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IPCC - Intergovernmental Panel on Climate Change [Folder 1] [1]

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3. Discounting. One of the problems that arises in developing an economic analysis of regulation is that the benefits and costs often occur in different time periods. When this occurs, it is not appropriate to simply add up the benefits and costs accruing over time for comparison purposes. Discounting takes account of the fact that resources that are available in a given year are worth more than the identical resources available in a later year. One reason for this is that resources can be invested so as to return more resources later. In addition, people tend to be impatient and thus to prefer earlier consumption over later consumption.

(a) General procedures. Discounting is not the same as correcting for inflation. An inflation adjustment is made with a price index, whereas discounting to present value is done with a discount rate. Even benefits and costs expressed in constant (i.e., unaffected by inflation) dollars must be discounted to present values before benefits and costs in different years can be added together to determine overall net benefits. The discount rate should be expressed in real terms (i.e., corrected for expected inflation) whenever the benefits and costs are expressed in constant dollars. The real rate can be estimated by subtracting the expected rate of inflation from a market rate of interest that corresponds to the time period over which the benefits and costs are expected to flow (see OMB Circular A-94). For example, if the nominal rate of interest is 10 percent and the forecast inflation rate over the same period is 3 percent, then the real rate of interest is approximately 7 percent.

Benefits and costs generally should be measured inclusive of (i.e., before) taxation. The reason for this is that a dollar of tax revenue generated or lost in any given year as a result of a regulation has a value which, to a first order approximation, can be assumed equal to that of any other dollar. This is appropriate unless there is reason to believe that the value of these tax revenue dollars differs significantly from direct benefits to consumers, e.g., as a result of redistribution.

The discount rate should not be adjusted for the effects of regulation on the provision of public goods or non-monetized impacts such as environmental effects. The annual pecuniary value of these impacts should be assessed (with non-pecuniary benefits converted to their pecuniary equivalents to the extent possible), and these equivalent pecuniary benefits and costs should then be discounted.

In assessing the present value of benefits and costs from a regulation, attention needs to be paid to the prospect of changing relative prices over time. For example, increasing scarcity of certain environmental resources would increase their value over time relative to conventional consumer goods. In such a situation, it is inappropriate to use current relative values for assessing regulatory impacts. In the example, taking into account changes over time in relative values has an effect

OMB rate minus
~~cost of~~ avg. marg.
 K tax rate

similar to discounting environmental impacts at a lower rate. However, it is important to clearly separate the effects of discounting from the effects of relative price changes in the economic analysis.

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The discount rate also should not be adjusted for risks related to the costs and benefits of the regulation. The appropriate procedure is to calculate the certainty equivalents of the risky benefits and costs, and to discount the certainty equivalents. For example, if there is an increase in the risk premium over time, as a result of increasing variance of benefits or costs, discounting the certainty equivalents will have an effect similar to discounting impacts at a higher discount rate. However, it is important to separate the effects of discounting from the posited effects of changing risk.

(b) Basic guidance on discount rates for intragenerational projects. When costs and benefits of regulation largely fall upon individuals within the same generation, the basic guidance entails a conservative methodology in which it is assumed that expenditures today displace private investment; the approach focuses on the opportunity cost of these funds. The appropriate measure of this opportunity cost, once one has calculated certainty equivalents, is the marginal return on a safe investment.

Traditionally economic analyses of regulations have employed the average return on all investments, combining safe and risky, high and low return investments, as described in OMB Circular A-94. Currently this average rate is estimated to be 7 percent in real terms. Since individuals seem, at the margin, indifferent between holding safe government bonds with real yields between 1 and 3 percent, and risky equities with after-tax real yields of approximately x percent, the risk premium can be estimated to be y-z percent. Further, marginal returns typically are lower than average returns. These considerations suggest that an appropriate measure for the marginal return on a safe investment is v-w percent. Conservative methodology requires the use of the upper bound of this range. It is important that throughout the calculations, the certainty equivalent of the costs and benefits be employed.

(c) Additional guidance. Modern research has emphasized that economic welfare is ultimately determined by consumption; investment affects welfare only to the extent that it affects current and future consumption. Thus, any effect that a government program has on public or private investment must be converted to an associated stream of effects on consumption before being discounted.

Such calculations entail estimates of capital displacements and reinvestment rates. While such calculations necessarily entail

I. Butson
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assumptions which are subject to dispute, a simplifying assumption is that monetary and fiscal authorities will determine aggregate levels of investment and interest rates, and the impact of the contemplated regulation on those decisions is sufficiently small that it can be ignored. In this context, the direct impacts (costs and benefits) of regulation are treated as changes in consumption, and these changes in consumption (or their certainty equivalents) should be discounted at the consumption rate of interest, that is, the safe rate of interest at which individuals borrow and lend. This rate is best approximated by the short term real rate of interest on government securities, which has averaged around 1.5 percent for the past century [check]; currently, it is about 3 percent. [A conservative methodology of discounting at 3 percent is consistent with the basic guidance described in the preceding paragraph.]

In the presence of capital market imperfections, individuals who wish to borrow may face different marginal rates of intertemporal substitution than lenders, to the extent that differences in borrowing rates do not accurately reflect actuarial differences in repayment probabilities. When significant proportions of benefits and costs are associated with such individuals, discount rates should reflect the higher interest rates such individuals face.

Agencies wishing to deviate from these basic methodologies should secure approval from OMB prior to doing so, and must clearly explain their solutions to the methodological and empirical challenges noted above.

(d) Intergenerational discounting. Comparisons of benefits and costs across generations raise special questions. The central issue is how to value marginal changes in consumption in different generations. If one takes the view that identical individuals in successive generations should be treated equally but that differences in standards of living across generations are relevant, then the intergenerational discount rate can be expressed as the sum of the rate of change of consumption and the consumption elasticity of marginal utility. Conventional estimates of increases in per capita income of 1.5 percent, combined with standard estimates of elasticities of marginal utility of between 1 and 2 yield discount rates of 1.5 to 3 percent. Uncertainty about the rate of increase of productivity is consistent with using a discount rate towards the lower or middle of this range, [since the certainty-equivalent rate of productivity and consumption growth would be lower in this case].

IPCC WGIII
Summary

April 26, 1995

Dear Jim:

Here are some comments on the latest version of the WGIII summary for policy makers. I am heartened by the new format and inclusion of information from the chapter leaders. I still believe that the summary for policy makers suffers from some serious problems and would like to talk with you about it. Let's set aside some time in Athens (and if not in Athens shortly thereafter) to discuss the summary at length. Here are a list of problems. I am also preparing a more detailed review - but prefer to discuss that with you in person.

- *Uneven balance in the document based on the importance and scientific information available from the literature. For example, the decision-making under uncertainty area is under-represented and the equity discussions are over-represented.*
- *Sections and sentences remain highly normative. They should not be retained in the next draft. Normative (i.e. policy prescriptive) statements distort the information found in the literature. Frankly, the reputation of the working group, and the IPCC, will suffer if value-laden language is left in the document. I believe that the literature speaks for itself in supporting a movement beyond "no regrets" actions. We do not need to patronize policy makers by telling them what to do.*

Examples of normative sentences that should be deleted follow.

page 2	lines 28-30
page 3	lines 7-8; footnote 3
page 5	lines 9-12; 22-24; 27-30; 32-line 1 of page 6
page 9	lines 24-26
page 14	lines 11-14; 27-28; 38 - page 15 line 8
page 15	lines 12-15
page 17	lines 11-12

- *Substantive areas of disagreement include cost-benefit analysis and equity discussions.*

Cost-benefit analysis and decision making frameworks: The US government response is a fair statement of the literature based on experts with different viewpoints. I strongly recommend that you use on language on cost-benefit similar to that sent to you on March 17th of this year. The treatment of decision-frameworks is too cursory given its importance. The critical themes of sequential decision-making, learning, and timing issues have been neglected.

page 4 lines 26-28

Few economists would know about "safe minimum standards". The safe minimum approach uses terms that few economists find meaningful: "reduce the risks of climate change to a level acceptable for sustainable development at an acceptable cost". The problem is how to set the "acceptable level" and what is an "acceptable cost". Given that the report is a synopsis of primarily the economics literature, it makes no sense to summarize the issues in uneconomic terms.

page 4 lines 19-20

Whereby environmental standards have been designed to safeguard human health without being informed by "economic costs", many countries are now moving away from this practice because resources for environmental protection are not infinite.

page 8

All of the approaches mentioned can be embraced in cost-benefit analysis, incorporating different degrees of risk aversion.

