful ground level ozone, acid deposition and other types of pollution. Taken together, all of these attractive aspects of energy efficiency make it a wise choice as a first-step policy option to deal with global warming.

If policy is based on anthropocentric and present-oriented ethical principles, energy efficiency is desirable because it does not incur significant costs (and can in fact result in cost savings) to present people. If policy is based on the idea of intergenerational equity, energy efficiency makes sense because (at little or no cost to present generations) it is, relative to most other options, highly effective in avoiding global warming and subsequent harm to future people. Finally, if policy makers recognize non-anthropocentric ethical principles, then energy efficiency is a wise choice because it helps to reduce the possibility that harm to nonhumans, habitat loss and reductions in biodiversity will occur due to human-induced climate change.

CHAPTER 3:
ENERGY EFFICIENCY

There is a direct link between energy use and the conditions that predicate the greenhouse effect. In today's world, energy use is predominated by the combustion of fossil fuels, and the atmospheric build-up of emissions from this process, especially the large quantity of carbon dioxide, is believed to be the primary contributor to the enhanced greenhouse effect (e.g. IPCC, 1990; NAS, 1991). If, as has been asserted by countless observers, society can implement energy savings strategies, then emissions of carbon dioxide (and other greenhouse gases) can be reduced, effectively lessening the rate of climate change. By implication, for each unit of carbon not emitted, there is a corresponding unit of decrease in the radiative forcing associated with global warming.

Just as "a penny saved is a penny earned", energy savings are energy resources. Cavanaugh et al (1989) suggest that if there is a perceived need for increased supply, conservation options should be weighed against the costs of generators, oil fields and gas wells. Following such a comparison, the option with the highest return should be chosen first.

> For the purposes of meeting the needs of a growing economy and population, energy preserved from waste is indistinguishable from energy delivered to customers by production facilities. Energy savings created in large quantity on a predictable schedule are energy resources, just like generators. Often, a saved kilowatt-hour or therm or barrel of oil is much cheaper than an additional unit of energy production (Cavanaugh et al, 1989: 279).

Compared to other options that have been suggested in response to the threats of global climate change, improved energy efficiency stands out as having the potential to benefit present and future generations of people as well as the environment as a whole (see Chapter 2). The following chapter provides further support, in the form of recent region-specific studies, in favor of adopting improved energy efficiency as a global warming response measure. In addition, it provides a description of some of the reasons why, despite its economic benefits, there tends to be an underinvestment in energy efficiency. Finally, there are some suggestions for overcoming the barriers to energy efficiency that exist in many of our social, economic, informational and other systems.

The examples of achieved cost savings and demonstrated potential for further efficiency improvement that are provided in the appendix (and summarized below) include city-, province-, country- and continent-specific cases from the Americas as well as from Asia, Australia and Eastern Europe. Energy efficiency potentials have also been discussed for the Middle East and for Africa (e.g. Sathaye and Goldman,1991b). The range of regions for which case studies are reviewed illustrates that the benefits of energy efficiency are applicable globally. Indeed, given the findings, it seems that improved efficiency is practical and beneficial (in many different respects) for all societies who utilize energy to produce the necessities of life - for humanity itself.

The Potential for Savings

There are numerous examples of improved energy efficiency that has been achieved in the recent past (see appendix). Even a brief overview of some of these improvements indicates that, at least in the initial stages of implementation, energy efficiency strategies are associated with real cost savings in addition to reduced emissions of gases contributing to global warming.[1]

Between 1973 and 1988, for example, a network of over 40 different Canadian industry associations (participating in the Canadian Industry Program for Energy Conservation) saved an estimated total of more than $20 billion of energy purchases (equivalent to 800 million barrels of oil) through energy efficiency and conservation measures (Kennedy, 1990). Efficiency improvements and related cost savings have not been exclusive to developed countries such as Canada. In India, for example, results of a 1987 study of conservation projects showed that, even in the absence of investment incentives by the government, private investors experienced high rates of return from energy conservation measures. All of the Indian projects with positive internal rates of return had discount payback periods of less than 3.5 years and more than half paid back their investments in less than two years. All conservation projects (with one exception) were determined to be less costly than domestic production of oil in India and, compared to the import of oil, all conservation projects were clearly determined to be economical (Anandalingam, 1987).

Despite the globally experienced efficiency improvements that have been achieved to date, analyses of energy use in various countries and regions around the world suggest that there is yet significant potential for reducing final energy consumption while at the same time saving money.

In the Canadian province of Alberta, for example, it has been suggested that 15% of fossil fuel usage and 60% of purchased electricity could be saved through energy

[1] There exists a huge literature in the field on energy use and conservation programs around the world. See the appendix of this document for more details on selected country-specific energy use patterns and conservation programs.

conservation, including fuel substitution and cogeneration (Alberta Energy, 1990b). Cost savings to all energy consumers associated with this efficiency improvement would be $2.2 billion per year (following the investment in $6.7 billion in conservation measures) (Alberta Energy, 1990b).

Breton (1990) estimates that U.S. carbon dioxide emissions could be kept at 1988 levels through 2010 solely by implementing programs that have a net cost savings (when using a 7% discount rate). Through the use of more efficient lighting alone, it is estimated that $18.6 billion (U.S.) would be freed from ratepayer bills for useful investment, while at the same time annual carbon dioxide emissions could be reduced by 211 million tonnes (Mt), the equivalent of the emissions from 42 million cars (Lawson and Kwartin, 1991).

In New York State, technicians from the Small Business Energy Efficiency Program calculate that, if all the energy conservation measures they recommended were implemented, the total potential savings would be more than $30 billion (U.S.) annually. The energy savings potential calculated for small businesses in New York equates to a reduction of 300 tonnes of sulphur dioxide, 110 tonnes of nitric oxides and more than 140 000 tonnes of carbon dioxide per year (SBEEP, 1991).

As part of a study to determine energy-related cost savings in industry for the state of California, Shin and Sioshansi (1990) calculated the net cost per tonne of carbon dioxide reduced for direct resistance heating relative to conventional (less efficient) electric heaters in metalworking and glass melting. They found that a savings of $178 (U.S.) per tonne of carbon dioxide reduced could be achieved by implementing the newer, more efficient technology (Shin and Sioshansi, 1990).

In Mexico, a cumulative total of $81 billion between 1991 and 2000 is the calculated potential savings that could be achieved if energy efficiency were maximized in industrial, transportation and residential sectors (Guzmán, 1987). Guzmán notes that such savings could be quite useful in helping to relieve Mexico's foreign debt (which in 1987 amounted to 100 billion dollars (Guzmán, 1987)).

For countries in Eastern Europe and what was formerly the Soviet Union, it has been estimated that national incomes could be increased by approximately one-half simply by achieving the same efficiency of energy consumption as members in the European Economic Community (Kramer, 1990).

In the Asian region in recent years, according to Shrestha and Acharya (1991), growth in electricity consumption has occurred at a faster rate than that of nonelectric energy use. Shrestha and Acharya discuss key options for improving the efficiency of electricity generation, supply and use and related policy issues in ten Asian countries: Bangladesh, China, India, Pakistan and Sri Lanka (low income countries) and Indonesia, Malaysia, Philippines, Republic of Korea and Thailand (middle income countries).

At present, carbon dioxide emissions in the selected countries amount to over 2% of the global emissions. This share is expected to be considerably higher in the future based upon evidence of the relatively fast growth of electricity production in most of the selected countries. The shares of thermal power generation in general and coal-based generation in particular are expected to grow rapidly in most countries in the study. Carbon dioxide emission from power plants in these countries (excluding Pakistan and Malaysia) is estimated to increase 2.63 times by 2000 (Shrestha and Acharya, 1991).

Together, China and India, where coal constitutes the primary electricity generation source, account for approximately 88 % of the estimated total emissions of carbon dioxide in the selected countries as a group in 1987. The efficiency of generation from coal-fired plants was found to be particularly low in China (about 30 %) and India (28.4%). This is in comparison to the average efficiency rate in OECD countries of 32.3% (Shrestha and Acharya , 1991). Thus, by increasing electricity generation efficiency in India and China to levels currently achieved in OECD countries, 10 to 15% reduction in coal use (and hence carbon dioxide emissions) in India and China could be achieved.

Improvements in end-use energy efficiency in the Asian region is of considerable importance for two main reasons. First, ownership of electrical appliances is growing rapidly. In Beijing, for example, the proportion of households with refrigerators rose from 1.5% in 1981 to 62% in 1987 (Kats, 1990). Second, due to relatively low purchasing power, owners are likely to use their appliances longer than their counterparts in more developed countries (Shrestha and Acharya , 1991).

New technology provides numerous means of saving energy. Due to improvements in efficiency, for example, energy consumption by refrigerators has been cut by up to 70% in the past 15 years in Asia (Kats, 1990). Large scale use of efficient appliances would entail costs; therefore, careful demand-side management programs are implicitly desirable. As household incomes are typically rather low in most of the countries studied, most utilities would have to devise cost sharing schemes to offset the initial costs of new appliances in order to promote them (Shrestha and Acharya , 1991).

Composition of the residential sector in developing countries in general is changing rapidly. There is significant rural to urban migration and a steady increase in the number of people living more modern lifestyles. Rising incomes are associated with greater energy consumption, especially due to the purchase of appliances. Fuel-switching from wood to kerosene and from kerosene to gas and electricity is characteristic of the residential sector as well. There is considerable potential in the long term for efficiency as newer more efficient appliances enter the stock (Sathaye et al, 1987).

Correcting for the Underinvestment in Energy Efficiency

Despite abundant documented proof that energy efficiency improvements can save money, the potential for cost-effective investment into energy efficiency is clearly not being fulfilled in most countries of the world. A variety of reasons may account for this observed underinvestment in energy efficiency. Many of these reasons may be viewed as obstacles or barriers that exist in current economic (as well as social, informational, technical, institutional and other) systems (Kozloff, 1987; Pinto, 1987).

Economic Barriers

With respect to electric utilities, market failures result from the inherent barriers of a natural monopoly (Hamburg, 1990). Also, externality costs, including the environmental damage cause by generation, transportation and consumption of energy, often are not adequately accounted for in the price of energy (Shioshansi, 1990). Kozloff (1987) found that, in Minnesota, one reason given for underinvestment in efficiency was the lack of utility incentives (especially where the marginal cost of generation is far above the utility's average rates).

The unavailability of capital to make efficiency improvements is a frequently cited reason for not making such improvements (Kozloff, 1987). Also, energy efficiency may not be marketed aggressively enough. Appliance or automobile salespersons may in fact have more incentive to promote less-efficient, over-stocked or slow-selling models than those with higher energy efficiencies (Sioshanshi, 1990).

Correcting for economic barriers to energy efficiency improvements might involve a number of policy options. Government intervention in the form of direct price controls, indirect controls through taxes and tariffs, and other regulatory policies can stimulate investment in conservation technology or restrict investment in consumptive technology. In addition, capital allocation or financial assistance constitute effective management strategies (e.g. Hamburg, 1990; Kozloff, 1987; Pinto, 1987).

In the context of anthropocentric and present-oriented policy rationale, an incentive such as a carbon tax might be justified based on the fact that it accounts for present (or near future) environmental and social costs related to emissions. In discussing the true costs of energy production and use, Hubbard (1991:42) suggests that "the answers that economists derive may depend as much on social values as they do on analytical solutions to well defined problems." With an increase in the social value placed on a healthy environment, a corresponding increase in levied pollution taxes might be justified. If producers and/or consumers were asked to pay more for environmental and other currently ignored external costs, estimates for the potential cost savings achievable through energy efficiency would be higher. (More costly conservation measures would become cost-effective with higher energy prices). Energy efficiency measures entailing moderate costs might become highly cost-effective when an appropriate pollution tax is added to the cost of fuel. Potential emission reduction levels at net savings might consequently be increased. The extent of this increase would depend upon the total cost of energy supplies.

