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To assess the magnitude of future energy problems and the potential effectiveness of strategies that respond to the global warming problem, it is important to understand how and why energy use has changed in the past and to identify future trends. This paper briefly reviews past trends in energy intensity by sector and then considers three scenarios for future energy demand and efficiency, coupled with three levels of energy prices and energy efficiency policies. The implications for the CO<sub>2</sub> question are briefly discussed.

Pour évaluer l'ampleur des futurs problèmes d'énergie et l'efficacité potentielle des stratégies qui répondent au problème du réchauffement de la planète, il est important de comprendre comment et pourquoi l'utilisation de l'énergie a changé dans le passé et d'identifier les tendances futures. Cet article passe brièvement en revue les tendances antérieures pour ce qui concerne l'intensité de l'énergie par secteur et envisage par la suite trois scénarios relatifs à la demande d'énergie et à l'efficacité futures, combinés avec trois niveaux de prix de l'énergie et de politique d'efficacité énergétique. Les implications par rapport au problème du CO<sub>2</sub> sont brièvement discutées.

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## Energy Efficiency Scenarios in OECD Countries – What To Do When CO<sub>2</sub> Comes Calling

LEE SCHIPPER

This presentation focuses on trends in the growth of energy demand and their implications for carbon dioxide emissions. To assess the magnitude of future problems and the potential effectiveness of response strategies, it is important to understand how and why energy use has changed in the past and where it is heading. We first briefly review past trends in sectoral efficiency. We then consider some new long-term projections, reporting on three scenarios for future energy demand and efficiency, coupled with three levels of energy prices and energy efficiency policies. Our analytical approach has considered three key elements in each sector: the level of activity, structural change, and energy intensity, which expresses the amount of energy used for various activities. At a disaggregated level, energy intensity is indicative of energy efficiency, but other factors besides technical efficiency also shape intensity.

### Past Trends in Energy Use

World energy use has risen by over one-third

since 1970, and grew steadily between 1983 and 1989. The forces of economic activity, structural change, and energy intensity have shaped energy use in different ways in the industrial, developing, and transitional countries. Here we focus on the industrial countries, whose share of world energy use declined from 60% to 48% between 1970 and 1990. Economic activity in these countries pushed moderately upward on energy demand during this period. Structural change increased energy demand in passenger travel (more reliance on cars and air), freight transport (greater use of trucks), and households (more living area and appliances per person), but pushed downward in manufacturing (a shift toward less energy-intensive industries). Energy intensities declined significantly in most areas. In manufacturing, there was considerable decline in energy intensity in all countries, largely due to ongoing technological innovation. Figure 1 shows energy intensities in eight OECD countries on the assumption that their 1973 industrial structures remained in effect.

For automobiles, changes toward greater size and power partially offset improvement in technical energy efficiency in Europe and Japan; intensity fell greatly in the US, but remained above the other OECD countries (Figure 2). Only in North America has on-road fleet efficiency changed much, but cars in the US still use 33% more fuel per mile than those in Europe. The share of freight carried by trucks in eight OECD countries increased and there was a slight decrease in energy intensity per vehicle. Energy intensity in the use of aircraft declined by 40-50%, but this was accompanied by a rapid increase in air travel.

Larger units and the addition of new features also balanced efficiency improvement for home appliances. In home heating, there was significant reduction in intensity in the US, but in Europe growth in the use of central heating somewhat offset improved efficiency (Figure 3). On average, decline in energy intensities caused a reduction in OECD primary energy use of around 20% between 1973 and 1988. Since 1982, however, there has been a marked levelling off in most energy intensities, especi-

ally in households and automobiles outside the US.

## Future Prospects for Energy Use

Most observers expect that market forces will result in only modest increases in international energy prices during the next 20 years. Thus, one of the factors that contributed to improvement in energy efficiency in the past will probably be less strong in the future. Even with only a moderate rise in energy prices, energy intensities in the industrialized countries will continue to decline in most sectors, especially in manufacturing, where technological progress is relatively independent of change in energy prices. Energy intensity in aircraft use is likely to fall at least 30% by 2010; in freight it is uncertain, with the intensity of truck freight now increasing. Energy intensities in space heating are likely to remain level, unless provoked by price increases or policy changes. Changing standards in the US and Europe will bring about intensity decreases in home appliances.