Equity

A persistent problem in the equity chapter is the lack of scientific rigour. The writing team does not have the technical expertise to evaluate the difficult topics that are included in this chapter. The text in the chapter reads as subjective commentary. My suggestion is to write text for the summary that reflects the inherent complexity of the issues and suggest that not much progress was made in the assessment. This should be an area highlighted for additional work next time. This section should be a few paragraphs in total. If we can be helpful by drafting some material (3-4 short paragraphs) please let me know.

- *Discussion of the value of a statistical life (bottom of page 9 and top of page 10). The Global Commons Institute elevated this issue most recently. While I agree that the methods for valuing a statistical life based on wage premia using a common metric of US dollars provides a biased (downward) measure of damages in developing countries, the issue does not merit such extensive treatment in the body of the summary for policymakers. It should be pointed out that the methods used to assess global damages is in its infancy. I believe that studies do exist where global statistical lives are calculated with a bipolar distribution of wages for risky occupations depending on developed versus developing country location; if this is true it should be mentioned.*
- *Damage estimates (first para. page 9)*

This section seems unbalanced. The second statement suggests to policymakers that impacts and adaptation costs are an inevitable corollary of increasing atmospheric concentrations of greenhouse gases; yet, depending on locale and pattern of warming, positive opportunities will undoubtedly arise.

It seems inconsistent to me that marginal damage estimates all "exceed \$5 (US) per ton of carbon" and "social cost estimates are uncertain". On what is the \$5/ton of carbon based? One important facet of the literature that is missing in the discussion is the recent attempts to include adaptation in market impacts studies and the important role of social system adjustment to exogenous changes. Again this is an area that should be highlighted as important for further research and assessment efforts.

There is no place in the document for a statement about limitless burden on communities that will either face damages or need to take adaptive measures (see lines 24-26).

- *Generic assessment of response options.* The existing list on page 10 is too simplistic. It makes better sense to treat the topics generically (see page 11 of US comments) and integrate with the material from chapters 8 and 9.
- *Top-down versus bottom-up.* The treatment in this version of the summary does not do justice to the richness of the debate. Please use the background chapter and US comments (pages 12-14) for additional text. The convergence issue is important; I believe that many models in the literature do reflect the convergence (ask the lead authors and John Weyant of the Energy Modeling Forum). Is the new curve B correct? Please check with Richard Richels and others to find out whether the location of the curve on the axes and shape of the curve are correct. The position of B1, B2, and B3 are not found on any version of the figure that I have.

I am concerned by the lack of consistency in treatment of topics in the manuscript. If mitigation technologies can come into the market almost costlessly, why are the damage figures so high? This harkens back to the timing issue and other complications. The connection between the damage estimates for a 2XCO₂ world with no learning and bottom-up estimates of little or no net costs of investment undertaken as information becomes available should be made.

- *Insights relevant to climate policy.* The material selected by authors of chapters 8 and 9 for the summary reads differently and more balanced than what is now included in the summary. Their focus is common insights from a perspective of many alternative methodological approaches and should be couched as such.

- *Integrated assessment.* The issues listed on pages 15 and 16, for example lines 5-16 on page 16 do not specific to integrated assessment, yet they are important points. To be more effective, the summary highlight the critical factors in a way that puts them in the proper perspective, possibly by cross-referencing.
- *Portfolio section.* The role of this section is problematic. Is this a synthetic treatment of all possible responses? This section should be reviewed for its objective and content.
- *Lack of treatment of major uncertainties and assessment needs for the future.* I would like to see a section that details the most challenging questions (such as how far to go beyond "no regrets", extensiveness of carbon leakage depending on carbon limitations or taxes let in a cluster of countries, etc in a section at the end. The policy makers should know by the end of the report, what is the state of the science: what will be known soon, what will take 5-10 years of methodological work to refine (non-market valuation).

TO: JOE STIGLITZ, CEA
FROM: RAY SQUINTERI, TREASURY

cc: SK

SECTION I: BIOGRAPHICAL INFORMATION (slight corrections 2/20)

Name: Joseph E. Stiglitz
Organization: Council of Economic Advisors, Washington
Area of Expertise: Microeconomics
Phone: 202-395-5036
Fax: 202-395-6958
E-mail: none

The following comments are on The Executive Summary

SECTION II: SUMMARY OF COMMENTS

- Economists do not subscribe to the idea of an absolute standard or a safe minimum standard. If these ideas are to be introduced, it must be clearly stated that most economists reject these ideas.
- Summary needs to state an important conclusion of recent economic research: near-term decisions along an optimal path will be the same (i.e., modest-cost mitigation measures) for a wide range of ultimate target concentrations.
- While the Summary reflects the view that one should go beyond no-regrets policies, it leaves the impression (without explicitly so stating) that immediate costly actions are in order; this is inconsistent with the chapters to follow.
- Summary omits important points made in Summary to Chapter 1.

SECTION III: DETAILED COMMENTS

- p. 2 l. 4-6. "The ultimate objective ... provides guidance ..." Statement is tantalizingly incomplete. What guidance? My understanding of recent decision analysis research (e.g. Richels and Edmonds 1993) is that for concentrations between 450 and 750 ppmv, the least-cost path requires only modest reductions in emissions in the near term. See comment on the bulleted list (p. 4), below.
- p. 2 l. 21. "However, these decisions are not very sensitive to the level ..." Paragraph says the optimal solution is robust, but does not say what that optimal (least-cost) solution is. I believe the key research result is that modest emissions reductions in the short run are consistent with a wide range of desired equilibrium concentrations.
- p. 2 l. 25ff. Are these actions being recommended? Text leaves the impression that they are. Most analysts would agree that the most cost-effective of these measures should be undertaken

without further scrutiny (negative-cost measures to reduce emissions, phasing out of existing distortionary policies, etc.). Less cost-effective measures (e.g. fuel switching) should not be undertaken while we still have more efficient alternatives to choose from. I suggest a sentence indicating the actions that would be included along an optimal path: in the short-run, governments should reduce energy subsidies and eliminate other distortions in energy markets; accelerate R&D; and promote joint implementation. Beyond this, for target concentrations within the range of 450 to 750 ppmv, only mildly costly mitigation actions are indicated.

- p. 4 l. 1. " ... \$50 per tonne of carbon ..." This number seems to have been pulled out of a hat, and contradicts results reported in other chapters that \$5 to \$20 per ton is the right range. Delete \$50 or make it consistent with later chapters. In this and other places, the chapter leaves the (incorrect) impression that economists agree that high-cost near-term mitigation are justified.
- p. 4 l. 19ff. Change sentence to read "A country's climate change actions will also reflect its objectives, economic conditions, and constraints."

The list of considerations that follow confuses conditions particular to a given country, and conditions that are more universal, such as international equity. More generally, the list of possible factors does not add much to the Summary, and does not reflect any consensus about the most salient factors. I suggest deleting remainder of paragraph. (Otherwise, it could be used as an excuse for less developed countries not to take any action.)

- p. 5 l. 14. Figure 1 is incorrect and should be redrawn. The paths indicated do not represent optimal paths, but simply conjectures reported in some scenario comparisons. An important recent result, referred to obliquely on p. 2, is that the optimal (least-cost) path is the same in the near term whether the ultimately desired concentration is 450 or 750 ppmv. I suggest asking John Weyant to produce a revised graph consistent with the results of EMF-12 and EMF-14.
- p. 6 l. 1. I continue to believe that since at this point in the report, there is no accepted goal of eventual concentration levels, it would be better simply to describe the thresholds: (a) if the eventual goal is stabilization at the level of.... then emission reductions of this magnitude are likely to be required; (b) if the eventual goal is.... then.....; (c) On the other hand, if the eventual goal is stabilization at a level of or above, then it is likely that no further substantial interventions will be required, at least before.....

- p. 6 l. 6-8. Before "The current commitments [of Annex I countries] are not sufficient to stabilize atmospheric concentrations of CO₂ ..." insert: "In the absence of some commitment by other countries" Without the insert, the reader is left to conclude that the answer is to tighten up on the commitments of Annex 1 countries. As several chapters demonstrate, without a commitment by the LDCs, atmospheric concentrations cannot be stabilized.
- p. 6 l. 14ff. To restate an earlier criticism: Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum standard."

All of these standards can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. Using this kind of language would significantly interfere with the creditability of the IPCC report in the economics community and beyond, and is likely to be sharply criticized by some governments. This is particularly true, given that the term "dangerous anthropogenic interference..." is nowhere defined. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. While it is true that environmentalists often argue for the absolute standard, and it is sometimes used in establishing health standards, most economists are strongly opposed to these approaches.

The "safe minimum" approach uses two terms that few economists would find meaningful: "reduce the risks of climate change to an acceptable level at an acceptable cost."

In the discussion of cost benefit, you should explicitly say that risk considerations can and should be brought into the cost benefit analysis.

If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that **most economists do not accept these approaches** and argue for the use of a cost benefit approach, with appropriate attention paid to the treatment of risk.