Prior to instituting market-based mechanisms with the specific intent of reducing atmospheric carbon dioxide, some goal for stabilizing or reducing carbon dioxide emissions must be determined. This goal may be expressed either in terms of a quantity of emissions, or of a price that the country (or other entity) is willing to pay to achieve reductions (National Economic Research Associates [NERA], 1991). Once a specific emission reduction target has been decided upon, different market-based mechanisms might be used to achieve whatever target is chosen.

One of such mechanisms is the use of tradable carbon coupons. According to a coupon system, for example, a firm would be required to submit one coupon for each tonne of carbon in the fuel that it produces or imports (NERA, 1991). As a result of restricting the amount of carbon in fuel, the coupons would be associated with a certain price. Higher fuel prices would in turn provide incentives for firms and consumers to switch to energy sources with less carbon and to use less energy (NERA, 1991). Because climate change is a global phenomenon, tradable coupons should be tradable globally (Ross, 1992). In this way, for example, Canadian companies, in attempting to lower carbon dioxide emissions, would buy coupons from countries with relatively low energy usage rates (e.g. certain developing countries) and, because the latter are relatively energy inefficient, the former would make available more energy efficient technologies in return. Canadian companies would do this because (and only when) it is cheaper to do so (Ross, 1992). This sort of global trading system would have many desirable effects, including reducing carbon dioxide emissions as cheaply as possible, transferring the best technologies and money to developing countries, and treating all people (everywhere on earth) the same. The difficulty in such a global scheme is first, getting all countries to agree to it and, second, deciding how to allocate the coupons (e.g. on a constant per capita basis independent of country or based on 1991 patterns of energy use, etc.) (Ross, 1992).

Another similar mechanism for encouraging energy conservation and directly affecting the amount of carbon dioxide entering the atmosphere is a carbon tax. In effect, the prices of carbon-based fuels would rise to reflect such a tax (NERA, 1991). The major difference between carbon coupons and a carbon tax would be in their respective responses to uncertainty.

> Carbon trading would set the quantity, but the price of the coupons would vary depending on the actual marginal costs of reducing carbon. In contrast, a carbon tax would set the price, but total emissions would vary with the costs of reduction. For example, if the cost of reducing carbon use proved to be higher than expected, the price of the coupons would go up, while with a tax the level of emissions would be higher than expected. Conversely, if the cost of reducing carbon were lower than expected, the price of coupons would fall, while a tax would achieve a lower emission level. (NERA, 1991: 16)

Carbon taxes and auctioned carbon coupons have the potential to raise large revenues for the government(s) that impose them (NERA, 1991).[2]

In principle, a carbon tax or the value of a coupon would be set at the proper global cost of emitting carbon dioxide into the atmosphere, thus internalizing the environmental externality and allowing the energy purchaser to make more informed decisions. In practice, however, the actual cost of emissions is extremely difficult to compute. At present, the (politically determined) targets that reflect these costs vary widely from country to country (Alberta Energy, 1991a).

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[2] It is quite possible that such revenues could be used to further research into energy efficiency technology and other global warming response strategies.

State regulation may constitute a dominant instrument of energy policy, particularly when the market fails to establish prices corresponding to actual social costs. Regulatory policy, for example, can create "market pull" by instituting rebate payments for purchases of energy efficient equipment or appliances; in addition, appliance dealers may be paid to create "market push" (Hamburg, 1990). In general, regulation can encourage utility management to produce customer satisfaction at a profit rather than simply to produce electricity (Subbakrishna, 1990).

According to Subbakrishna (1990:709),

> While conservation deals with the saving of electricity from technological retrofits and replacements independent of supplier participation, Demand-Side Management (DSM) explicitly articulates a partnership between electric utilities and consumers to promote and in some instances subsidize, the provision of energy efficient equipment and processes, as well as provide other price incentives for reducing electricity consumption.

Benefits from demand-side management to the consumer include reduced energy bills and, less tangibly, improvements in productivity and welfare. The supplier (power utility) may experience benefits including avoided capacity, avoided energy generation and an improved service value.

In developing countries as well as in industrialized countries, pricing and physical controls are among the policy tools that might be used for energy planning and management (Munashinghe, 1987). Munashinghe explains that, in less developed countries, methods of physically limiting consumption are most effective in the short-run when there are no unforeseen shortages of energy.

International economic cooperation can also play an important role in improving energy efficiency in developing countries. In the conference statement of the International Conference on Global Warming and Sustainable Development (1991:6), it is suggested that

> developing countries need not go through the evolutionary process of previous industrialization but rather, they must 'leapfrog' directly from a status of underdevelopment through to economically efficient, environmentally benign, technologies.

Conference participants noted the fact that the major transfer of technology between developed and developing countries is military hardware. They emphasized the importance of curtailing military expenditures in order that resources can be made available for sustainable development. Such development would undoubtedly include the efficient production and use of energy. Development assistance, it is argued, should be directed toward helping countries to discover the most environmentally and economically effective combination of efficient supply side and end use expenditures. (Globally tradable carbon coupons, as described above, would perform this latter function quite effectively.)

According to the Conference statement (1991:9),

> Foreign debt is a major cause of resource depletion and forest degradation, because it forces countries to increase the rate of resource exploitation to earn the foreign exchange necessary to pay this debt. This, in turn, reduces the capital available for investment in new energy technologies.

In light of this situation, it is arguable that debt reduction agreements linked to forest protection, reforestation, agricultural lands improvement and renewable and efficient energy investment should be developed.

Informational, Perceptual and Technical Barriers

Numerous types of informational barriers contribute to underinvestment in energy efficiency. In general, high transaction costs face customers in obtaining timely, credible and relevant information when purchasing major energy appliances or making decisions about conservation options (Sioshanshi, 1990). Information barriers discovered in Kozloff's (1987) Minnesota study included the common situation in which end-users were not aware of the energy-saving potential in their homes or businesses. Pinto (1987) concurs that individuals may not be aware of the cost of energy in their personal or occupational activities. Furthermore, consumers may not realize that individual decisions noticeably affect energy efficiency or that the potential exists for significant savings through energy efficiency.

Consumer behaviour that runs counter to efficiency improvements can result from a lack of information or from other perceptual barriers. One example of this is the relatively high discount rate consumers apply to such items as appliances. If an energy saving device does not pay for itself in six months to three years, a consumer is not likely to make the investment to acquire it (in sharp contrast to the low discount rate and 20-30 year payback period typically used by utilities) (Sioshansi, 1990).

Kozloff (1987) found that the perceived risk of making erroneous decisions due to uncertainties about future energy prices, in conjunction with typically short-range planning horizons, tends to discourage investment into retrofitting and other conservation measures and to imply high discount rates. In businesses, for example, conservation-related investments are perceived as comparing unfavourably with investments designed to enhance productivity; and, in homes, actions to increase energy conservation are seen as unfavourable when compared to investments to enhance the immediate enjoyment of the dwelling or its market value. Another barrier to improved energy efficiency is the generally slow turnover rate of energy-using capital stock. Such stock, including buildings, industrial equipment and appliances are not usually replaced until they wear out or break down. Furthermore, when buildings and equipment are replaced, first cost considerations typically take precedence over life-cycle costs (Kozloff, 1987).

A further obstacle to efficiency improvements occurs in the form of a lack of technical knowledge and/or availability of appropriate technology and related goods and services (Pinto, 1987).

Pinto suggests some general management strategies for inducing rational decision-making on energy conservation. One strategy would involve legislative and institutional agencies that develop and administer informational and promotional programs. These agencies might oversee the budgets for industrial energy audit programs, technical assistance, home insulation and research and development. Some countries have also established energy audit or technical assistance functions within, or linked to, energy supply firms such as utilities and oil companies (Pinto, 1987). As part of an educational or promotional program, government agencies, commercial and industrial trade associations, private consultants, academic institutions and energy supply firms can supply a variety of technical services to analyse and offer suggestions for improvements in energy-use for firms and households (Pinto, 1987).

Also recommended is the development of energy information systems (Pinto, 1987). A long-term goal might be to build up a national energy information system adequate to monitor energy-use patterns so that demand management and supply strategies can be developed, assessed and revised in an effective manner.

Specific programs aimed at providing technical assistance might be established through government agencies, commercial and industrial trade associations, private consultants, academic institutions and energy supply firms. Especially in developing countries, technical assistance is an important and effective tool for improving efficiency (Munashinghe, 1987). Organizations such as the World Bank and the United Nations Development Program, for example, can contribute to conservation efforts through offering appropriate loans and other support. These international lending agencies might provide technical assistance for energy audits, retrofitting programs, the establishment of energy conservation centres, improved power system management and distribution systems, the development of more efficient wood stoves and urban traffic management projects (Pinto, 1987).

Institutional Barriers

One common institutional barrier to energy efficiency investment, according to Kozloff (1987), is the relationship between landlord and tenant. In cases where the tenant pays for energy, the landlord has little incentive to lower energy costs; and the availability of tax deductions for operating expenses reduces the incentive for saving energy when the landlord pays the energy bills. A similar situation occurs when developers, concerned more about initial costs than life-cycle costs in order to enhance their competive position, underinvest in efficiency features in new buildings. Sioshanshi (1990), who refers to this situation as a "forced purchase decision", adds that the results include low-effiency housing stock and high operating costs that are eventually borne by the occupant over time. (In principle, it should be noted, informed buyers will overcome this problem.)

A strategy that might serve to deal with this type of institutional barrier is the forming and administration of building regulations at national, state and local levels (Rao, 1987). Rao also recommends establishing design energy budgets (DEB) for different building types and standard evaluation techniques for computing design energy consumption and checking against DEBs. Regulations, he adds, should be easily implementable and should not limit the flexibility or architectural expression of designers. Above all, the success of building regulations depends upon the effectiveness of enforcement.

In addition, energy management could be incorporated into building operations. This would involve monitoring, recording, analysing and controlling the energy-flows through the building and its service systems. An effective program would include the education of users to instill a conserving ethic and to enrol cooperation, training of operators and establishment of maintenance schedules to ensure effective and efficient operation throughout the life-span of equipment. A good practice, according to Rao, is to keep records of consumption and costs of electricity, oil, and gas on a monthly basis. Electricity consumption may even be sub-divided into use for lighting, chillers, pumps, fans, elevators and general small power usage using separate electric-run meters (Rao, 1987).

Rao also advocates the use of life-cycle costing when taking conservation measures into consideration. In the past, minimizing the initial cost outlay has been viewed as the number one priority. Increasingly, however, it has been demonstrated that long-term operational costs should not be ignored. Evaluation of different energy-use systems should be based on such measures as payback, rate of return and present worth, rather than simply initial cost (Rao, 1987).

Government can positively influence decisions regarding energy conservation in buildings through tax rebates, low interest loans, and direct financial aid for energy efficient building design. Disincentives in the form of surcharges for wastage and utility tariff rates that truly reflect the costs of energy production might also be adopted (Rao, 1987).

Conclusion

Energy efficiency is posed as a desirable component of global warming policy. Not only would effort aimed at energy efficiency serve to reduce greenhouse gas emissions (and consequently decrease the radiative forcing associated with global warming) but it could also result in monetary savings in the near future. Examples drawn from both industrialized and developing countries illustrate some of the notable cost savings that can be achieved through the implementation of energy efficiency and conservation programs. There is considerable room, nevertheless, for even greater improvements in efficiency, particularly if certain economic, informational, technical and other barriers can be overcome. Market-based mechanisms, including tradable carbon coupons, carbon taxes, direct price controls and financial assistance for investments in efficiency are among the tools that could be utilized to overcome economic barriers. Recommended means of overcoming other types of obstacles to energy efficiency include the administration of informational and promotional programs and the development of energy management and technical assistance programs.