Averaged over all sectors the net decline in energy intensity over the next two decades will likely be much smaller than that which occurred before 1985, and is unlikely to keep pace with the pressure on energy demand from rising activity. Certain types of energy-intensive activity, especially travel, will probably grow faster than GDP. Structural change at a macroeconomic level and in the manufacturing sector will contribute to lower aggregate energy intensity, but the shift toward energy-intensive modes is increasing energy use somewhat in transportation.

There is a large potential for cost-effective energy efficiency improvement in existing and new systems in all sectors and all parts of the world. Technical change in processes, equipment, and buildings comprises the largest part of the potential, but change in operations, maintenance, and in the operating environment are also important. In industrial countries, reductions in energy intensities of 30-50% relative to current levels appear to be technically achievable and probably economic as

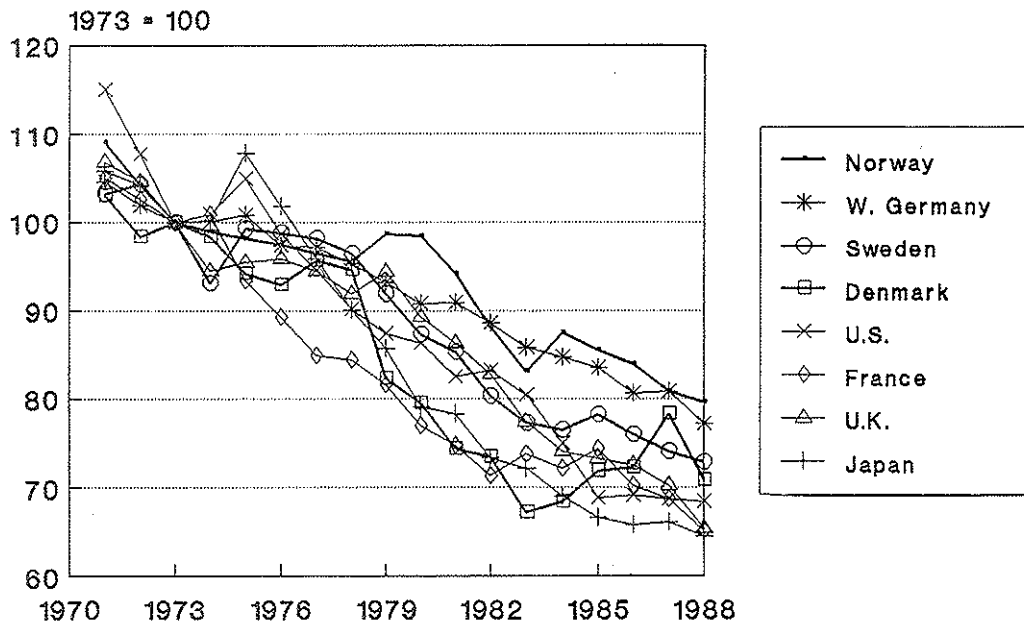


Figure 1: Manufacturing Energy Intensity – Constant 1973 Industry Structure

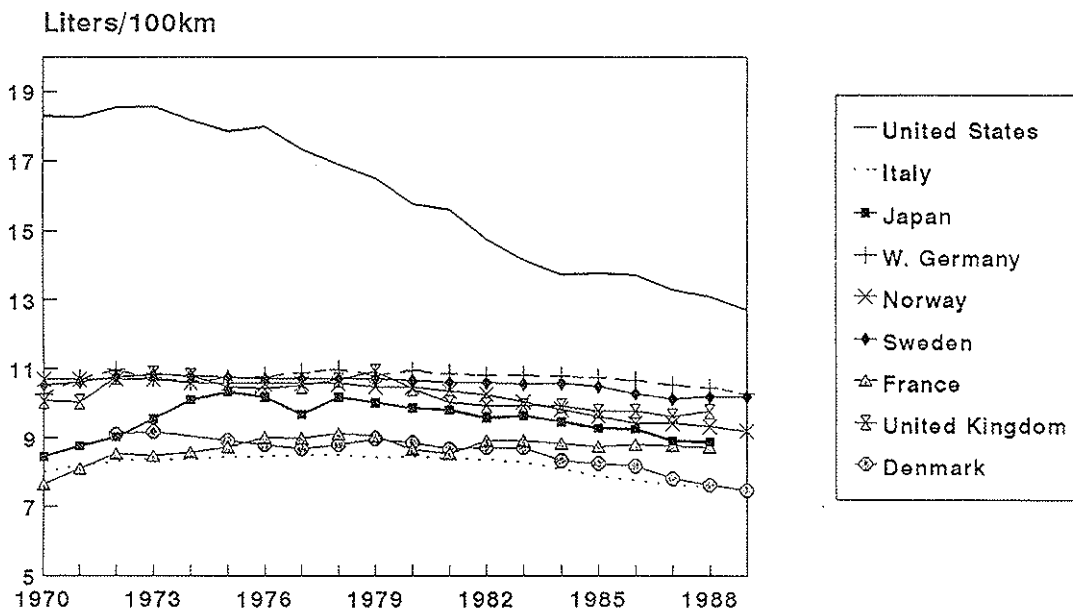


Figure 2: Automobile Fuel Intensities – On Road (actual) Fleet Intensities

well, considering life-cycle costs and a reasonable social discount rate. For the most part, achieving these reductions does not require

development of new technologies, but rather more widespread adoption of technologies that are currently available or could be soon.

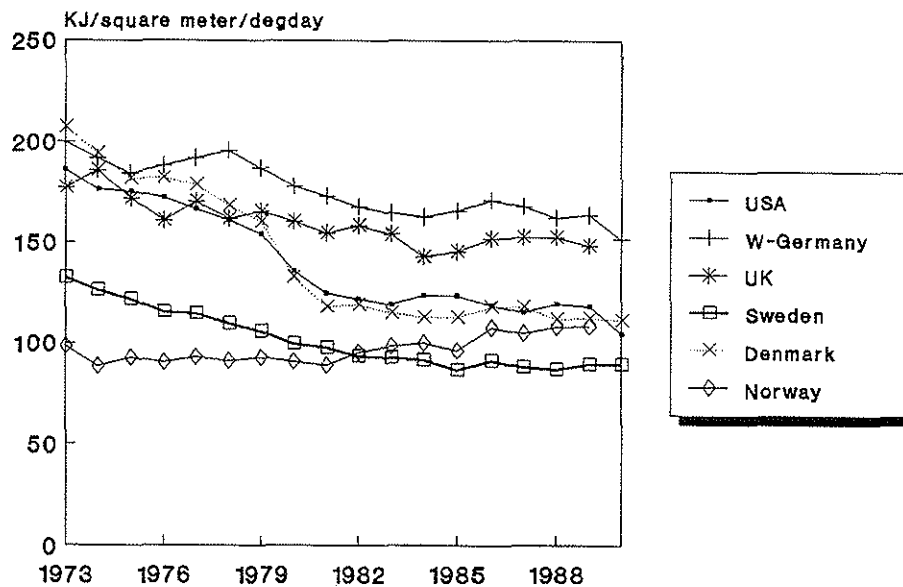


Figure 3: US and Europe Space Heating Intensity Useful Energy