Figures 3(a) and 3(b) are particularly troublesome, as they draw attention to statements in the text about acceptable and unacceptable risks, while nowhere providing a formal way of quantifying the effects or valuing those effects relative to the economic impacts.

- p. 9 l. 4ff. Figure 4 is misleading and should be redrawn. The double dividend idea is in part an argument that more distortionary and burdensome taxes should be replaced by less distortionary and burdensome taxes. All public finance economists would like to see taxes reformed in this way. But tax reform is not the same thing as climate change

mitigation, and the two should not be thrown together.

Curve C implies that revenue recycling will indeed yield the economic "double dividend" that some have suggested. But scholarly opinion differs on the magnitude and even the sign of the dividend. Some results have suggested that Curve C may even lie above curve B.

Curve D implies that concentrations of greenhouse gases and ordinary (criteria) air pollutants change in the same way. This is true for some gases, but not for others. For example, as the IPCC 1992 summary concludes, sulfate aerosols reduce radiative forcing in the short run; reducing sulfate aerosols would increase thus add to global warming. This means that curve D may well lie above curve C (and therefore above curve B).

If the figure is to be used, it should be accompanied by a statement that it is only schematic, and that the magnitudes of the effects displayed, and even relative locations of the curves, could differ from those shown.

- p. 10 l. 27ff. Either this section or somewhere else needs a statement to the effect that:

Efficiency will require full participation of the developing countries, including some forms of commitments for emission reductions. Without some form of commitment, actions by the developed countries can be partially, largely, or more than completely offset by actions in the developing countries.

- p. 10 l. 37. Population growth needs at least a mention. Suggested insert:

Total emission increases arise both from increases in emissions per capita and from increases in population. Whether emission rights are to be distributed on a per capita basis, and whether countries will be rewarded for controlling population growth, must be addressed by future negotiations.

- p. 11 l. 36. This paragraph should include a sentence such as: "However, past emissions will not have contributed much to ambient concentrations a century or more from now, when the impact of greenhouse gas concentrations are likely to be felt.
- p. 12 l. 10ff. This paragraph, which calls for increased travel budgets for the LDC representatives, seems out of place in a summary of the state of economic knowledge on climate change.
- Points to be added to Executive Summary, taken from Conclusions of Chapter 1:

- The risks of climate change are highly asymmetrical, with a large probability of a small loss, and a small probability of a large loss.
- Even in the presence of significant uncertainty, this asymmetry, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond no-regrets policies to those that incur net costs.
- Climate change demands a decision process that is sequential, can respond to new information with mid-course corrections, and can include insurance, hedging, and the option value of alternative courses of action.
- The challenge today is to identify short-term strategies in the face of long-term uncertainty. The question is not, what is the best course over the next 100 years, but rather, what is the best course for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course.
- In an interrelated global economic system, an attempt to reduce greenhouse gas emissions in one region or one sector of the economy may be offset by increases in other regions or sectors.
- Efficiency requires that emission reductions occur where their cost is lowest, irrespective of who bears the financial responsibility.

IPCC
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Weir SL London
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

To: Members, IPCC Drafting Team (list attached)
cc: Prof. B. Bolin
Chairman of the IPCC
From: Dr. N. Sundararaman
Secretary of the IPCC
Date: 22 May 1995
Subject: Second meeting of the Drafting Team on the IPCC
Synthesis Report, London, 3-5 July 1995

Total
pages: 35

Dear Colleague,

I have the distinct pleasure of inviting you to the second meeting of the Drafting Team on the IPCC Synthesis Report. The meeting will take place in London from 3-5 July 1995, beginning at 0900 hours on Monday, 3 July. The meeting venue is:

Church House Conference Centre (Rooms 3 and 4)
Dean's Yard
Westminster
London SW1P3NZ

Phone: +44 171 222 2348
Fax: +44 171 233 1439.

Information on the meeting venue and hotels is attached. There is no formal agenda for the meeting. The main item of business will be to revise the first draft of the IPCC Synthesis Report for review by experts and governments.

The IPCC Trust Fund will support the travel of the team members from the developing and transitional economy countries (most direct route economy airfare with excursion fares when available, and per diem and taxi fares as fixed by the UN). The travel arrangements will be made through the respective UNDP offices. Please note that you are responsible for your hotel booking and payment.

Looking forward to seeing you in London and with many regards,

N. Sundararaman
Secretary of the IPCC

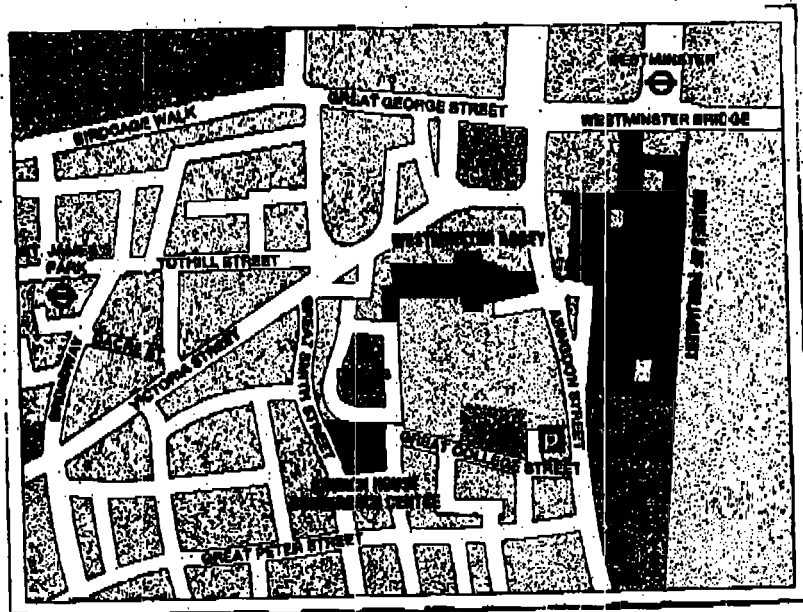
Conference Centre

Meetings will be held in Rooms 3 and 4 of:

Church House Conference Centre
Dean's Yard
Westminster
London SW1P 3NZ

TEL: +44-171-222-2348

FAX: +44-171-233-1439



Immediate
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Church
House
Conference
Centre.

Location and Travel

Dean's Yard is next to the main door of Westminster Abbey, and approached through an arch. The nearest Underground station is Westminster or St James's Park.

The New Linden Hotel is near to Bayswater Underground Station : take the District/Circle Line (green and yellow) to Westminster or St James's Park (7 or 8 stops).

Strand Palace Hotel is near to Charing Cross Underground Station : take the Northern Line (black) to Embankment (1 stop) (or walk there) and then District/Circle Line (green and yellow) to Westminster or St James's Park (1 or 2 stops).

The Palace Hotel is near Marble Arch Station : take the Central Line (red) to Notting Hill Gate (3 stops) and then District/Circle Line (green and yellow) to Westminster or St James's Park (6 or 7 stops).

St Giles Hotel is near Tottenham Court Road Station : take the Northern Line (black) to Embankment (3 stops) and then District/Circle Line (green and yellow) to Westminster or St James's Park (1 or 2 stops).

Hotel Information

1. The New Linden Hotel
Leinster Square
London W2

A rate of £45.00 has been negotiated with this hotel. This is for single occupancy, inclusive of VAT, and includes Continental Buffet Breakfast.

To make a booking, phone Vienna Hotels, on +44-171-288-5294 (Fax: +44-171-229-3917). You should quote that it is the Conference external rate negotiated with Iain Lindsey and Lisel Jordan by Judy Lakeman, IPCC, the Met Office, and this should allow you the rate of £45.00 per night.

2. By booking through Expotel agency, a discounted rate can be obtained at many London hotels. Below are three examples. To gain the quoted rate, contact Expotel on :
TEL: +44-171-328-1790, from 8.30am to 6.00pm.(BST) Monday to Friday, or +44-181-759-9114
6am to 8.30am, 6pm to 11pm.

- A. St Giles Hotel
Bedford Avenue
London WC1B 3AS

Standard Expotel rate (with bath) – £60 per single occupancy per night

- B. Strand Palace Hotel
The Strand
London WC2

Standard Expotel rate (with bath) – £85 per single occupancy per night

- C. The Palace Hotel
31 Great Cumberland Place
Marble Arch
London W1

Standard Expotel rate (with bath) – £60 per single occupancy per night (includes continental breakfast)

(see accompanying map for approximate locations)

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From: Sally M. Kane (KANE_S)
To: Stiglitz_J
Date: Tuesday, May 2, 1995 3:49 pm
Subject: IPCC WG3 -- Summary for Policy Makers

Jim Bruce and Eric have requested a response from you by May 4th. If we can not finalize your comments today, I believe we should send preliminary remarks. The preliminary remarks can be sent (under my name if that is preferable) using the material I drafted on Friday last week.