CHAPTER 4:
REDUCTIONS THROUGH ENERGY EFFICIENCY AT HOME AND ABROAD

The following is the draft chapter (submitted to Dr. William Ross for final editing) to be included as part of the Humanities Institute book on ethics and climate change.

Introduction

If agreement can be reached among policy makers that some form of harm due to global warming will occur without human intervention, a number of specific issues must be resolved before policies to deal with global warming can be implemented. In particular, it is necessary to determine in what form and to what extent such a policy should be adopted. Determining the specific features of a global warming response strategy may be viewed as an exercise in applied ethics. An examination of different options reveals that, as a first step, increasing energy efficiency in both industrialized and developing countries accords with a number of ethical principles. Beyond cost-effective energy efficiency, the degree of investment in any global warming response strategy will depend in large part on whether future generations and/or non-human beings are considered morally relevant.

Policy-Making: An Exercise in Applied Ethics

It is arguable that the best policies are based on rational, well defined principles. In their most basic form, these are ethical principles ascribing moral standing and/or rights to some of those predictably affected by the policy decision at hand. The relative size of the circle within which the interests of affected beings are considered will inevitably affect the sort of policy that is derived; and, in general, the larger the circle of interests recognized according to an ethical principle, the more controversy that ethical principle will tend to stimulate.

One of the least controversial ethical principles is that which places greatest importance on the interests of presently existing human beings. According to this person-centered ethic, the best course of action is that which ensures the maximum possible benefits to current generations. Future generations may matter indirectly (in the sense that present people may care about future people); nevertheless, any consideration of the effects such action will have on future generations is secondary (Hurka, 1992).

A more controversial moral principle is one that assigns equal weight to the interests of presently living and future human beings (e.g. Shrader-Frechette, 1981). While this principle of intergenerational equity recognizes the rights of future people and guides against actions that may have deleterious effects on them, it does not necessarily place importance on the interests of non-humans. The environment, according to this second ethical principle, is a means to achieving purely human interests.

A third and considerably more controversial principle calls for an expansion of ethical thinking to include consideration of the interests of non-human elements of the environment. Commonly referred to as an environmental ethic, this third moral principle is itself divisible into different types of rationale (Hurka, 1992). One of these is an argument which states that all sentient organisms, including non-humans, have moral standing and, as such, should be allowed to flourish without subjection to unnecessary suffering (e.g. Singer, 1973). Another argument that falls under the environmental ethics principle is one (made popular by Aldo Leopold in 1966) known as the land ethic. Proponents of this argument maintain that there is special value in biodiversity or the existence of a wide variety of species and that, insofar as the loss from existence of all individuals from a species is significant loss, it is desirable to prevent such species' extinction. Furthermore, according to the land ethic, the biotic community as a whole, including the health of plant species, soil and water as well as that of sentient beings, deserves concern in issues that might effect them.

Policy and the Greenhouse Effect

Rapid climate change as the result of human activity has become a much discussed subject at national and international levels of policy decision-making (e.g. International Panel on Climate Change [IPCC], 1991; National Academy of Sciences [NAS], 1991). Though some degree of scientific uncertainty and a lack of consensus regarding the impacts surround these discussions, some basic assumptions must be made about the phenomenon known as the greenhouse effect in order to facilitate policy discussion.

Primarily it must be conceded that global warming is, or at least has the liklihood of, occurring. Recent scientific reports, such as the one prepared by the IPCC, rather strongly conclude that global warming is occuring. Secondly, a discussion of policy related to global warming only makes sense if it can be agreed that implied climatic changes will or might affect some people or things in a negative way. Many of the future scenarios developed (e.g. Schneider, 1990) suggest, for example, that among the potential effects of rapid climate change are human and nonhuman suffering, species extinction and loss of biodiversity. Thirdly, there is an explicit assumption that some form of human intervention would be effective in avoiding the harm. Finally, and perhaps most importantly for the purposes of an ethical evaluation of policy, it must be conceded that future generations do matter. Use of the term "potential" when describing the harm to be avoided implies that the harm related to global warming will occur in the future. It is quite difficult to justify policy deliberations aimed at avoiding or mitigating a future harm if there is not some value accorded to the interests of beings who will exist at the time of the harm, namely, of future generations.

Taking into account the above assumptions, it would certainly follow that that, should harm as the result of the greenhouse effect be realized without action having been taken to avoid it, some basic moral rights will have been violated and moral obligations ignored.

If it is agreed that there is a need for human intervention as directed by policy, then several issues must be resolved: "When, in what form and to what extent should this intervention occur ?" In attempting to answer these pivotal questions concerning greenhouse warming policy, one is forced to consider ethical principles, including some of the more controversial notions of interests, rights and obligations across generations and species. In effect, deciding how to respond to the potential threats of global warming is an exercise in applied ethics. The extent to which action is taken to avoid predicted effects of climate change will largely be determined by the ethical principles accepted and applied by policy decision-makers.

Examples of response options from a national perspective are provided by a panel from the National Academy of Sciences [NAS] (1991). The NAS panel sorts possible U.S. policy responses to the threats of greenhouse warming into five categories: reducing or offsetting greenhouse gas emissions; enhancing adaptation to greenhouse warming; improving knowledge for future decisions; evaluating geoengineering options; and exercising international leadership. The NAS panel suggests that implementing any of the more specific options within these broad response strategies could be effective in avoiding some of the potential harm associated with climatic change. A review of each of these options, however, reveals that there is significant variation between them with respect to cost (economic and social) and effectiveness. Moreover, when evaluated in terms of ethical principles, some of these policy options are clearly preferrable to others.

Global Warming Policy and the Interests of Current Generations

A greenhouse warming response strategy might be developed according to an ethical principle that recognizes a relatively small circle of morally relevant beings - that is, strictly with reference to what is in the best interest of currently existing populations of human beings. (In such a case, the interests of future generations may count, but only indirectly and not with weight equal to the interests of present generations. Also, according to such an ethical principle, non-human interests are irrelevant.) Avoiding harm due to climate change is not clearly in the interest of presently existing human beings many of whom may not be living when the harm can presumably be expected to occur. For these individuals, the desirable policy response is one that will result in an improved quality of life in the present. Slightly less preferable (but still justified) are actions that will not negatively affect the existing quality of life.

In very obvious ways, consumption and quality of life are closely linked. Life cannot be said to have a great deal of quality without adequate nutrition, shelter and mobility, all of which in some way involve consumption. Beyond the clear connection between the consumption required to fulfill basic human needs and quality of life, however, it is difficult to determine exactly what is necessary to give life quality (Porritt, 1989). When discussing quality of life in the aggregate, indices such as total economic activity, gross national product (GNP) and per capita GNP have often been used (though it is not necessarily true that these yardsticks alone provide sufficient indication of quality of life) (Porritt, 1989). By implication, quality of life may be enhanced in a situation where net monetary savings are experienced.

Measured in economic terms, it is in the best interest of presently existing human beings to implement policy that will result in net savings or, at the least, will incur no net cost over the course of these people's lifetimes. Actions that lead to immediate or near-future cost savings, satisfying the more present-oriented and anthropocentric of ethical principles, would thus constitute the least controversial greenhouse warming response strategy available to policy-makers.

Getting More Out of Energy

Compared to all other response strategies, energy efficiency and conservation stand out as having substantial potential to be effective in avoiding the effects of global warming while at the same time incurring net monetary savings (NAS, 1991).[1] The link between energy efficiency and avoided climate change is relatively straightforward. In general, energy conservation or efficiency results in less use of fossil fuels and hence less carbon dioxide emissions. Carbon dioxide has been responsible for over half of the greenhouse effect due to human activities in the past (IPCC, 1990). Therefore, reduced carbon dioxide emissions due to energy conservation produces less human induced climate change.

Government planners typically base energy requirement projections on an assumption that energy consumption increases porportionately with economic growth (MacKenzie, 1991). However, studies such as the one undertaken by Jose Goldemberg (1987) illustrate that a positive correlation between energy consumption and economic growth does not necessarily exist. Between 1973 and 1985, according to Goldemberg, total energy use per capita in the Organization for Economic Cooperation and Development (OECD) countries (the world's most industrialized market economies) fell 6 percent while per capita gross domestic product (GDP) increased 21 percent. Over the same period, per capita energy use in the U.S. fell 12 percent while per capita GNP rose 17 percent. In Japan, per capita energy use fell 6 percent and per capita GNP rose 46 percent.

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[1]That these measures result in net savings does not mean that they do not involve implementation costs. Rather, given a particular positive discount rate, the total cost of these measures over the period of analysis is less than its direct benefit (NAS, 1991)

Proponents of energy efficiency such as Amory Lovins (e.g. Lovins and Lovins, 1990) and Ralph Cavanagh (e.g. Cavanagh et al, 1989) insist that, rather than coupling economic growth with energy consumption and dedicating money to projects that will supply perceived energy requirements, planners should instead evaluate the end products or services needed by consumers. Cavanaugh et al (1989) suggest that if there is a perceived need for increased energy supply, conservation options should be weighed against the costs of such things as oil fields and gas wells. Following such a comparison, the option with the highest return should be chosen first.[2]

> For the purposes of meeting the needs of a growing economy and population, energy preserved from waste is indistinguishable from energy delivered to customers by production facilities. Energy savings created in large quantity on a predictable schedule are energy resources, just like generators. Often, a saved kilowatt-hour or therm or barrel of oil is much cheaper than an additional unit of energy production. (Cavanaugh et al, 1989: 279).

There are many cases where different technologies serving identical purposes require very different amounts of energy (Mills, Wilson and Johansson, 1991). If, as Cavanagh emphasizes, energy savings equal energy sources, then plans for supplying energy should take into account the possiblity of making existing energy go further.

Shin and Sioshansi (1990) describe supply-side efficiency improvements and repowering as options for an electric utility trying to meet a target reduction in greenhouse gas emissions. In the production of electricity, fuel consumption may be reduced by such means as cogeneration, waste heat recovery and cutting transmission and distribution losses. Cogeneration, for example, can improve thermal

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[2]According to Munashinghe (1987), in developing countries, the best overall strategy of planning is to seek the least-cost method of meeting future energy requirements. However, he adds, there are numerous other, often conflicting, objectives such as reducing dependence on foreign sources of oil, supplying basic energy need of the poor, reducing trade and foreign exchange deficits, ensuring continuity of supply, and preserving the environment. To the extent that these objectives result in higher energy costs, however, they also result in more costly energy conservation measures being attractive in developing countries.

conversion efficiency from 1/3 to roughly 2/3 by using the same energy for production of both electricity and thermal energy (Shin and Sioshansi, 1990). Repowering is the conversion of an existing conventional gas- or oil-fired steam plant into a combined-cycle plant by integrating combustion turbines. Conversion of this kind can improve fuel efficiency by about 15-20% and results in reduced carbon dioxide emission for the same amount of energy use (Shin and Sioshansi, 1990).

On the demand side (i.e. with respect to the effects of certain actions on customer demand for energy), an electric utility can reduce its electricity use and hence its carbon dioxide emissions in cooperation with its customers. Lighting, heating, ventilating and air conditioning (HVAC) systems and other efficient end-use technologies can reduce energy consumption up to 75%. Strategies such as this are often referred to as demand-side management (DSM) programs (Shin and Sioshansi, 1990).