As stocks of energy-using capital turn over and energy users make improvements on long-lived systems, energy efficiency will gradually increase in many if not most areas. But a variety of barriers cause the 'natural' adoption of higher energy efficiency to be much less than what is economically attractive for society. Accelerating efficiency increase is especially important and promising in electrical end uses, since much saving is possible at lower cost than new electricity supply. Other strategies can also bring important energy savings, especially in transportation, where comprehensive approaches are needed to encourage greater reliance on modes with lower energy intensity.

### Scenario Analysis

More detailed analysis of these views of the future is available in the new book upon which this talk is based (Schipper *et al*, 1992). Three scenarios, which illustrate the potential impacts of different efficiency strategies, were considered.

1) *Trends*: GDP growth in the OECD averages 2.8%/yr, with industrial growth averaging 2.4%/yr. Crude oil prices reach approxi-

mately \$30 US/bbl (1990 US\$) in 2010. Environmental concerns are not impressed into the patterns of economic or energy growth, beyond those rules already mandated. Energy intensities continue to fall as a continuation of historical trends (manufacturing, air travel) or a manifestation of past improvements in knowledge that have made new systems (homes and buildings, lighting, household appliances, autos in some countries) less energy intensive than those already in place. Existing efficiency initiatives (appliance standards, thermal performance standards, DSM programs, etc.) remain in place. Overall energy intensity "improves" 24%, falling nearly 1%/yr between 1985 and 2010.