By sending the preliminary remarks, we will be establishing our view that major weaknesses exist in the summary. We can work out exact wording next week when you are back.

Bob Watson would like to see your comments and recommends that you speak with Bert Bolin. In Bob's mind, your comments to Jim Bruce and Bert Bolin provide information on scientific quality from both an experts perspective and that of the USG.

CC: Branch_L

Gene Stankin
Disability



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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cc: KS
S/K

RECEIVED

IPCC

TO: Writing Team 1
FROM: Erik Haites *Erik*
RE: Comments from Bert Bolin
DATE: February 14, 1995

The attached are comments from Bert Bolin on issues that should be addressed in the Summary for Policymakers. However, to be included in the Summary, it has to be discussed in one of the chapters, would you consider covering these issues in your chapter?

RECEIVED

Post-It™ Fax Note 7671E		Date Feb 15	# of pages 12
To Joe Stiglitz	From Erik Haites	Co.	
Co/Dept.		Phone #	
Phone #		Fax #	
Fax # (202) 395 6958			

Economic Growth, Carrying Capacity, and the Environment

by

**Kenneth Arrow, Bert Bolin, Robert Costanza, Partha Dasgupta,
Carl Folke, Buzz Holling, Bengt-Owe Jansson, Simon Levin, Karl-
Göran Mäler, Charles Perrings, and David Pimentel¹**

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National and international economic policy has usually ignored the environment. In areas where the environment is beginning to impinge on policy, as in the GATT and NAFTA, it remains a tangential concern, and the presumption is often made that economic growth and economic liberalization (including the liberalization of international trade) are, in some sense, good for the environment. This notion has meant that economy-wide policy reforms designed to promote growth and liberalization have been encouraged with little regard to their environmental consequences, on the presumption that these consequences would either take care of themselves or could be dealt with separately.

Here we discuss the relationship between economic growth and environmental quality, and the link between the carrying capacity of the environment and economic activity (2). We first focus on the driving forces behind environmental degradation and their connection with the process of economic growth. This is followed by a discussion of the link between economic growth, carrying capacity and ecological resilience. We conclude by reconsidering the scope for addressing environmental degradation through a strategy of economic growth.

Economic growth, externalities, and the environment

The general proposition that economic growth is good for the environment has been justified by evidence that there exists an empirical relation between per capita income and some measures of environmental quality, similar to the Kuznets relation between income and income inequality (3). More particularly, as income goes up it has been shown that there is increasing environmental degradation up to a point, after which environmental quality improves. That is to say, the relation has an "inverted U" shape (Figure 1 provides an example).

So far the relation has been demonstrated only for selected pollutants (4). However, as it is consistent with the notion that environmental quality is a luxury good (as their income rises people will spend proportionately more on it), economists have conjectured that it applies to environmental quality generally (5). It is, however, important to be clear about the conclusions that can be drawn from these empirical results. They do indicate that economic growth may be associated with improvements in some environmental indicators as income increases. But they do not imply either that economic growth is sufficient to induce environmental improvement in general or that the environmental effects of growth may be ignored.

First, the inverted U relation between income and environmental quality has been shown to be valid for pollutants involving substantial local short-term costs (sulphur, particulates, fecal coliforms, etc.) but the jury is still out on pollutants involving

longer-term and more disperse costs (such as carbon dioxide), and the accumulation of stocks of waste that have no immediate, apparent, environmental costs are unambiguously increasing functions of income (6). The relation is also less likely to hold wherever there are significant stock feedback effects (7). Resources with stock feedback effects are those for which the stock of the resource affects production, such as soil or forests. The kinds of air pollutants for which the inverted U relation has been shown do not have these strong stock feedback effects. More generally, the relation is less likely the more the relevant indicator is a consequence of transboundary or intertemporal externalities (7).

Second, the inverted U relation — like the notion of demographic transition — predicts that growth will, at some point, induce a reduction in some types of emissions. Recent studies using pooled time-series and cross sectional data (8) of total country emissions rather than of urban concentrations have shown that although the inverted U relation does hold for SO_x , NO_x , CO, and particulates, the turning points in the curves are at much higher income levels than previously estimated (closer to \$10,000 per capita rather than \$5,000 per capita). Most of the world's population therefore has a long way to go just to reach the turning points for emissions. In the absence of corrective measures, this implies that aggregate emissions of these pollutants are still expected to rise into the foreseeable future. We return to this point in the next section.

Third, the inverted U relation is a strictly partial one. It says nothing about the general equilibrium or whole-system consequences of emission reductions. For example, reductions in one pollutant may be made possible by increases in another pollutant, or by transfer of the pollution to other countries where their effects are not as fully internalized. Without information on the general equilibrium effects of changing levels of emissions, it is difficult to infer much about the general environmental consequences of a change in emissions of any one pollutant.

Unless demand for environmental quality does increase with income, economic growth will necessarily lead to increased environmental degradation. Environmental externalities will not be internalized. The inverted U-relation shows that demand for some indices of environmental quality does increase with income above a certain point. In most such cases, this has been associated with institutional reforms, environmental legislation and market-based incentives designed to internalize harmful external effects. But these have occurred where local communities have an incentive to internalize the environmental costs of their own activity: i.e. where the costs are borne by those able to change institutions, laws or economic policy. Where the environmental costs of economic activity are borne by the poor, by future generations, or by other countries, the incentive to address environmental questions

has been much weaker. The environmental consequences of changes in the structure of production in growing market economies may, accordingly, be very mixed (7,9).

Economic growth is not the solution to environmental externalities, and in the short run, it is certain to increase the rate of environmental degradation. The solution to environmental externalities is institutional reforms which compel private users of environmental resources to take account of the social costs of their actions (10). The inverted U relation is evidence that this has happened in some cases. It is not evidence either that it will happen in all cases, or that it will happen in time to avert the important and irreversible global consequences of growth.

Carrying Capacity and Ecosystem Resilience

Are there limits to the scale of the economy or the carrying capacity of the planet under a given structure of production and consumption? The answer to this is unambiguously, yes. If ecosystem deterioration cannot be delinked from economic activity, then at some point, economic growth will be stopped by the planet's limited capacity to absorb such deterioration. On the other hand, if pollution and ecosystem deterioration *can be* delinked from economic activity, then continual economic development is possible. This does, however, imply major change in the structure of production and consumption: in favour of resource-conserving qualitative improvements in productivity (development) and away from resource-consuming extensive growth. The proposition that economic development is consistent with improving environmental quality implies that, at least in some respects, this is currently happening. However, the core of the problem of environmental externalities in growing economies is the absence of effective signals of the environmental effects of economic growth. This is particularly serious if growth threatens the carrying or assimilative capacity of the environment.

The simple version of the notion of carrying capacity comes out of the logistic equation for the growth of a single animal population in a limited, highly simplified environment. Carrying capacity in this simple form is of limited use for the complex issues described above. Actual carrying capacity in nature is not a fixed, static or simple relation for either animal or human populations. It is contingent on technology, preferences, and the structure of production and consumption. It is also contingent on the everchanging state of the interactions between the physical and biotic environment. The capacity of the planet to support human life is limited for a given set of preferences and technology. This limit can be raised by lowering average quality of life or by changing technology and preferences so that production and consumption are less damaging to the environment (11). It is not, therefore, useful to state a single number for human carrying capacity. Such a number would

be meaningless because the consequences of both human innovation and of biological evolution are inherently unknowable. Nevertheless, a general index of the current scale or intensity of the human economy in relation to that of the biosphere is still useful. For example, Vitousek et al. (12) calculated that the total net terrestrial primary production of the biosphere currently being appropriated for human consumption is around 40%. This number says nothing about the carrying capacity, but it does put the scale of the human presence on the planet in perspective.

A more useful and operational concept for environmental sustainability is that of ecosystem resilience. Resilience is generally understood in two different ways. One, due to Pimm, focuses on ecosystem dynamics in the neighbourhood of an equilibrium. It is a measure of resistance to disturbance and speed of return to such an equilibrium (13). A second, due to Holling, focuses on ecosystem dynamics where there exist multiple (locally) stable equilibria. It is a measure of the disturbance that can be absorbed before a system centered on one locally stable equilibrium flips to another (14). Ecological economic systems are sustainable only if they are ecologically resilient. While ecological resilience may be difficult to measure and varies from system to system, and from one kind of disturbance to another, some useful indicators and early warning signals may be possible. For example, the diversity of organisms or the heterogeneity of ecological functions have been suggested as signals of ecosystem resilience. But ultimately, the resilience of systems may only be tested by intelligently perturbing them and observing the response using what has been called "adaptive management" (15). That approach essentially turns regional development policy and management into experiments where interventions at several scales are made to achieve understanding, to produce social or economic product, and to identify options.