Munasinghe (1987) summarizes options for conservation in developing countries in transportation, buildings, industry and electricity supply. With respect to transportation, any measure that reduces the amount of energy used per passenger-kilometre or tonne-kilometre contributes to conservation. These measures might include utilizing less energy-intensive transport modes, increasing the technical efficiency of certain modes and changing behaviour and overall systems effects. Three factors that affect energy consumption in buildings are behavioural characteristics and attitudes of occupants, energy-using equipment installed and architectural design practices and material used. Munasinghe adds that the physical nature of a region also affects consumption. In particular, keeping living and working spaces lighted and cool is a priority in tropical countries, so many of which fall into the developing country category. In the petroleum industry, conservation could be achieved if losses in refinery operations and distribution activities were reduced. Similarly, there is marked potential to conserve energy in the generation, transmission and distribution of electric power. In addition, end-use conservation might be dramatically enhanced with improvements in the technical efficiency of energy using devices and through demand management and load control techniques.

At the International Conference on Global Warming and Sustainable Development (1991:6), participants put forward that

> developing countries need not go through the evolutionary process of previous industrialization but rather, they must 'leapfrog' directly from a status of underdevelopment through to economically efficient, environmentally benign technologies.

Conference participants agreed that industrialized nations and international funding agencies have an obligation not to burden developing countries with obsolete, ineffieicnt, polluting technologies, but to make appropriate technology available on favorable terms. Technology transfer and even funding by developing countries would thus appear in order. Moreover, in light of the tremendous improvements in efficiency that could be achieved, such funding would probably be cost-effective. Specifically, such investments by developing countries might well meet the dual objectives of yielding a high return on investment and being the most cost effective way of reducing greenhouse gas emissions. Examples of projects that might be funded by the World Bank, the United Nations Development Program and other similar agencies, include technical assistance for energy audits, retrofitting programs, establishment of energy conservation centers, improved power system management and distribution systems, development of more efficient wood stoves and urban traffic management projects (Pinto, 1987).

According to the NAS panel (1991), improved building energy efficiency and vehicle efficiency (without any fleet changes) are technically feasible measures in the U.S. for which the net costs are less than or equal to zero. Assuming 100 percent implementation of each of these options in reasonable applications, it is estimated that emission reduction potentials are 900 and 300 million tonnes (Mt) of carbon dioxide equivalent per year respectively (NAS, 1991). Furthermore, at an estimated net benefit or at a low cost (defined by the panel as between 1 and 9 U.S. dollars per tonne of carbon dioxide equivalent reduction), industrial energy management, transportation system management and power plant heat rate improvements could save an additional 600 Mt per year. Together these five measures have the potential to reduce the 1988 U.S. carbon dioxide emission rate of 4800 Mt per year (Boden, Kanciruk and Farrell, 1990) by 36 percent.[3]

Another set of figures has been derived from a scoping study undertaken on behalf of the U.S. Environmental Protection Agency (EPA). According to this study, carbon dioxide emissions could be kept at 1988 levels through the year 2010 solely by means of implementing programs estimated to have net cost savings for the U.S. Of these programs, the options with the greatest net savings are conservation programs in the transportation, residential, and commercial sectors (Breton, 1990).

Emission reduction potentials have been calculated at sub-national levels as well. Based on an analysis of energy use and conservation potential in the Canadian province of Alberta, it is projected that, by 2005, a 7.3 percent reduction in the 1988

[3] It is reasonable to assume that the reductions are achieved as soon as 100 per cent implementation has occurred.

carbon dioxide emission level could be achieved through implementing energy efficiency and conservation programs with an approximate payback period of 3.1 years (Alberta Energy, 1990). The estimated 6.7 billion Canadian dollars of initial investment into conservation related retrofits might at first appear outside the best interest of presently existing persons. Nevertheless, the payback period, relative to the lifetime of a human being, is very short. It would certainly appear that such near-term savings satisfy ethical criteria that give greatest weight to the interests of presently existing humans.[4]

In 1983, a report by Friends of the Earth Canada concluded that, under conditions of strong economic growth (an increase of more than 200 percent in gross domestic product) and moderate population growth (an increase of over 50 percent), it would be technically feasible and cost-effective to operate the Canadian economy in 2025 with 12 percent less secondary energy than was required in 1978. In addition, it was estimated that a shift from 16 to 77 percent reliance on renewable energy sources by 2025 would be possible. Given a scenario in which the Canadian economy grows by 140 percent to 2025, there is moderate population growth and the cost of energy efficient and renewable energy technologies drops slightly, the report concludes that it would be feasible and cost-effective to use 34 percent less secondary energy in 2025 than in 1978, with 82 percent of that energy provided by renewable sources. According to the latter scenario, energy use per capita falls to between one-half and two-fifths of its level in 1978 and energy use per dollar of gross domestic product falls to just over one-quarter of its level in 1978 (Friends of the Earth Canada [FOE], 1983).

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[4]Compared to those of other energy investments, the payback period of efficiency programs often appear even more attractive. Investors nevertheless appear to make irrational decisions in this respect. According to Cavanaugh et al (1989), when people and organizations can be persuaded to consider energy efficiency, they demand a much higher return on their investments than energy companies earn on their energy production projects. Conservation is typically expected to recover its full costs in three or fewer years, while a decade or more must pass before many new oil fields, coal mines and power plants begin to earn any income.

Though a carbon dioxide reduction potential is not calculated as part of the Friends of the Earth study, it is reasonable to assume that, as the result of substantially greater energy savings and a switch to renewable energy sources, carbon dioxide emission rates would be considerably lower than those suggested by the Alberta Energy study.

Energy efficiency can effectively save costs in developing countries as well. Amulya Reddy derived energy policy suggestions for the state of Karnataka, India. Relative to other policy directives being considered, Reddy's suggestions for energy efficiency entail lower costs as well as lower carbon dioxide emission expectations. He estimates that Karnataka could meet its energy needs, avoid the currently predicted doubling of carbon dioxide emissions by 2000 and, at the same time, save the $3000 (U.S.) per tonne of carbon dioxide it would have cost under supply expansion plans the government made in the late 1980s (MacKenzie, 1991).

Full Cost Accounting

Though there is strong consensus that cost savings are possible through energy efficiency and conservation, there is some discrepancy between estimates of the greenhouse gas reduction potential (and therefore harm avoidance potential) as the result of measures that might be implemented with a cost savings. This may be due in part to the different base prices of fuel assumed in cost calculations.

Despite plentiful proof that energy efficiency and conservation can save money and, as a result, improve the quality of life, decisions based on this proven potential are not being made. A host of reasons have been given to explain why, to date, the savings associated with energy efficiency have not approached what is evidently possible. A major economic barrier to energy efficiency is that energy use decisions are based on energy prices to the end-user that do not reflect marginal costs (e.g. Kozloff, 1987; Pinto, 1987; Hamburg, 1990; Shioshansi, 1990). If the energy price charged to consumers is less than its economic opportunity cost or if tariffs, taxes, interest rates or other economic policy variables restrict the availability of energy-efficient equipment, then markets may not respond rationally or quickly to conservation measures (Pinto, 1987).

Economic barriers to conservation exist in developing as well as industrialized countries. According to Shrestha and Acharya (1990), electricity pricing in many Asian countries is not reflective of the true costs of supply nor does it account for the external costs. In some countries, residential and agricultural users are cross-subsidized by commercial and industrial customers although the marginal costs of supplying power to the former sectors is higher than to industrial users. Subsidized electricity prices have serious implications with respect to energy conservation. They lead to higher levels of consumption and, in effect, make the prospect of purchasing more efficient appliances by customers less attractive financially.[5]

The price of fuel to consumers is of course an important factor in determining the cost savings that can be realized through energy efficiency and conservation. As the price per unit of fuel to run an automobile, provide a hot shower or produce electricity goes up, the monetary savings associated with using fewer units of fuel to achieve these ends are increased.

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[5]Despite the implications of subsidies on carbon dioxide emissions, Shrestha and Acharya stress it is important to remember that many subsidies have been implemented on social grounds. Given that rates are often based on equity and rural development arguments, the electricity subsidy problem is not necessarily a clear-cut one. Others might argue that such subsidies, though otherwise appropriate, should not be provided if they require environmentally inappropriate activities such as excessive energy use.

Social and political values are among the many factors that may affect fuel prices (e.g. Alberta Energy 1991a). Where the health of the environment is valued, for example, polluting fuels should be priced higher than where the health of environment is not valued. Full cost accounting is a technique that can be used to ensure that costs to all valued entities incurred by consumption are included when setting fuel prices.

In order to understand the benefit of full cost accounting, it is useful to consider the implicit costs of not implementing a certain policy. Given a primary mandate to honor the interests of presently living humans, the economic and social costs of continuing current rates of energy use are significant. Utilizing more energy than is needed to maintain a desired standard of living consumes money that might otherwise be spent to improve that standard of living. (This line of reasoning is particularly relevant in developing countries.) Furthermore, the external costs of inefficient energy use cannot be overlooked. Energy efficiency and conservation, in addition to reducing emissions of greenhouse gases, are key factors in other areas of pollution abatement. The costs of not implementing energy efficiency and conservation strategies include those of health and environmental recovery from harmful levels of ground level ozone, acid deposition, and, to a lesser extent, stratospheric ozone depletion. In many respects, then, it is costly to present societies not to pursue energy efficiency and conservation policy.

A group of researchers in Sweden calculated the costs (in money and carbon dioxide) of efficiency for a number of scenarios involving different energy supply mixes (MacKenzie, 1991). In order to meet the country's service needs, the research team found that no amount of efficiency was enough to reduce carbon dioxide emissions to the targeted (1986) level (of 11 Mt per year) if the basic source of power was fossil fuel. The scenario that produced the least carbon dioxide was determined to cost less than simply letting market forces prevail.[6] Nevertheless, this scenario was not the cheapest. On the other hand, carbon emissions under the cheapest plan, though less than under market forces, were found to be far too high to meet Sweden's target. The difference in cost between the cheapest plan and the one that produced the least carbon dioxide was estimated at $102 for each tonne of carbon not released. This, according to Thomas Johansson of the research team, may be viewed as the cost to society of adopting an energy policy which minimizes carbon dioxide versus one that minimizes costs (MacKenzie, 1991).

The reduction of greenhouse gases through cost-effective means may not be sufficient to avoid rapid climate change entirely. A strategy that seeks only to minimize near-term costs may eventually lead to a need for adaptation measures to be implemented in the future. If, in the interests of future generations, the costs of adaptation are seen as unfavorable, then higher emission reduction targets may be set and more costly measures included in an overall policy strategy (as in the current policy in Sweden). In the United States, Breton (1991) estimates that programs with costs under $200 per

[6]The high level of energy efficiency under this scenario saves enough money to pay for the investment needed to switch to biomass production. Under such a plan, Sweden would gain approximately $40 for every tonne of carbon it does not produce that it would have produced under market forces alone (MacKenzie, 1991).

metric tonne of carbon removed would permit a 13 percent reduction of carbon dioxide emissions relative to 1988. Depending upon the ethical principles applied, this $200 cost per metric tonne could be incorporated as a greenhouse (carbon) tax.

Assessing a tax with the intention of reducing longer-term threats due to global warming may not accord with policy based on a present-oriented ethical principle. In order to justify a greenhouse tax, or some comparable measure for which the desired effects may be experienced in the relatively distant future, there would need to be greater weight given to the interests of future generations. As a preliminary step to implementing a greenhouse tax, then, policy makers may need to accept intergenerational equity as an applicable ethical principle. In general, the amount of a greenhouse tax would depend on the degree to which intergenerational equity is accepted as well as on the degree to which the effects could be expected to be felt by presently living individuals.