2) *Efficiency Push*: Energy efficiency policies are developed or expanded. Environmental concerns spur some of these policies. Broad agreement among actors leads to important efficiency improvements in household appliances and motor vehicles. Through taxes, energy prices increase to levels 25-50% higher than those in the *Trends* scenario. Policies aimed at reducing transportation pollution and congestion raise the cost of mobility. Intensities fall 40%, at a rate close to that experienced bet-

ween 1973 and 1985.

3) *Vigorous Effort*: A broad worldwide consensus is achieved over both the likely impacts of the buildup of greenhouse gases in the world's atmosphere, as well as on the value to present and future generations of reducing those impacts by careful restraint or reduction in CO<sub>2</sub> and other related emissions. Carbon taxes raise energy prices 50-100% over levels in the *Trends* case, as soon as 1995. Far stronger policies are developed for motor vehicles, through agreements among manufacturers, governments, and consumers. Escalating research into radically new approaches to major energy using-technologies, spearheaded by the most important energy users in the private sector, creates a clear break with *Trends* by the latter part of the 1990s. Intensities fall more than 60% overall between 1985 and 2010, at about the rate of the 1979-1983 period, when energy prices rose sharply and various conservation policies were implemented.

The effects of these differing scenarios on energy intensity are shown in Figure 4. The *Trends* case captures the existing decline in energy intensity. Industrial fuel intensity falls 2.5%/yr, electricity by 0.3%/yr. In the service sector, fuel intensity falls by 25%, electricity intensity by 10%. Automobile energy intensity converges to 9 litres/100 km (26 mpg); in air transportation the reduction is 25%; in trucking 10% (a break with the trend). Home heating energy intensity falls by 15%, and appliances and lighting by 25%. Overall these changes in energy intensities would reduce energy demand by 24%. Commitments to many of them are already in place.

If the higher energy price *Efficiency Push* scenario were to be pursued, overall energy intensity would fall 41% by 2010. This rate of change approximates that experienced between 1973 and 1985. Industrial energy intensity would fall by 2.5%/yr, automobiles would consume 6.5l/100 km, home heating intensity would fall by 40% and home appliances would operate at the lowest energy intensities available today. While this scenario is based on reasonable goals, European and North American countries are not at present moving to-

wards policies consistent with them.

By comparison, the *Vigorous Effort* scenario would require a massive commitment to new policies and R&D, a doubling of energy prices and some changes in lifestyles. It involves the reestablishment of energy intensity reduction rates experienced in the 1979-83 period and would bring about an overall decline in intensity of 60% by 2010. Industrial intensity falls by 3.4%/yr, automobiles require only 2.5l/100km, and both aircraft and trucking intensities are less than 50% of 1985 levels. Space heating intensity falls by 50-75% and people are satisfied with lower temperature settings. Their home appliances use 75% less electricity than today.

These effects, combined with increases in economic activity and structural changes result in increases in total OECD primary energy demand (including power generation) under the first two scenarios and an absolute decrease under the third scenario (Figures 5 and 6). Under *Trends* energy use in 2010 is nearly 40% above the 1985 level; under *Efficiency Push* it is 10% higher. Under *Vigorous Effort* energy consumption in 2010 would be 22% below that of 1988.

## Energy Efficiency and the CO<sub>2</sub> Problem

The scenarios help us to understand in some detail the steps involved in moving from an evolutionary path now underway to a more aggressive approach to improving energy efficiency and controlling overall energy demand. They also suggest the spread of possible outcomes in relation to carbon dioxide emissions in OECD countries. Reduction in CO<sub>2</sub> emissions are unlikely under the *Trends* scenario. The *Efficiency* scenario could stabilize OECD emission rates. The *Vigorous* scenario would certainly lead to an absolute decline in emissions. This tells us that the stabilization of CO<sub>2</sub> emissions in the OECD countries by 2010 is clearly in the realm of possibility, but that actual reductions will be difficult, requiring very tough policy stances that would be difficult to implement politically.