The loss of ecosystem resilience is potentially important for different reasons. For one, the discontinuous change in ecosystem functions as the system flips from one equilibrium to another may be associated with sudden loss of biological productivity, and so to a reduced capacity to support human life under any technology. For another, it may imply an irreversible change in the set of options open both to present and future generations. If there are significant irreversible effects, or effects are very expensive to reverse, the hopes that future increases in current national income may be associated with a reduction in the level of emissions offers no protection against the consequences of environmental degradation. Effects that are in this category include soil erosion, depletion of ground water reservoirs, desertification and loss of biodiversity. More than this, though, the potential for discontinuous and irreversible change from familiar to unfamiliar states increases the uncertainty of the environmental effects of economic activities.

In order to assure the sustainability of economic development, it is important to assure the resilience of the ecological systems on which the economies depend. In a static regime of fixed preferences and fixed technologies, and in a non-evolutionary environment, this might well imply restricting the level of economic activity to that allowed by the carrying capacity perceived for those systems. In an evolving system where the notion of carrying capacity is less helpful, the limits on the nature and scale of economic activity are much less certain. But they are nevertheless real, and the problem for environmental policy is to ensure that they are taken into account.

Economic Growth and Environmental Policy

Economic growth will not automatically resolve the problem of environmental degradation. Nor will it automatically be sustainable. The source of difficulty is that appropriate signals of environmental damage, including the loss of ecological resilience, do not typically occur incrementally but abruptly. Moreover, the signals that do exist are often not observed or are wrongly interpreted. This is due to ignorance about the dynamic effects of change in ecosystem variables (especially thresholds, buffering capacity, and loss of resilience) and to the presence of institutional impediments, such as the nonexistence of property rights. The development of appropriate institutions, depends on our understanding on ecosystem dynamics and the maintenance of appropriate indicators of change.

Better science is a precondition for improved management through institutional reform. But the key feature is that this science must recognize that ecosystems and economic systems are of inherently limited predictability. We must determine what aspects of the system's performance are in principle predictable and design signals, adaptive management systems, and instruments that probe, test, and respond to the unpredictable and changing properties of human and biological nature. The most limited capacity we have is our capacity to understand and predict the future. In the face of this fundamental uncertainty and unknowability, and the dramatic consequences for the entire species of guessing wrong, we should act in a precautionary way to maintain the variability and diversity that sustains ecosystem resilience and buffering capacity.

Economic growth in itself is neither the problem nor the solution to dealing with the environment. It is neither a panacea for improving environmental quality nor does it have an inherently negative impact on the environment. What is important is the content of growth. It is better to concentrate on internalizing external environmental effects and protecting the resilience of ecological systems. The first will promote greater efficiency in the allocation of environmental resources at all income levels. The second will assure a sustainable scale of the economic system. Even low income

countries can and should improve efficiency and hence welfare by internalizing environmental externalities and even high income countries can and should restrict consumption and production so as to protect the resilience of the ecological systems on which they depend.

NOTES:

1. We would like to thank the editor and two anonymous referees for helpful comments.
2. This is a report of the Second Askö Meeting, held August 31 - September 2, 1994 in the archipelago outside of Stockholm, Sweden. The meeting was sponsored by the Beijer International Institute of Ecological Economics, Royal Swedish Academy of Sciences, Box 5005, S-104, 05 Stockholm, Sweden. The aim of the meeting was to establish a substantive dialogue among a small group of ecologists and economists, to get a sense as to whether there is an interdisciplinary consensus on the issues of economic growth, carrying capacity, and the environment, and to determine what could be said about the joint development of economic and environmental policy.
3. S. Kuznets, *Am. Econ. Rev.* 45, 1 (1955)
4. Phenomena for which the relation holds most clearly includes poor sanitation, impure water supplies, suspended particulates, SO_2 , NO_x , and CO . N. Shafik and S. Bandyopadhyay. *Economic growth and environmental quality: time series and cross country evidence*. Background Paper for the World Development Report, World Bank, Washington, DC (1992). G.M. Grossman and A.B. Krueger, pp. 165-177 in *The U.S. Mexico Free Trade Agreement*, P. Garber, ed. (MIT Press, Cambridge, 1993).
5. W. Beckerman, *World Development* 20, 481 (1992).
6. Shafik and Bandyopadhyay (see (4) above), find that CO_2 emissions are an increasing function of per capita income. W. Moomaw and M. Tullis, pp. 157-172 in *Industrial Ecology and Global Change*, R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. (Cambridge Univ. Press, Cambridge, 1994) show that while cross-sectionally CO_2 emissions per capita rise with income per capita, the experience in individual countries over time is highly variable, depending on the structure of individual economies. They conclude that there are many different development paths, some of which can delink economic growth from CO_2 emissions, but adequate institutions are required and it is by no means an automatic consequence of growth.

7. R. Lopez, *J. Environ. Econ. Manag.* 27, 163 (1994).
8. T.M. Sciden and D. Song. *J. Environ. Econ. Manag.* 27, 147 (1994)
9. K. Anderson and R. Blackhurst, eds. *The Greening of World Trade Issues* (Hemel Hempstead, Harvester Wheatsheaf, 1992)
10. A related issue is the measurement of economic growth at the macro level. The conventional measure — Gross National Product — is far from adequate as a measure of true economic performance. We need a more comprehensive index that includes the flow of environmental services as well as the value of net changes in the stocks of natural capital so that the true social costs of growth can be internalized.
11. Ehrlich, P.R. , pp. 38-56 in A.M. Jansson, M. Hammer, C. Folke, and R. Costanza. eds. *Investing in Natural Capital: The Ecological Economics Approach to Sustainability* (Island Press, Washington, DC, 1994)
12. P.M. Vitousek, P.R. Ehrlich, A. H. Ehrlich, and P.A. Matson. *BioSciences* 36, 368. 1986.
13. S.L. Pimm, *Nature*, 307, 321 (1984)
14. C.S. Holling, *Annu. Rev. Ecol. System.* 4, 123 (1973).
15. C.S. Holling, ed. *Adaptive Environmental Assessment and Management*. (Wiley, London, 1978). C.J. Walters, *Adaptive Management of Renewable Resources* (MacMillian, NY, 1986). K. Lee, *Compass and the Gyroscope*. (Island Press, Washington, DC 1993).

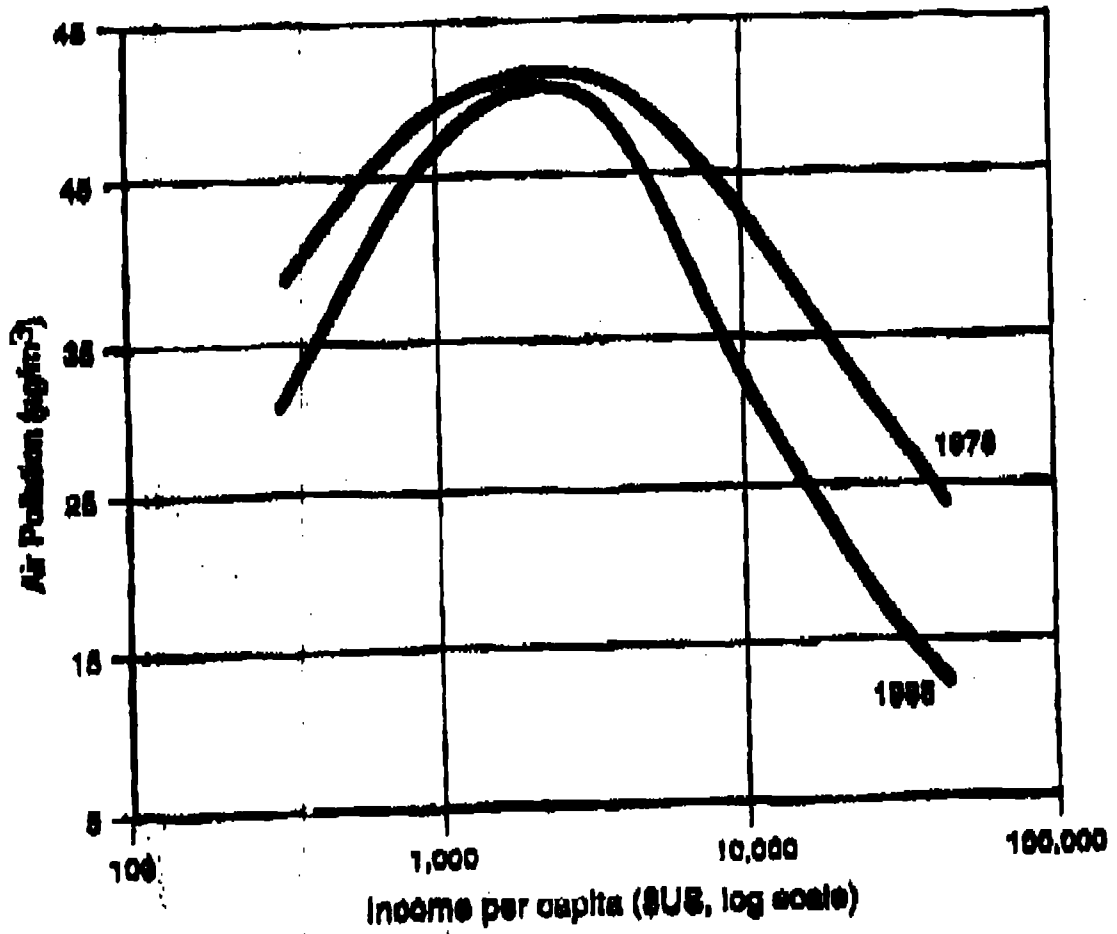


Figure 1. Income per capita versus. air pollution (4).