Thus, with progressively increasing weight assigned to the interests of future generations, there is a corresponding shift in importance from policy that maximizes cost-savings in the present to policy that provides more insurance against future harm. Where intergenerational equity is applied, energy efficiency remains one of the most effective first steps of a greenhouse avoidance strategy. In contrast to policy that is more present-oriented, however, a principle of intergenerational equity would justify a government imposed greenhouse tax (or other regulatory measures) to achieve higher emission reductions than would otherwise be cost effective.

Global Warming Policy and Non-Human Interests

When the circle of relevant interests (or rights or moral standing) is expanded to included non-humans, then there are increasingly stronger ethical grounds for considering investment into avoidance strategies. The latter is a conclusion based on suggestions (e.g. IPCC, 1990; Schneider, 1989; NAS, 1991) that certain species of plants could neither adapt nor migrate in order to avoid extinction in the event of rapid climate change.

On the grounds that species extinction is undesirable (i.e. based on the characteristically holistic land ethics principle), it is possible to justify larger investments in global warming avoidance measures than those based solely on the interests of humans beings. Also, given that the degradation of ecosystems due to global warming would likely involve death and suffering among sentient animals, then greater investment into avoidance may be justified if one accepts (the sentience-based ethics principle) that suffering and death should be should be taken into account (and presumably avoided) when evaluating the potential consequences of global warming and response strategies.

An Attempt to Quantify the Effectiveness of Energy Efficiency

The NAS panel (1990:16) developed the graph below based on model generated estimates of the impacts on the global equilibrium temperature associated with changes in anthropogenic emissions of greenhouse gases (from 1990 to 2030).

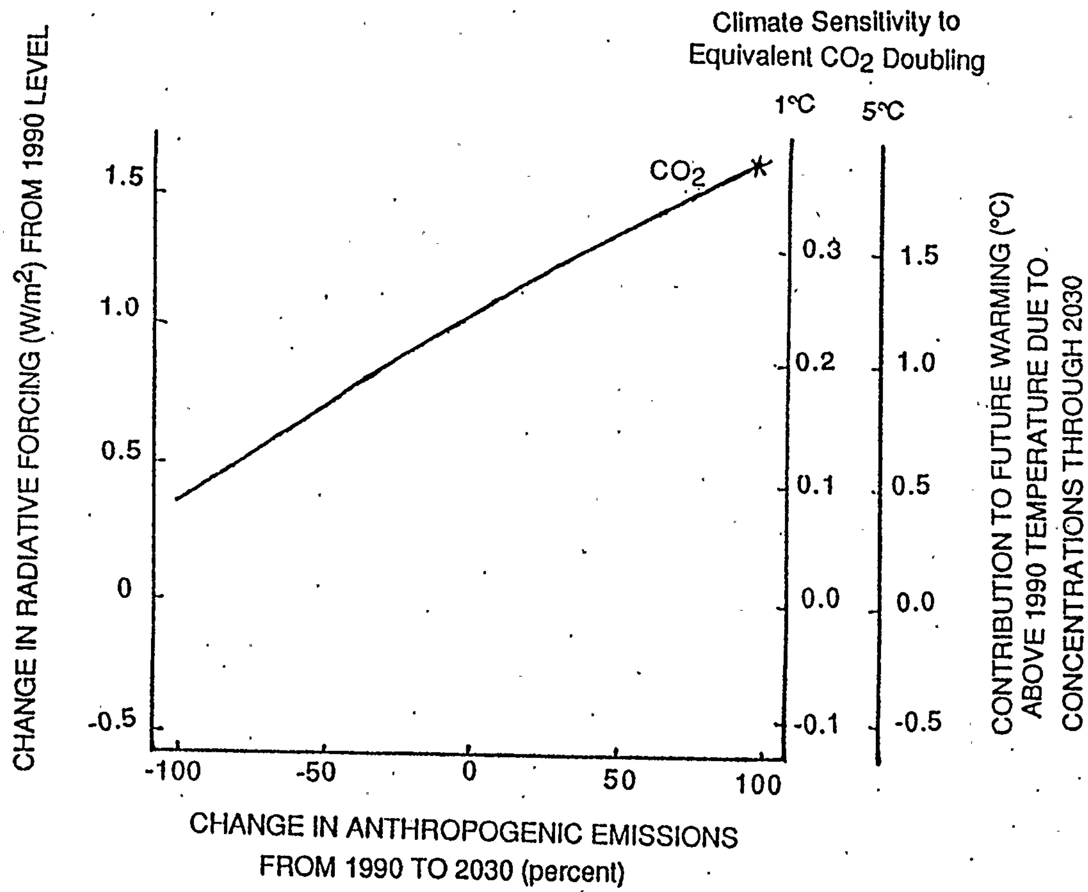

FIGURE 4.1 IMPACTS ON THE GLOBAL EQUILIBRIUM TEMPERATURE ASSOCIATED WITH CHANGES IN ANTHROPOGENIC EMISSIONS OF CARBON DIOXIDE (1990-2030)

Note: An incremental change in radiative forcing between 1990 and 2030 due to emissions of carbon dioxide implies a change in global average equilibrium temperature responses. The scales on the right-hand side show two ranges of global average temperature responses. The first corresponds to a climate whose temperature response to an equivalent of doubling of the preindustrial level of carbon dioxide is 1°C; the second corresponds to a rise of 5°C for an equivalent doubling of carbon dioxide. These scales indicate the equilibrium commitment to future warming caused by emissions from 1990 through 2030.

To determine equilibrium warming in 2030 due to continued emissions of carbon dioxide at the 1990 level, find the point on the curve labeled "CO_2" that is vertically above 0 percent change on the bottom scale. The equilibrium warming on the right-hand scales is about 0.23°C for a climate system with 1° sensitivity and about 1.2°C for a system with 5° sensitivity.

Scenarios of changes in committed future warming accompanying different emission rates can be constructed by repeating this process for given emission rates.

This graph can be used to construct scenarios of temperature change resulting from different emission rates.[7,8]

For such an exercise, it is useful first to examine a business-as-usual scenario where there is an implied growth in emissions from 1990 levels. The calculated temperature change associated with a business-as-usual emission scenario may then be compared to temperature changes that can be expected to accompany various emission reduction scenarios. The emission reduction scenarios presented below have been chosen to illustrate, on the one hand, the temperature increase associated with a commonly suggested emission target (i.e. holding emissions at 1990 levels), and, on the other hand, the temperature change associated with a somewhat more rigorous (though still easily achievable, given the emission reduction potentials cited by the NAS panel (1990) and by the Friends of the Earth (1978)) emission rate (i.e. reducing 1990 emissions by 37%).

[7]The panel cautions that it is difficult to predict the degree to which global warming will occur based on temperature measurements alone. Though it would be helpful in this regard to monitor the radiation balance of the earth, there are no satellites currently in existence that are capable of directly measuring outbound infrared radiation (NAS, 1991).

[8]In the IPCC report (p. xxxiv), four scenarios are developed to illustrate the potential climatic changes associated with different levels of greenhouse gas emissions. One scenario poses a situation where "large efficiency increases are achieved" and "deforestation is reversed"; another scenario assumes that "a shift towards renewables and nuclear energy takes place in the second half of next century"; and a third illustrates the potential effects when "a shift to renewables and nuclear in the first half of the next century reduces the emissions of carbon dioxide, initially more or less stabilizing emissions in the industrialized countries". Because they involve a number of arbitrary and unquantified mitigation measures however, it is difficult to use these scenarios in assessing the effectiveness of different specific reduction targets in abating climate change.

•A business-as-usual scenario (which implies growth in emissions from 1990 levels) would produce a global average temperature increase from 1990 to 2030 of .1.32° C.[9]

• Based on estimates derived by Breton, implementing programs in the U.S. with a net cost savings could hold carbon dioxide emissions to 1990 levels (through 2010). Applied on a global scale, this emission rate would have a corresponding effect on warming above 1990 temperatures through 2030 of (very roughly) 0.88° C.[10] This increase in temperature is lower than that estimated for the business-as-usual scenario by 0.44° C.

• According to the NAS panel, energy efficiency improvements have the potential to reduce the 1990 U.S. carbon dioxide emission rate by 37 percent. Applied on a global scale, this emission rate would have a corresponding effect on warming above 1990 temperatures through 2030 of (very roughly) 0.59° C. [11] This increase in temperature is lower than that estimated for the business-as-usual scenario by 0.73° C.

Thus, carbon dioxide emission targets based on either of the above energy efficiency improvement scenarios would substantially reduce temperature increases (at least until the year 2030) commonly associated with a business-as-usual emission rate of carbon dioxide. That is, in lieu of an increase of 1.32°C, lower increases of 0.88° or even 0.59°C would occur.

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[9]The asterisk on the NAS graph corresponds with the global average temperature increase (from 1990) that is expected to take place by 2030 given a business-as-usual scenario. This point shows global average temperature to have increased by between .37 and 1.8 ° C in 2030. For purposes of comparison, a single value for global average temperature increase within this range has been chosen. This value has been calculated as two-thirds of the upper estimate plus one-third of the lower estimate: (2/3 x 1.8°) + (1/3 x 37°) = 1.32° C. (The factor of 2/3 is used because of the author's supposition that temperature changes are likely to be closer to the upper estimate.) The same calculation of a single value of temperature change is used for subsequent (alternative) scenarios.

[10](2/3 x 1.2°) + (1/3 x .23°) = 0.88° C

[11](2/3 x 0.8°) + (1/3 x 0.18°) = 0.59° C

However, given that, due to the radiative forcing effect of carbon dioxide, global average temperature has increased by between .15 and 0.3°C during the last hundred years[12], the above temperature changes estimated for the year 2030 are relatively high. Thus, even as the result of seemingly low carbon dioxide emission targets, some (probably undesirable) increases in global equilibrium temperatures are likely to occur. This may in turn suggest that emission reductions are important but, alone, are insufficient to ward off significant climate change by the middle of the next century.

There are countless mitigation options other than improved energy efficiency suggested by scientists. For example, options with costs of between $1 and $99 US. dollars per tonne of carbon dioxide equivalent include landfill gas collection, halocarbon usage reduction, and changes in agricultural and reforestation practices (NAS, 1990). In addition, there are adaptation measures such as building bridges and developing drought-resistant crops that might be considered. Many different global warming strategies could be drawn up, each consisting of a different mix of avoidance and/or adaptation measures.

Conclusion

The degree of investment in any strategy will depend on discount rates and costs of different measures, including those determined through full cost accounting. In turn, discount rates and costs may be subjectively determined, depending in part on values and ethical principles applied. Regardless of the ethical principles accepted, energy

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[12]The average global temperature has increased between 0.3 and 0.6 ° C during the last 100 years (NAS, 1991) and just over half of this increase is due to carbon dioxide (IPCC, 1990). Therefore the range of increase in temperature due to carbon dioxide is calculated by halving the lower and upper values.

efficiency and conservation, both in industrialized and developing countries, are desirable options in dealing with global climate change. If policy makers reject the more controversial ethical principles, then attention may be devoted to the short-term gains of efficiency in conjunction with adaptation strategies.

Accepting as important the interests of future generations of humans and those of non-human beings, however, estimates for short-term cost savings may be increased by adjusting full cost accounting to include these interests. Accordingly, greenhouse taxes and other perhaps more costly avoidance measures may be justified. Even under the most stringent emission reduction policies, it may be impossible to avoid climate change entirely. Thus, the ideal policy strategy probably includes a mix of mitigative (and perhaps adaptive) measures with energy efficiency as a desirable first step.