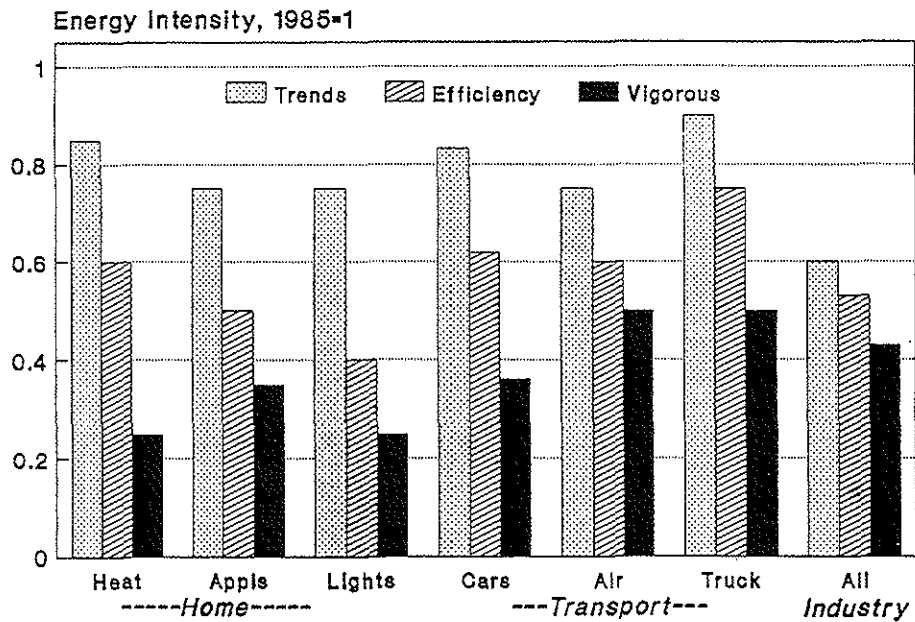


Figure 4: OECD Energy Intensities – 2010 Scenarios

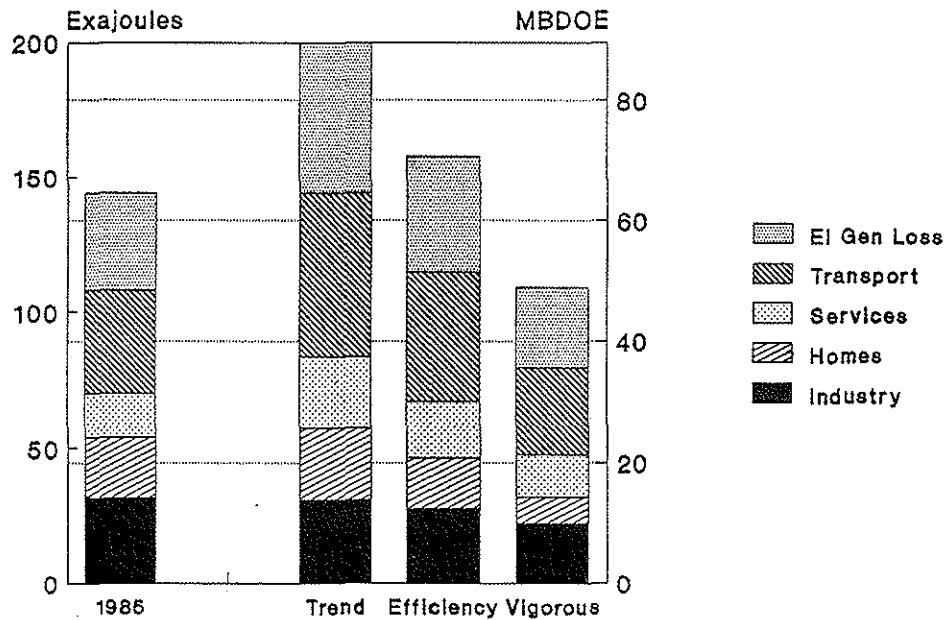


Figure 5: OECD Primary Energy Use, 1985 & 2010 – Scenarios of Efficiency Improvement

What do our scenarios say about the costs of restraining CO<sub>2</sub> emissions in OECD countries? By definition, the *Trends* scenario in-

volves no additional costs. The *Efficiency Push* scenario does involve some additional costs, but it is important to recognize that it is not