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DATE: 02/15/95

NUMBER OF PAGES: 02

FROM: Prof. José Goldemberg

TO: Erik Haltes

FAX: (001-416) 369-0922

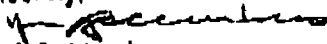
MESSAGE:

Dear Erik,

1. Thanks for Bert Bolin's comments which, I understand, result from the Second Askö Meeting.
2. Writing Team I was quite aware of most of the points made by Bolin and we tried to address them in Section 1.5.3.1 (Revising National Accounts) and 1.6 (Sustainable Development). Bolin's paper in page 4 - top paragraph and footnote 10 say that.
The idea of "delinking" economic growth and environmental degradation is well known and the empirical evidence shows that for "local" and "regional" pollution such delinking is taking place (except for municipal waste, which in principle could be solved by recycling). It's only for "global pollution", i.e. changes in the composition of the atmosphere that things do not go that way. May be one could highlight that.
3. However the only novelty I see in the paper is the idea of "ecosystem resilience" which could be incorporated in our Overview, particularly a reference to Vitousek et al (Bioscience 36, 388, 1986) which attempt to quantify the problem.

Please retransmit this FAX to Joe Stiglitz (and to Bolin if appropriate).

Sincerely,


José Goldemberg

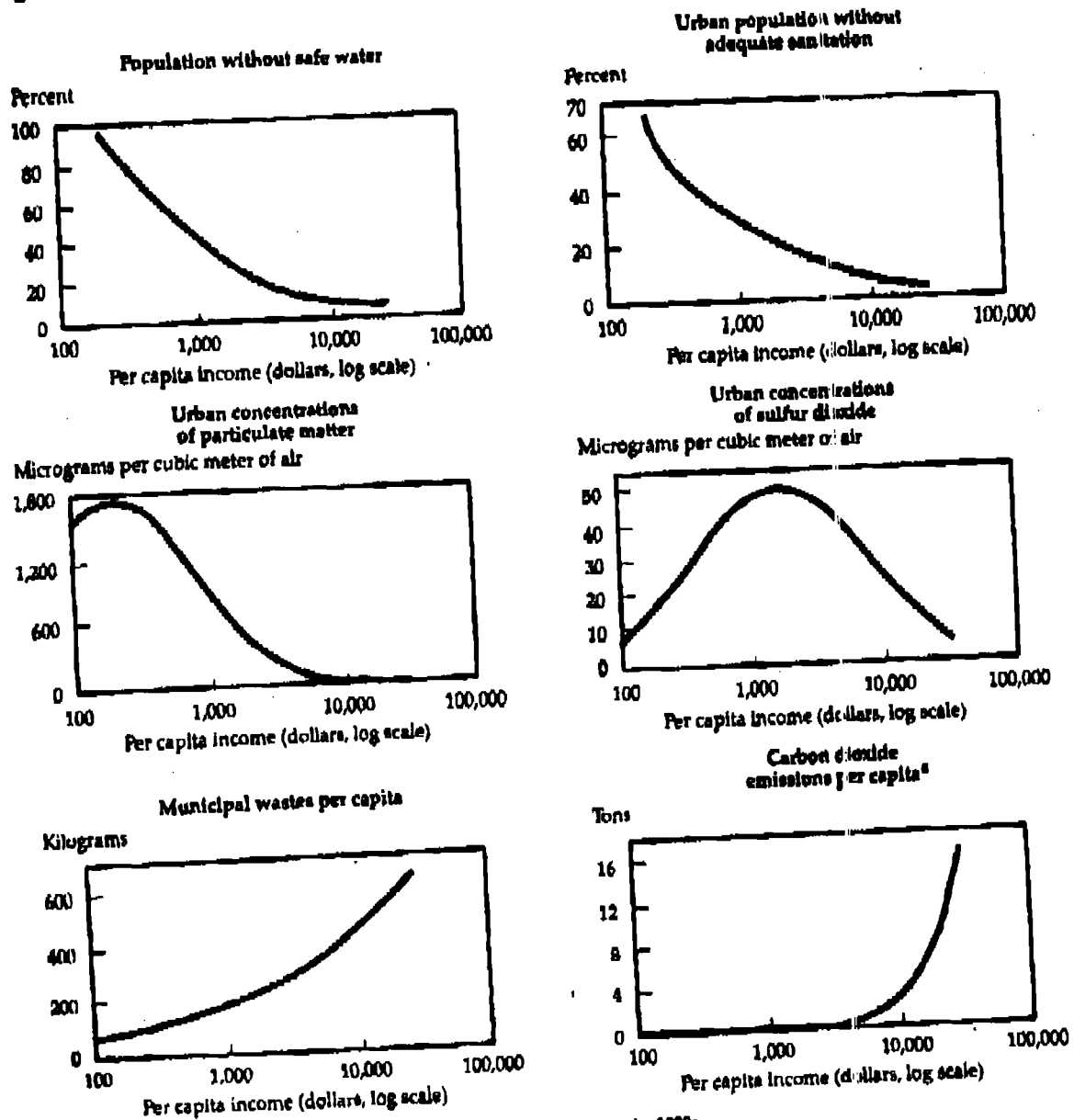
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TO:

Environmental problems may worsen or improve with income growth, some worsen, then improve

Figure 4 Environmental indicators at different country income levels



Note: Estimates are based on cross-country regression analysis of data from the 1980s.

^a Emissions are from fossil fuels.

Source: Shafik and Randsdhyay, background paper, World Bank data.

1PCC

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OFFICE OF ECONOMIC POLICYDATE: 24 FEB 95NUMBER OF PAGES TO FOLLOW: 6FAX TO: JOE STIGLITZADDRESSEE'S FAX NUMBER (202) 395-6958ADDRESSEE'S CONFIRMATION NUMBER (202) 395-6853FAX FROM: RAY SQUITIERITREASURY

SENDER'S FAX NUMBERS: (202) 622-1294

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COMMENTS/SPECIAL INSTRUCTIONS:

***** U N C L A S S I F I E D *****

SECTION I: BIOGRAPHICAL INFORMATION

Name: Joseph E. Stiglitz
Organization: Council of Economic Advisors, Washington
Area of Expertise: Microeconomics
Phone: 202-395-5036
Fax: 202-395-6958
E-mail: none

The following comments are on

Chapter 2: Decision Making Framework**SECTION II: SUMMARY OF COMMENTS**

- Chapter is not yet in a form that can be reviewed by experts or governments.
- Chapter presents normative conclusions unsupported by scientific argument. This is not appropriate to a scientific assessment.
- Chapter fails to focus attention on its major conclusions; the conclusions it does highlight are often at variance with economists theory and empirical results.
- Logical foundation for many claims is shaky.
- Chapter does not make a balanced presentation of the issues.
- Writing is not up to the standard of a major IPCC publication.

SECTION III: DETAILED COMMENTS**Notes:**

- 1) The rough state of the present draft makes it difficult to give helpful comments yet;
 - 2) These comments are only a small fraction of the many that could be offered. Addressing these comments alone without other major work would probably still not result in a chapter that would gain acceptance in the economics profession.
- p. <Summary, page unnumbered> 1. 23-24. Causal relationship not established.
 - p. 2, section 2.1.2. Uncertainties are summarized better in

Chapter 1; this list should be improved or deleted.