CHAPTER 5:
SUMMARY
AND RECOMMENDATIONS

The potential consequences of global warming include human and non-human suffering and losses in biodiversity. As the circle of morally relevant (and rights possessing) beings is enlarged, such suffering and loss may be seen as increasingly undesirable and efforts to avoid such consequences become increasingly justifiable.

The degree of investment in any global warming response strategy will depend on its cost-effectiveness as well as its ethical acceptability. Cost-effectiveness, in turn, is a measurement that depends upon the discount rate and costs of different options, including those derived through full cost accounting. Both in terms of cost-effectiveness and ethical acceptability (regardless of the size of the circle of morally relevant interests), improvements in energy efficiency in both developed and developing countries make sense as a first step in any global warming strategy.

With more attention given to the rights (and/or interests) of future generations and of non-human beings, estimates of short-term cost savings associated with energy efficiency may be increased by adjusting full cost accounting to include these rights (and/or interests). The use of greenhouse taxes or other comparable market-based mechanisms would be increasingly justified with a greater recognition of rights and moral standing across generations and species or with a higher value placed on the well-being of whole ecosystems. With such taxes or equivalent measures, even greater energy efficiency options become cost-effective.

Even under the most stringent emission reduction policies, including those emphasizing energy efficiency, it may be impossible to avoid human-induced climate change entirely. In order to satisfy certain ethical principles (particularly the more controversial ones) it may be necessary to pursue measures that are less cost-effective than energy efficiency. In essense, the ideal policy strategy would probably include a mix of mitigative (and perhaps adaptive) measures with energy efficiency as the most desirable first step.

Based on the findings contained this document, the following recommendations are offered for further consideration:

• More information is needed to ascertain the rate and significance of climate change as well as the potential impacts associated with human-induced global warming. As scientists continue to collect such information, efforts should begin immediately to implement energy efficiency programs. At little or no cost (or at a cost savings), improved efficiency will reduce carbon dioxide emissions and effectively slow the rate of climate change, buying more time to gain a better understanding of the global warming phenomenon than would be available under a business-as-usual scenario.

• Because the greenhouse effect is a global phenomenon, increased interaction is needed at the international level. International coöperation in setting reduction targets and in developing such measures as a globally tradable carbon coupon system would be extremely useful in the context of global warming policy.

• As has been emphasized throughout this document, policy-making is an exercise in applied ethics and the best policies are based on rational, well defined ethical principles. With respect to the global warming issue, decision-makers need to discuss (and, ideally, to state explicitly) what ethical principles they are applying. In particular, it is or will soon be, of considerable importance for policy-makers to understand the extent to which future generations of people and non-human beings have standing and/or rights.

APPENDIX:
EXAMPLES OF ENERGY USE PATTERNS AND THE POTENTIAL FOR SAVINGS IN VARIOUS SELECTED COUNTRIES

Canada

In Canada, the National Energy Board (NEB, 1991) uses a long-term economic growth rate of 2.3 % per year in establishing its projections for supply and demand in the next twenty years. Based on this growth rate, however, different energy use scenarios might be developed. As the NEB report explains, the particular structure and type of economic activity significantly influences the level and mix of energy demanded.The NEB projects economic growth in Canada characterized by continued reliance upon the energy-intensive production of goods but where such production contributes a declining share of total economic output for the country from over 10.5 % in 1989 to less than 10 % by 2010. By implication, the less energy-intensive service industry is expected to take on an increasing share in the economic output.

It is interesting to note that substantial energy savings have been achieved in some sectors of the country's economy. The Canadian Industry Program for Energy Conservation (CIPEC) was established in 1976 as a voluntary, industry-organized and government assisted energy conservation task force program (Kennedy, 1990). The activities of CIPEC include setting voluntary energy efficiency improvement goals; reporting annually on the progress toward these goals; increasing energy management awareness in industry; exchanging information on energy management and technology; promoting energy conservation in general by encouraging employees to adopt energy conservation in their homes; and establishing and maintaining an industry-government dialogue on energy conservation matters. According to Kennedy, CIPEC has kept energy conservation in the forefront of Canadian industry in the interests of greater productivity and international competiveness. The network includes 14 sectoral task forces, with over 40 different industry associations participating in the program and representing thousands of establishments (Kennedy, 1990).

Between 1973 and 1988, a weighted average of energy efficiency progress made by the 14 task forces equalled 28.8%. Numerous large energy intensive industries have shown impressive improvements (e.g. chemicals 41.1%, industrial minerals 27.7%, petroleum refining 31.3%, and pulp and paper 31.1%). Other industries that use large amounts of energy (but are not considered energy intensive) also achieved notable progress (e.g. electrical and electronics 52.9%, food and beverage 28.7%, plastics processing 45.0%, textiles 32.6%, manufacturing 22%, and wood products 35.2%. The CIPEC task force companies saved an estimated total of more than $20 billion of energy purchases, equivalent to 5,000 Petajoules of energy or 800 million barrels of oil (Kennedy, 1990).

While energy consumption for the nation as a whole may point to a projected decrease in energy intensiveness (and hence a reduction of carbon dioxide emissions) across sectors, a closer examination of province-specific energy use scenarios illustrates areas with potential for significantly greater savings.

According to a report by the Energy Efficiency Branch of Alberta Energy (1990a), for example, the western province of Alberta is the highest per capita emitter of carbon dioxide in Canada and the second highest overall after Ontario. There are two primary reasons for this. First, Alberta is home to a relatively large energy industry (the products of which are used throughout North America) and, second, most of the province's electricity is generated by burning coal.

A detailed breakdown of the emissions for each energy using sector is provided for 1988 and, based on projections by the Energy Resources Conservation Board (ERCB), emissions from 1988 through 2005 are presented. Table A.1 shows the conversion factors used in the Alberta Energy (1990a) calculations.

Alberta Energy's (1990a) analysis included the following observations: Alberta's total carbon dioxide emission in 1988 is estimated to be 124 megatonnes (Mt) and this is expected to grow to 177 Mt by 2005; the largest source of carbon dioxide emissions is the energy industry, accounting for about 42% of the total and emissions from the residential, commercial, transportation and other industry sectors are all very similar, accounting for between 12 and 16% of the total each (See figure A.1).

Alberta Energy also developed a discussion paper on the emissions reduction potential for Alberta for 1988-2005 (Alberta Energy, 1990b). In the Alberta Energy study, it was found that there is considerable potential for energy savings in the province. Based on the 1988 retrofit analysis, 15% of fossil fuel usage could be saved and 60% of purchased electricity could be saved through energy conservation, including fuel substitution and cogeneration. Cost savings to all energy consumers would be $2.2 billion per year following the investment in $6.7 billion in conservation measures (Alberta Energy, 1990b).

TABLE A.1 CARBON DIOXIDE CONVERSION FACTORS

Fuel	Factor (kilotonnes CO_2/Petajoule)
Fuel gas (assumes natural gas)	49.7
Propane (space heating and transportation)	59.8
Light Fuel Oil	73.1
Heavy Fuel Oil	74.0
Coal (sub-bituminous Alberta)	93.6
Kerosene	67.7
Diesel	70.7
Refinery Process Gas	51.0
Refinery Coke	86.0
Oil Sands Coke	89.4
Oil Sands Feedstock Gas	49.7
Oil Sands Process Gas	58.0
Petrochemical Feedstock	5.6
Flared Gas	49.7
Motor Gasoline	68.0
Synthetic Crude	70.0
Aviation Gasoline	69.4
Turbo Fuel	70.8

NOTE: The conversion factors are normally the fuel's higher or gross heating value assuming 100% combustion of hydrocarbons to carbon dioxide.

SOURCE: Chapter 11 of the Mitigation Panel report (NAS, 1991).

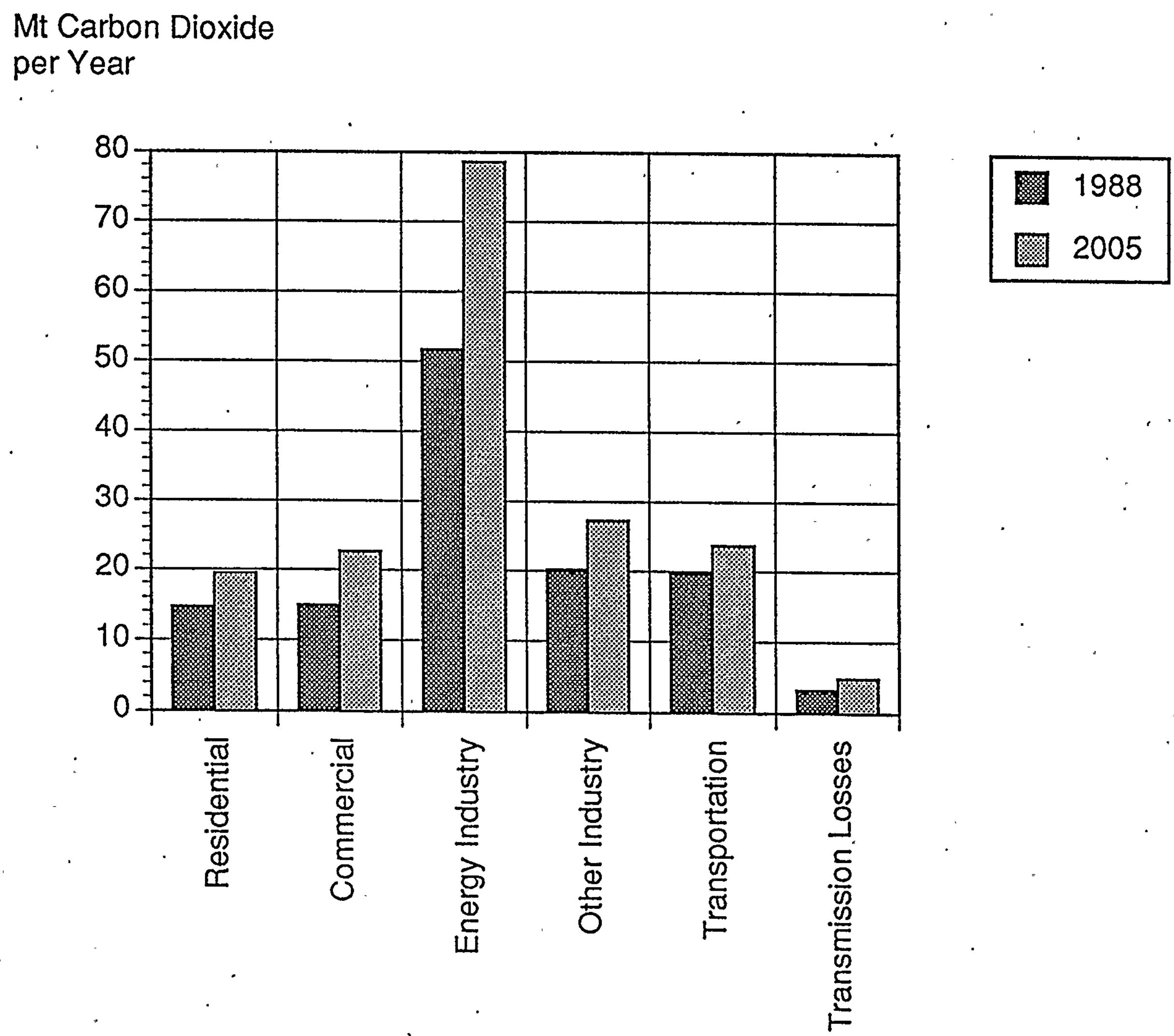

FIGURE A.1 ALBERTA CARBON DIOXIDE EMISSIONS
(ELECTRICALLY GENERATED CARBON DIOXIDE
ALLOCATED TO SECTORS)

Under the conditions of conservation described above for Alberta, the total carbon dioxide emission level in 2005 could be reduced by 61.5 Mt by the year 2005. The 1988 emission level is estimated at 124.3 Mt per year, and the potential exists to reduce this level to 115.3 Mt per year by 2005 (Alberta Energy, 1990b).