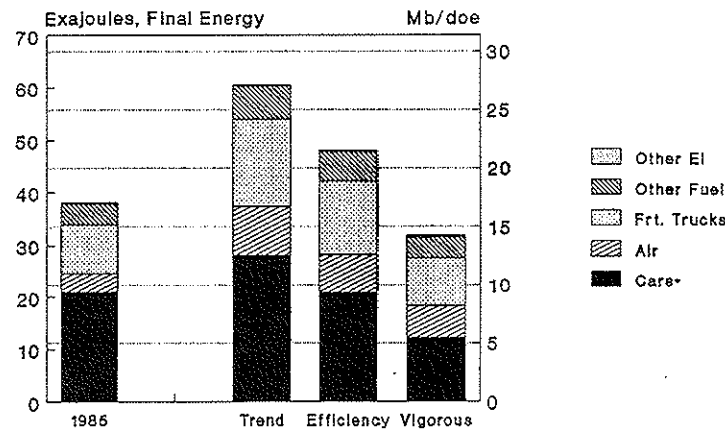


Figure 6: OECD Transport Fuel Use Scenarios of 2010 Demand

\* includes personal light trucks.

expensive. It is based on known technology, the adoption of which will bring net returns. The third scenario, on the other hand, requires significant expenditures on R&D, aggressive taxation policies, and other measures.

A number of issues will have a large impact on the choices to be made.

The foregoing scenarios describe energy use under a variety of conditions and assumptions which are self consistent. But, should the preconditions for either the second or third scenario be established (i.e., the appropriate prices, taxes, government policies, and a social consensus), there is still no guarantee that the end-uses themselves will evolve as suggested.

Some of the uncertainty arises because there may be hidden costs involved in the policies designed to implement our efficiency strategies. This problem is often dismissed by analysts. Yet we have very little hard evidence of what many proposed energy savings programs will really deliver, and at what cost. Particularly uncertain, in my opinion, are the many programs being undertaken by electric utilities, as well as schemes proposed to stimulate consumers to buy less fuel-intensive cars.

Unpredictable human behavior is, of course, one factor that unsettles our forecasts. We know that improved levels of energy effici-

ency are likely to make society better off than it would be if such levels were not to prevail. What if people simply then decide to drive large cars farther and farther? What if they are prepared to embrace more energy intensive lifestyles than we have foreseen in these scenarios? What if they are satisfied on average that their energy costs are under control, and decide on average to ignore the appeals to cost savings made by those advocating improved energy efficiency?

On the economics of CO<sub>2</sub> reduction, the question of its desirability was roundly dismissed by many public figures prior to the Rio conference on the environment, including President Bush and his advisors, who simply said: "Too expensive." Their response was to the wrong question. We want to know at what point does the next reduction in energy use, or indeed CO<sub>2</sub> emissions, cost us as individuals, or as a society, more than the extra reductions are worth? The question is difficult to answer for three reasons. First, the real reductions in energy use that a given package of policies and technologies will achieve are not that well understood. Second, the amount by which fossil-fuel use or CO<sub>2</sub> emissions must be reduced from a future base line to a given target (if targets are specified) depends on the base line,

and so do the costs of reduction. Last but not least, no one today really knows what the damage function for decrements or increments of CO<sub>2</sub> is, although William Cline (1992) and William Nordhaus (1992) each have attempted to answer this question.

Some observers believe that the so-called "no regrets" strategies should be adopted. These people (including James Baker, then President Bush's Secretary of State) suggest society should only do for climate change today what makes sense whether or not there is a global warming problem. They base their objection to "net spending" on CO<sub>2</sub> reduction on their observation that scientists are uncertain about the seriousness of the problem. The "no regrets" strategy is really a red herring being used to avoid the issue. Many economists active in the debate over restraining CO<sub>2</sub> argue vociferously that there are no "no regrets" investments to save energy — if these investments really left "no regrets," the people who could benefit from them would have made them. Actually, I believe that such opportunities exist, and will be exploited through a variety of policies and price changes. But even if we were to accept the "no free lunches" assumption, why would society not be willing to pay a premium to buy insurance? That is, if restraining CO<sub>2</sub> emissions today would buy more options for tomorrow, we would likely

be better off. The right premium to pay is, of course, a matter of debate. But we should not shirk from such an approach just because we can't "breathe" the direct economic benefits today.

Perhaps the most unsettling issue of all is the need to come to grips with our valuation of the climate as it is (or was). What do we as a society want to pay to maintain that climate? And how can we include the possible objections of future generations to any climate changes that are virtually irreversible? Climate change caused by us will affect future generations, yet the future cannot influence our behavior today. Thus, at the centre of the riddle over what we should do about global warming is an ethical question, not simply one of climate science, engineering, or economics.

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