- p. 3, l. 2-5. "Some expect ..." This is what economists generally believe, and should be presented as the prevailing view.
- p. 3, point 3. Text leaves the impression that Cline's damage estimates, which have not received wide acceptance among economists, are the accepted values. Nordhaus, Tol, and Fankhauser have also published comprehensive damage estimates.
- p. 4, section 2.1.2.1. This paragraph assumes the conclusion.
- p. 5, l. 6-7. "... sea level rise in Indian subcontinent could be higher than in, say, North America." How would the Indian Ocean rise more than the Atlantic and Pacific Oceans?
- p. 5, l. 8. Insert words in bold: "... could have more or less impact ..."
- p. 5, figure 2.1. Delete temperature estimates. It is not the accepted view that for 2°C warming, damage would be "substantial." Also, graph appears to present probability density functions (but then what is the curve that starts highest on the probability axis?). If that is the case, the areas under the curves should be the same, the tails of the curves should extend to the left of the origin (implying some probability of benefits from warming), and other logical problems should be corrected.
- p. 5, figure 2.2. Probability of welfare impacts is irrelevant to the discussion. I suggest a graph of delta Temperature (x-axis) against delta Welfare (y-axis).
- p. 6, l. 32. Text missing.
- p. 7, l. 14-16. Assumes the conclusion, which may be wrong.
- p. 8, l. 10 ff. "... if humanity lived a lifestyle corresponding to about 0.66 tonne of carbon equivalent emissions per person, per year..." With no warning, sentence suddenly appears to endorse one side of a delicate political issue; out of place in a scientific assessment.
- p. 8, section 2.2.3. "... trend risk and not a sudden risk..." What does this mean? L. 28: "... higher abatement costs are justified in case of trend risk..." Why is this? Because CO2 in atmosphere has an infinite lifetime?
- p. 9, l. 1. "Therefore, small but regular ... if not impossible." This may be correct, but it is not self-evident and does not fit here.

- p. 9, section 2.2.4. Why insert this political argument here? Political arguments belong in the INC.
- p. 11, l. 1. What is the "apex forum?"
- p. 11, l. 11. Change sentence: "To a few low-lying island states, climate change may threaten their existence. To oil exporters, climate change mitigation measures threaten their revenues."
- p. 11, l. 12. "Again, it concerns differently economists and environmentalists." What does this mean?
- p. 12, l. 7. Parry and Rosenzweig (cited) do not find large vulnerability in food supplies, contrary to impression left by text.
- p. 13, section 2.3.2.2. Economists will not take seriously this presentation of "Ecocentrism," e.g., "To put it sharply, humankind's abrogation [?] of decision making power's regarding nature is questioned. The ecocentric view proposes to curtail such decision making power... Equity is not only among human beings but also between human beings and other living species." In economics, value is generally defined with reference to willingness to pay. Resources have value because of someone's willingness to pay for their use (or even just for their existence). Section 2.3.2.2 appears rest its argument on the idea that a resource may have value to other species; do other species have a willingness to pay, apart from our willingness to pay to protect them or make them happy?
- p. 14, l. 20. "While the rich can argue ..." This political argument does not belong in a scientific assessment.
- p. 15, l. 6. "... the practice of discounting the future is severely questioned," etc. Sentence should be deleted, as Chapter 4 settles this issue. Also, Cline's estimate cited in first paragraph is not widely accepted by economists. This reference should carry a note to that effect, or should be deleted.
- "This substitutability assumption is highly questionable." This statement assumes the conclusion. The section should either make the case for its assertion, or be silent.
- p. 16, l. 4. "... then not doing anything is morally unacceptable." This is a moral judgement, not a statement of scientific agreement.
- p. 16, section 2.3.3.1. First paragraph should also note that cutting back on growth in the North -- for example as a result of climate change programs -- is likely to hurt residents of the South as well, through a drop in southern exports.

- p. 18, l. 5. "That is, due to delay in abatement, global risks are externalized." Alternatively, spending a lot now on the wrong programs could easily impoverish our descendants.

- p. 18, l. 25. "Thus risk tolerance of, say South should matter more than that of North." This conclusion is unsupported.

"... homeless dying from heat stress ..." At least in the U.S. many more homeless die during winter than during summer.

- p. 18, l. 27. "Most models developed in the North do not effectively build in the perspectives of the South in adapting to climate change." Economic models, like physical models, should be value-free. Do we speak of Northern physics and Southern physics -- or just good physics and bad physics? An economic model may be flawed for several reasons: it may be poorly formulated, or based on flawed estimation results; it may be internally inconsistent, or may predict poorly. We may say that it fails to reflect available resources, or misstates likely behavioral responses, but not that it does or does not "build in perspectives of the South."

- p. 19, section 2.3.3.4. This section presents political conclusions as if they were scientific conclusions, e.g., "Currently there are many countries whose use of environmental space far exceeds their justifiable share of that space. J. Parikh has indicated that these privileges are worth US \$70 billion per year."

The section also presents apparently scientific conclusions that are probably wrong, e.g., "The cost of delay in emission reduction (by the North) in terms of South's foregone opportunities to development is substantial." (see Richels and Edmonds 1993, Schlesinger and Zhang 1992, etc.)

- p. 20, section 2.4.1. This section -- and indeed the entire chapter -- inappropriately presses a certain political point of view. For example, l. 28: "Remember that if 550 ppm is chosen, it is difficult to go back to 440 ppm, but vice versa is possible."

- p. 22, above table. "This is referred as purchasing power parity." Wrong use of the term.

- p. 27, section 2.5. Why begin with the quote from Dowlatabadi and Morgan? Placed at the top of the section "Economic Formulation of Individual and Collective Decision Making", it suggests that the most important consideration is the prejudices of the decision makers. These may indeed be important, but the contribution of scientific analysis lies elsewhere.

- p. 28, l. 17-20. "... Bayesian approach, which represents information in the form of conventional, necessarily precise,

probability distributions ..." The writer appears to be unaware of the voluminous and widely disseminated work on decision analysis that has appeared since the late 1950s.

- p. 29, l. 26 ff. "From such a standpoint, a subjective probability can always be formulated as a 'bet on a certain event'." What does this mean?

- p. 29, l. 12. "In sum, climate change seems to imply a certain degree of irreducible unpredictability beyond the common categories of risk and uncertainty." Climate change is a difficult analytical problem, but not for this reason. Decision analysis has been applied to many questions involving great uncertainty.

- p. 31, l. 3. "The most catastrophical fluctuation yet analyzed ..." Why describe this event as catastrophical? I don't believe we have any evidence of any large die off of plants or animals, or of an unusual number of species extinctions.

- p. 31, l. 7. "The discrepancies between the paleoclimatic observations of abrupt change and the smooth gradual warming prognosticated by today's models could not be more pronounced." This is false and irrelevant. GCMs can in general show rapid changes.

- p. 32, l. 13. "...low probabilities attached to large potential damages." This is not a fatal problem, as the text claims.

- p. 35, l. 8. "... there might be as many rationalities as there are cultures." This may or may not be true, but it adds nothing to an assessment of the state of scientific knowledge.

- p. 38, l. 11 ff. The writer does not seem to be familiar with the terms that economists use in describing risk. E.g.: "A risk averter can be a diversifier and spread his portfolio over different assets--or a "plunger" and invest wholly in bonds and money." "Cautiousness: Defined as decreasing risk aversion ... (Schaifer, 1961; after Pratt, 1995)." It would be useful to consult a basic text such as Raiffa (1964).

- p. 38, l. 26 ff. This section strings together terms from decision theory like cranberries on a Christmas tree, with no explanation of their meaning, and no attempt to relate them. Throwing around jargon and padding it with scholarly references will not help most readers.

- p. 40, l. 10. "... trade securities insurance contracts." Of what relevance is this here?

- p. 40, l. 15. "According to Shlyakhter et al. (1995), those risks that fall below a particular threshold of probability--and thereby are ignored by a particular group or society--are called

"de minimis" risks."[emphasis in original]. This is not a research result but merely a definition.

- p. 40, l. 29. "... 5 percent chance of a climate-related catastrophe within their lifetime." It is difficult to imagine what climate-related catastrophe could occur by, say 2050.

- p. 44, l. 6. "... implies that the industrialized nations should take strong measures..."[emphasis in original]. This is a political conclusion. Why is it included here?

- p. 54, l. 14. "... would it not be cautious to insure ...?" This statement assumes the conclusion, and inappropriately makes a policy recommendation.

- p. 55, l. 5 ff. Paragraph is highly speculative and does not belong here.

- p. 55, footnote 19. "The more risk averse you are, the more you will insure (Chichilnisky, 1994)."[emphasis in original] This is not a research result.

- p. 56, l. 8. "Economics is about differences in preferences leading to trade (Chichilnisky, 1994)." This is not a research result.

- p. 56, l. 9. "Betting on climate states ..." What is this sentence saying?

- p. 56, l. 23. "To illustrate, the Alliance of Small Island States (AOSIS) has proposed that an "International Insurance Pool" be established...." Here, and in many other places, a tangential discussion deflects the reader's attention from the major arguments. This should go in a footnote or be deleted.