The United States

Hydrocarbon fuel combustion in the United States accounts for about 25% of worldwide carbon dioxide emissions (Subbakrishna, 1990). Of the United States' contribution to worldwide emissions, approximately 27% comes from transportation, 29% from industry, 28% from power production and 16% from the residential and commercial sectors (Subbakrishna, 1990). Extrapolating these figures to a global level, Subbakrishna estimates that power production in the United States accounts for about 7.5% of worldwide carbon dioxide emissions.

Breton (1990) estimates that U.S. carbon dioxide emissions could be kept at 1988 levels through 2010 solely by implementing programs estimated to have a net cost savings for the nation (when using a 7 % discount rate). Programs with costs averaging $200 per metric tonne of carbon dioxide reduced would permit a 13 % reduction of carbon dioxide relative to 1988. Implementing all the programs evaluated, including those costing more than $200 per metric tonne of carbon removed, would allow for a 25 % reduction in emissions through 2010.

Of the programs Breton studied, energy conservation programs in the transportation, residential and commercial sectors were determined to entail the lowest cost. The next best (cost-wise) programs were found to be renewable electricity generation substitutes for conventional fossil fuel generation plants. The results of Breton's study suggest that a 20 % reduction in carbon dioxide could be achieved by 2010 without causing the U.S. to incur significant costs.

Implementation programs need to be created to bring about the above reductions. Also, the achievement of these results depends on an early start (by 1992 according to Breton) toward installing high efficiency end use devices and improving the design and lowering the cost of renewable technologies.

The US Environmental Protection Agency (EPA) has organized a voluntary, non-regulatory program encouraging major corporations to install energy-efficient lighting designs and technologies. The goal of the EPA's "Green Lights" program is to reduce pollution and save energy through replacement of conventional light bulbs. Crucial to this program are the partnerships the EPA establishes with private industry in order to build the customer base for energy-efficient lighting (Lawson and Kwartin, 1991). According to program proponents Jerry Lawson and Bob Kwartin (1991), Green Lights works on an underlying principle stated as "Environmental Protection at a Profit". This profit is purported to include lower electricity bills, improved lighting quality and increased worker productivity. In addition, through adoption of Green Lights' ideas, such pollutants as carbon dioxide, sulfur dioxide and nitrogen oxides, which constitute negative externalities associated with the production of electricity, are reduced.

Lighting accounts for 20-25 % of the electricity used each year in the United States. Of all this electricity, 80-90 % is utilized in industry, commercial stores, offices and warehouses (Lawson and Kwartin, 1991). The potential cost savings and emission reduction due to installation of energy-efficient lighting is noteworthy. If, for example, energy-efficient lighting were used wherever it were profitable to do so, it is estimated that $18.6 billion (US) would be freed from ratepayer bills for useful investment. Furthermore, annual carbon dioxide emissions would be reduced by 211 million tonnes, the equivalent of the emissions from 42 million cars.

The EPA collects and distributes case studies as evidence that the Green Lights program is in the best interest of corporations. For example, Green Lights received a subission from Jim Hardin, the construction manager of a hospital in Indiana. This hospital, a 40 000 square-metre facility, having completed 30 % of intended conversion from conventional to high-efficiency lighting, has saved 2 million kilowatt hours (kWh) and $100 000 on annual utility bills. Additional benefits reported include a significant reduction in maintenance costs, improved lighting quality, a 30 % savings in summer air conditioning utility costs due to reduced heat loads, and improved security (proximity switches indicate people moving in some areas of the hospital). The initially projected payback period of two to three years now appears to be conservative. This is partially attributed to the fact that materials used for an efficient lighting system have come down in price considerably in recent times. As Hardin points out, hospitals, where lighting is used 24 hours per day, seven days per week, have much to gain by adopting the Green Lights program (EPA, no date).

In 1986, The New York State Energy Office implemented an energy management program known as the Small Business Energy Efficiency Program (SBEEP). Funding for the program resulted from legislation which required distributing Exxon and other Petroleum Overcharge Funds. Among the services provided by SBEEP are free energy surveys and technology transfer seminars for small business, not-for-profit organizations, and farms and agribusinesses in New York State. Between July 1986 and September 25, 1991, SBEEP conducted 23 402 surveys. Seminar presentations reached an additional 6000 residents of the state. According to the SBEEP update of

October, 1991, if all the energy conservation measures recommended by SBEEP technicians were implemented, the total potential savings would be more than $30 million annually. On average, each business could save nearly $1300 per year while avoiding about 16 % of its energy bills. The average cost of implementing the energy-saving measures is $2560 with a simple payback period of two years.

Since 1986, the top five SBEEP recommendations have remained consistent:

•Use energy efficient fluorescent tubes; average annual savings of approximately $300; average cost just under $400 for a 1.3 year simple payback period;

•Use energy efficient incandescent light bulbs; average annual savings, approximately $150; average cost of $110 for a payback period of less than one year;

•Insulate hot water storage tanks; average annual savings, $70; cost, a little over $20; payback in less than four months;

•Replace incandescent light bulbs with fluroescenht lighting; average annual savings, approx. $230; average cost, $300 for a 1.3-year simple payback period; and

•Install current reducers on fluorescent lights; average annual savings, $570; cost, $500; simple payback period, less than one year.

Based on recommendations made by SBEEP, it is estimated that the $30 million potential energy savings would be enough thermal energy to heat approximately

43 000 average-sized homes for one year. If all recommendations were acted upon, the fuel savings would equate to a reduction of 300 tonnes of sulphur dioxide, 110 tonnes of nitric oxides and more than 140 000 tonnes of carbon dioxide annually.

In the state of California, calculations for energy-related cost savings in industry illustrate the benefits of more efficient and technically feasible processes. Where, for example, direct resistance heating for metalworking and glass melting replaces conventional electric heaters, the net cost per tonne of carbon dioxide reduced (net cost is the cost relative to the conventional technology being replaced) and the total annual carbon dioxide reduction by the new technology have been calculated by Shin and Sioshansi (1990:590).

•Fuel used by conventional technology per unit of output = 1 270 000 kWh/year

•Fuel used by new technology per unit of output = 823 000 kWh/year

•Carbon dioxide emission coefficient = 1.195 lbs/kWh

•Annualized cost of conventional technology per unit of output = $137 000/year

•Annualized cost of technology per unit of output = $93 700/year

•Market penetration of new technology in 2005 = 60 000 000 kWh/year

•Carbon dioxide reduction by application of new technology
= (1 270 000 - 823 000) kWh/year x 1.195 lbs/kWh x 1/2200 tonnes/lbs
= 243 tonnes/year

•Net cost per tonne of carbon dioxide reduced by new technology =
(93,700/year - $137,000/year) divided by 243 tonnes/year
= -$178/tonne (This is a <u>savings</u>, not a cost.)

•Total annual carbon dioxide reduction in 2005 by new technology =
267 tonnes/year x 60 000 000 kWh/year divided by 823 000 kWh/year
= 19 000 tonnes/year

Under contract for the Southern California Edison Company, Science Applications International Corporation has developed a database that documents the energy savings, capital costs, annualized costs, payback period and carbon dioxide reduction for 27 supply- and 188 demand-side technologies. Of the supply-side options studied by Shin and Sioshansi, all were found to be cost-effective but the magnitude of carbon dioxide reduction possible was estimated to be relatively small. The most effective supply-side option was determined to be the conversion of plants from coal to natural gas generation. Wind generation appeared to be relatively expensive, given its large initial capital cost.

All demand-side options were calculated to have a negative cost. The replacement of blast furnaces with direct arc melting in the metals industry, according to the calculations, would have the largest carbon dioxide reduction potential, followed by lighting efficiency improvements. Industrial process heat pumps and heating, ventilation and air conditioning pumps with water heating in the residential and commercial sectors also showed significant carbon dioxide reduction potential.

Though their model suggests that net savings would result from implementing energy efficiency measures over the lifetime of the investments, Shin and Sioshansi say that the initial capital requirements are likely to be substantial (for a utility) and should not be treated lightly (1990:596).

Australia

It has been estimated that between 107 and 194 million tonnes of annual carbon dioxide emissions could be saved through energy efficiency measures in the residential, commercial, transport and industrial sectors in Australia by 2005 (Tilley, 1991). As means of minimizing the cost of achieving both the low and high emission reduction scenarios in Australia, a number of strategies are recommended for the residential sector in the areas of water heating, refrigeration and other major appliances (which account for about 55% of the carbon dioxide emissions in this sector).

With respect to water heating, one recommendation is to increase the number of households using gas powered water heaters in households already connected to gas (of which one third utilize other forms of water heating) as well as in newly connected households. The capital costs of this course of action would be outweighed by the savings in running costs. Other recommendations include the adoption of solar-electric heating only outside the gas reticulated area, and the adoption of a combination of solar and natural gas for water heating (Tilley, 1991).

Because it is not currently possible to change the type of energy used for refrigeration, the main alternatives for emission reduction in this area are to decrease the demand and increase the efficiency of refrigeration. In the case of both refrigerators and other major appliances, the sales-weighted efficiencies in 2005 can be expected to exceed the current best-on-the-market (Tilley, 1991). In order to have an effect on emissions reduction, rates of market penetration by more efficient appliances must be much higher than current rates and would require market intervention to be achieved. Changes in installation preferences would need to begin almost immediately (Tilley, 1991).

In Australia's industrial sector, the potential for changes in production efficiency generally fall into three categories. The first of these is the upgrading or renovation of plants to accomodate more efficient processes. For example, increased and improved use of waste heat may be built in. The second category of change is that of improved training, monitoring and targeting. This may involve the use of sophisticated monitoring computers (which can decrease energy usage by up to 10%).The third category is that of new technology (Tilley, 1991).

A key element in improving efficiency in all of the various sectors in Australia, as in most other countries, is the development of communication programs aimed at reduction and performance improvement (Tilley, 1991).

Mexico

According to Guzmán (1987:2),

> ..it is of the utmost importance to Mexico to decelerate its inordinate growth in domestic energy demand. Otherwise, the Mexican energy sector will need considerable new investments, particularly in the oil sector, investments that do not seem financially feasible at the present time or in the near future.

Guzmán's report suggests that Mexico has been wasting considerable amounts of energy at all levels, particularly since the beginning of the 1970s. Given the tremendous energy waste that has occurred in Mexico, there is significant potential for conservation and improvments in energy efficiency. A cumulative total of 81 billion (US$) between 1991 and 2000 is the calculated potential savings that could be achieved for Mexico if energy efficiency were maximized in industrial, transportion and residential sectors. Money saved through conservation could do much toward relieving Mexico's massive foreign debt (which in 1987 amounted to 100 000 million dollars) (Guzmán, 1987:320).

Asia

In the Asian region in recent years, according to Ram Shrestha and Mahesh Acharya (1990), growth in electricity consumption has occurred at a faster rate than that of nonelectric energy use. Shrestha and Acharya discuss key options for improving the efficiency of electricity generation, supply and use and related policy issues in ten Asian countries: Bangladesh, China, India, Pakistan and Sri Lanka (low income countries) and Indonesia, Malaysia, Philippines, Republic of Korea and Thailand (middle income countries).

At present, carbon dioxide emissions in the selected countries amounts to over 2 % of the global emission. This share is expected to be considerably higher in the future based upon evidence of the relatively fast growth of electricity production in most of the selected countries. The shares of thermal power generation in general and coal-based generation in particular are expected to grow rapidly in most countries in the study. Carbon dioxide emission from power plants in these countries (excluding

Pakistan and Malaysia) is estimated to increase 2.63 times by 2000 (Shrestha and Mahesh, 1990).

Together, China and India, where coal constitutes the primary electricity generation source, account for approximately 88 % of the estimated total emissions of carbon dioxide in the selected countries as a group in 1987. The efficiency of generation from coal-fired plants was found to be particularly low in China (about 30 %) and India (28.4%). This is in comparison to the average efficiency rate in OECD countries of 32.3% (Shrestha and Mahesh, 1990). Thus, by incrasing electricity generation efficiency in India and China to levels currently achieved in OECD countries, 10 to 15% reduction in coal use (and hence carbon dioxide emissions) in India and China could be achieved.

Improvements in end-use energy efficiency in the Asian region is of considerable importance for two main reasons. First, ownership of electrical appliances is growing rapidly. In Beijing, for example, the proportion of households with refrigerators rose from 1.5% in 1981 to 62% in 1987 (Kats, 1990). Second, due to relatively low purchasing power, owners are likely to use their appliances longer than their counterparts in more developed countries (Shrestha and Mahesh, 1990).

New technology provides numerous means of saving energy. Due to improvements in efficiency, for example, energy consumption by refrigerators has been cut by up to 70% in the past 15 years in Asia(Kats, 1990). Large scale use of efficient appliances would entail costs; therefore, careful demand-side management programs are implicitly desirable. As household incomes are typically rather low in most of the countries studied, most utilities would have to devise cost sharing schemes to offset the initial costs of new appliances in order to promote them.

Composition of the residential sector in developing countries is changing rapidly. There is significant rural to urban migration and a steady increase in the number of people living more modern lifestyles. Rising incomes are associated with greater energy consumption, especially due to the purchase of appliances. Fuel-switching from wood to kerosene and from kerosene to gas and electricity is characteristic of the residential sector as well. There is considerable potential in the long term for efficiency as newer more efficient appliances enter the stock (Sathaye et al, 1987).

Malaysia

In the Southeast Asian country of Malaysia, electricity for residential use is presently available to over 90 % of the population. In addition, effort has been made to ensure that energy supplies and infrastructure are available for industrial, rural and agro-related activity (Mohammed Ali, 1991).

Malaysia is well endowed with energy resources, including natural gas, oil, coal and hydroelectric power sources. In Malaysia, beginning in the 1970s, there occurred a gradual transformation from a predominantly resource-based agricultural economy to an economy characterized increasingly by manufactured goods export. Currently, manufacturing is the leading growth sector of the economy, with exports, including electronics, textiles and rubber based products, making up over 50 % of export earnings in 1990 (Mohammed Ali, 1991).

Associated with this emphasis on industrialization and manufacturing has been a growth of energy use in the industrial sector. Industry, according to Mohammed Ali, consumes 32% of the final energy demanded in the country, second only to transportation, which accounts for 42 %. It is expected that industrial energy demand will grow at 9.9 % annually and that the share consumed in the transportation sector will fall to 40 % while that in the industrial sector will increase to 34 %. Oil and petroleum products contributed 66 % of the primary fuel mix in 1990; however, this is expected to fall to 60 % by 2000, mainly as the result of a switching over to natural gas.

The overall growth in demand for energy in Malaysia will no doubt be a factor in carbon dioxide and other greenhouse gas emissions. It has been estimated that carbon dioxide emissions totalled 22 million tonnes in 1990 and that this total will increase to 35 million tonnes (1.6 tonnes per capita, as compared to 1988 per capita emissions of 16.9 tonnes in Canada, 19.4 in the U.S, 3.7 in Mexico, and 2.1 in China (NAS, 1991).) by the end of the century (Mohammed Ali, 1991).

Mohammed Ali explains that, while reducing the activities that require energy is not an appropriate option in developing countries, using energy more efficiently and reducing the carbon-intensity of the primary fuel mix is economical and desirable. The Malaysian government is thus actively involved in implementing conservation strategies. These include developing more appropriate pricing policies that discourage wasteful energy use, supporting energy awareness programs, improving efficiency in power production and distribution, and working with power utilities to develop demand-side management programs.

Malaysia has been rapidly expanding natural gas exploration, extraction, use and exportation. Use of natural gas has been focused primarily in power generation, with development, in the 1980s, of a major gas-fired combined cycle plant. In addition, a trans-peninsular transmission line is being constructed which will facilitate delivery of natural gas to industrial-intensive areas and exportation of gas to Singapore in the south (Mohammed Ali, 1991).

The change over from oil and petroleum based energy supply to natural gas is considered an important factor in the decrease of carbon dioxiode emissions Malaysia hopes to achieve due to the lower carbon dioxide intensity of the latter. (This is assuming methane leakage can be kept to a minimum.) Large untapped hydroelectric potential is also cited as a means of reducing Malaysia's contribution to global carbon loading (Mohammed Ali, 1991).

It is interesting to note that, in the case of Malaysia, most of the changes related to reduced carbon dioxide emissions (relative to overall energy demand) have been implemented for economic reasons rather than for a concern about greenhouse warming (Mohammed Ali, 1991).

Singapore

K.R. Rao (1987) advocates energy conservation in developing countries because, as he says, the energy saved through conservation can be considered a new source of energy available to meet additional demand. In developed countries, most of which are characterized by temperate and cold climates, 35-40% of all primary energy consumed is used in buildings (K.R. Rao, 1987). In these countries, residential buildings use nearly twice as much energy as all other types of buildings and a significant majority of this residential energy use goes toward space and water heating. There is quite a different situation in developing countries according to Rao. In the warmer climates of most developing countries, residences consume much less energy than their counterparts in the developed world because there is generally no air-conditioning. On the other hand, large hotels and commercial and office buildings in many of the developing countries' larger cities are typically air-conditioned continuously and intensively. Rao found that in Singapore, for example, there is considerable room for savings given that the methods of electricity generation are less than 30% efficient in converting primary to secondary energy. Rao emphasizes that efforts to conserve energy in developing countries should be focused on large commercial and office buildings.

Rao studied the potential for energy savings in commercial buildings in Singapore and concluded that, besides the savings achievable in the operation of buildings, there is clearly potential for energy savings in the construction of such buildings. Steel, aluminum, concrete, glass, brick, plastics and the many other materials that go into construction require energy themselves in production. Processing and manufacturing of some material requires more energy than others. Production of a reinforced concrete structure, for example, will use less than 60% of the energy necessary to produce a complete standard steel structure (Rao, 1987). Thus, conservation could be achieved in the construction industry through the use of less energy-intensive materials. A handbook, as suggested by Rao, that lists the various energy cost per unit of building components, might be a useful tool for building designers.

Pakistan

The present level of per capita energy consumption in Pakistan roughly corresponds to half the average for developing countries, one-seventh the world average and one-twentieth of the average for industrialised countries. With a population of 115 million (2 % of the world population), Pakistan consumes about 29 million tonnes of oil equivalent of commercial energy (oil: 39%, gas: 39%, coal:7%, hydro: 15% and nuclear 0.3% respectively) and contributes 0.3 % of the global emission of carbon dioxide due to energy related activities (Khan, Jalal, Mumtaz and Latif, 1991).

The electric power industry accounts for one-third of the total primary energy consumption in Pakistan and this share is steadily increasing with time (Khan et al, 1991). For Pakistan in general, the electric power generation alternative with the lowest carbon dioxide emission factor is gas-fired (especially combined cycle) plants and that with the highest is coal-fired plants (using indigenous coal).

India

Anandalingam (1987) describes a benefit-cost analysis undertaken in India where industrial energy conservation projects, on the one hand, and improved energy supply, on the other, were compared. For each project, the present value of public and private net benefits, supply prices, volume and value of energy savings and the internal rate of return were calculated. Anandalingam found that the conservation measures in the steel industry were by far the most costly while those in the food processing industry had the lowest average supply price. Overall, however, it appeared that the type of conservation project (e.g. insulation, waste heat recovery, etc.) was more influential in determining the economics than the type of industry. Simple housekeeping measures seemed to be the most economical per energy unit conserved, followed by waste heat recovery and process changes.

Analysis results showed that all the conservation projects in the Anandalingam study were economic from the public perspective when energy savings were evaluated at shadow prices and no taxes were factored in. All investments were deemed economical if 25% or more of the investments were returned to the firm as a credit on taxes owed. Furthermore, all conservation measures that involved only basic insulation or other housekeeping were economical from both public and private perspectives.

Even in the absence of investment incentives by the government, private investors could expect quite high rates of return from energy conservation measures (Anandalingam, 1987). All of the conservation projects in India evaluated by Anandalingam with positive internal rates of return had discount payback periods of less than 3.5 years; more than half paid back their investments in less than two years. Anandalingam recommended further work in evaluating the impact of government incentives such as tax credits, depreciation allowances and relief from taxation for revenue increases due to energy conservation. Nevertheless, conservation measures were shown to be notably economical even in the absence of such assistance.

On the basis of supply prices, the various conservation projects evaluated by Anandalingam were, with one exception, all less costly than domestic production of oil (both offshore and onshore) in India. Coal production was more costly than 70% of the conservation projects on cost a per unit of energy basis. Finally, compared to the import of oil, all conservation projects were clearly economical in their own right (Anandalingam, 1987). It might be concluded, based on this study, that the shift of resources in India (and indeed in many other developing countries) from energy supply to conservation could be cost-effective. Anandalingam estimated that with only 8 to 14% of the total public sector outlay for energy in India's Sixth Five-Year Plan, a savings of 25% could be achieved in the industrial sector.

Eastern Europe

Kramer (1990) explains the reasons why conservation is desirable and yet why it is not always viewed as economically attractive. On the one hand, it has been found that in Eastern Europe the monies necessary to increase power-generating capacities by 1000 MW yield an equivalent of 2000 MW when spent on conservation measures. Furthermore, it typically costs one-half to two-thirds less to conserve than to produce an equivalent amount of energy.

According to Kramer, there is considerable potential for conservation in Eastern Europe and the Soviet Union. On average these countries consume between 30 and 50 (and sometimes as high as 80) % more energy as most industrialized capitalist countries to produce similar units of national income. It has been estimated that countries in Eastern Europe and the Soviet Union could increase their national incomes by approximately one-half simply by achieving the same efficiency of energy consumption as members in the European Economic Community.

Fundamentally, says Kramer, the excessive consumption of energy in Eastern Europe is related to the Stalinist "command economy" and a concomitant strategey of extensive growth that did not merely ignore conservation, but actively discouraged it. Though post-Stalin regimes have modified the pure Stalinist model, its essential features persist and foster excessive energy consumption. Fulfillment of production targets is the key objective to which all others, including energy efficiency, are subordinate. Producers in fact perceive an economic incentive to maximize expenditures on energy inputs, as these and other inputs are used as indicators of fulfillment of output targets.

Pricing systems may also impede conservation. Prices have reflected the preferences of the political elites rather than the dictates of supply and demand. Because, according to Marxist thought, natural resources are "free goods," and also due to an encouragement to produce commodities with a high energy input, prices for energy resources have been too low to stimulate efficiency (Kramer, 1990).

A further contributing factor is the emphasis in the Stalinist model on developing energy intensive heavy industry. Also, the overall state of technology is relatively outdated and obsolete, characterized, for example, by old coal-burning industrial furnaces, boilers and other power equipment. In addition, the housing stock is described by Kramer as poorly constructed, insulated and maintained, resulting, for example, in major inefficiencies in heating (Kramer, 1990).

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