- p. 60, l. 4. "An operational model to analyze the optimal portfolio of climate change policies for a country is not feasible given the state of our knowledge." No economic model will produce an error-free, bullet-proof answer to anything; on the other hand, several models already exist to examine precisely the question stated. The writer may want to consult recent papers of the Energy Modeling Forum at Stanford (for projects EMF-12 and EMF-14) for more details.

- p. 64, figure 2.8. What is the message of this figure?

From: Sally M. Kane (KANE_S)
To: Stiglitz J
Date: / Friday, February 24, 1995 4:30 pm
Subject: IPCC wg comments

I am sending the CEA's comments on the summary for policy makers to those who are compiling the reviews.

I have taken the material from Ray and double-checked against what we sent to Jim Bruce during the last round of comments. In addition to correcting some text placement mistakes, I added other comments that had been ignored that were discussed by us and included but were possibly not in your list of comments (for example damage estimates).

The cover note to the compilers says that these are the first of two sets of comments. Next week we will send comments on equity, decision-making, social costs, benefit-cost, and emission scenarios chapters. Mark Mazur and others are providing comments to us as well.

I strongly recommend that we continue to draft text where appropriate.

CC: Branch_L

SECTION I: BIOGRAPHICAL INFORMATION

Name: Joseph E. Stiglitz
 Organization: Council of Economic Advisors, Washington
 Area of Expertise: Microeconomics
 Phone: 202-395-5036
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The following comments are on **The Executive Summary**

SECTION II: SUMMARY OF COMMENTS

- Economists do not subscribe to the idea of an absolute standard or a safe minimum standard. If these ideas are to be introduced, it must be clearly stated that most economists reject these ideas.
- Summary needs to state an important conclusion of recent economic research: near-term decisions along an optimal path will be the same (i.e., modest-cost mitigation measures) for a wide range of ultimate target concentrations.
- While the Summary reflects the view that one should go beyond no-regrets policies, it leaves the impression (without explicitly so stating) that immediate costly actions are in order; this is inconsistent with the chapters to follow.
- Damage estimates are presented as though they are robust, even in developing countries. The estimates do not match what is found in chapter 6 (social costs).
- Summary omits important points made in Summary to Chapter 1.

SECTION III: DETAILED COMMENTS

- p. 2 l. 4-6. "The ultimate objective ... provides guidance ..." Statement is tantalizingly incomplete. What guidance? My understanding of recent decision analysis research (e.g. Richels and Edmonds 1993) is that for concentrations between 450 and 750 ppmv, the least-cost path requires only modest reductions in emissions in the near term. See comment on the bulleted list (p. 4), below.

p. 2 l. 21.

"However, these decisions are not very sensitive to the level ..." Paragraph says the optimal solution is robust, but does not say what that optimal (least-cost) solution is. I believe the key research result is that modest emissions

reductions in the short run are consistent with a wide range of desired equilibrium concentrations.

p. 2 1. 25ff.

Are these actions being recommended? Text leaves the impression that they are. Most analysts would agree that the most cost-effective of these measures should be undertaken without further scrutiny (low or negative-cost measures to reduce emissions, phasing out of existing distortionary policies, etc.). Less cost-effective measures (e.g. fuel switching) would not be undertaken while we still have more efficient alternatives to choose from. I suggest a sentence indicating the actions that would be included along such an optimal path:

insert: "In the short-run, governments would reduce energy subsidies and eliminate other distortions in energy markets; accelerate R&D; and promote joint implementation. Beyond this, for target concentrations within the range of 450 to 750 ppmv, only mildly costly mitigation actions are indicated."

- p. 4 1. 1. " ... \$50 per tonne of carbon ..." This number seems to have been pulled out of a hat, and contradicts results reported in other chapters that \$5 to \$20 per ton is the right range. Delete \$50 or make it consistent with later chapters. In this and other places, the chapter leaves the (incorrect) impression that economists agree that high-cost near-term mitigation are justified.

- p. 4 1. 12 "The actions taken by a particular country may reflect considerations ..." Delete sentence.

The list of considerations that follow confuses conditions particular to a given country, and conditions that are more universal, such as international equity. More generally, the list of possible factors does not add much to the Summary, and does not reflect any consensus about the most salient factors.

- p. 4 1. 17-19 I suggest deleting the sentence otherwise, it could be used as an excuse for less developed countries not to take any action.
- p. 4 1. 19 This sentence is not necessary and should be deleted.

- p. 4 1. 24-32 This paragraph is written in a prescriptive (and patronizing tone). The following changes should be made.
 - 1. 24 Delete "can and should"
 - 1. 26 Delete "will probably"
 - 1. 27 Replace "complex flexibility" with "costless change in policies."
- p. 5 1. 14. Figure 1 is incorrect and should be redrawn. The paths indicated do not represent optimal paths, but simply conjectures reported in some scenario comparisons. An important recent result, referred to obliquely on p. 2, is that the optimal (least-cost) path is the same in the near term whether the ultimately desired concentration is 350 or 750 ppmv. I suggest asking John Weyant to produce a revised graph consistent with the results of EMF-12 (and if possible preliminary results from EMF-14).
- Why has the range from 350 to 750 ppmv been chosen to report? Is there a scientific justification? If so it should be mentioned or otherwise explained.
- p. 6 1. 1. I continue to believe that since at this point in the report, there is no accepted goal of eventual concentration levels, it would be better simply to describe the thresholds: (a) if the eventual goal is stabilization at the level of.... then emission reductions of this magnitude are likely to be required; (b) if the eventual goal is.... then.....; (c) On the other hand, if the eventual goal is stabilization at a level of or above, then it is likely that no further substantial interventions will be required, at least before.....
- p. 6 1. 6-8. Before "The current commitments [of Annex I countries] are not sufficient to stabilize atmospheric concentrations of CO₂ ..." insert: "In the absence of some commitment by other countries ...". Without the insert, the reader is left to conclude that the answer is to tighten up on the commitments of Annex 1 countries. As several chapters demonstrate, without a commitment by the LDCs, atmospheric concentrations cannot be stabilized.

How are the current commitments being measured? Are they taken from the national plans?
- p. 6 1. 14ff. To restate an earlier criticism: Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum

(4)

standard."

Cost-benefit analysis and figure 3

All of these standards can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. Using this kind of language would significantly interfere with the creditability of the IPCC report in the economics community and beyond, and is likely to be sharply criticized by some governments. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. It is now generally understood that absolute standards are points of reference to be adjusted using cost-benefit considerations.

The "safe minimum" approach uses two terms that few economists would find meaningful: "reduce the risks of climate change to an acceptable level at an acceptable cost."

In the discussion of cost benefit, you should explicitly say that risk considerations can and should be brought into the cost benefit analysis.

If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that **most economists do not accept these approaches** and argue for the use of a cost benefit approach, with appropriate attention paid to the treatment of risk.

Figures 3(a) and 3(b) are particularly troublesome, as they draw attention to statements in the text about acceptable and unacceptable risks, while nowhere providing a formal way of quantifying the effects or valuing those effects relative to the economic impacts.

- p. 8 1. 3 A sentence should be added stating that the estimates of damages for many economies in the temperate and Northern climate zones are small, and in some cases possibly negative.
- p. 8 1. 4 Replace "between ... (end of sentence)" with "anywhere from less than 1% to 2.5%" .
- p. 8 1. 7 Replace "at least 2% with a maximum central estimate of 9% for GDP for some regions" with "higher than OECD countries". Little is known about the impacts in the developing countries and the chapter on social costs rightly points out the strong uncertainty yet qualitatively describes why the impacts are thought to be higher than that found in OECD countries.

- p. 8 l. 12 Damages on a per unit basis ranging from \$5-\$25 with a few estimates of \$125 is not informative enough for policy makers. Which models were used to generate these estimates and how are they simplistic? How rough are the estimates?

- p. 9 l. 4ff. Figure 4 is misleading and should be redrawn. The double dividend idea is in part an argument that more distortionary and burdensome taxes should be replaced by less distortionary and burdensome taxes. All public finance economists would like to see taxes reformed in this way. But tax reform is not the same thing as climate change mitigation, and the two should not be thrown together.

Curve C implies that revenue recycling will indeed yield the economic "double dividend" that some have suggested. But scholarly opinion differs on the magnitude and even the sign of the dividend. Some results have suggested that Curve C may even lie above curve B.

Curve D implies that concentrations of greenhouse gases and ordinary (criteria) air pollutants change in the same way. This is true for some gases, but not for others. For example, as the IPCC 1992 summary concludes, sulfate aerosols reduce radiative forcing in the short run; reducing sulfate aerosols would increase thus add to global warming. This means that curve D may well lie above curve C (and therefore above curve B).

If the figure is to be used, it should be accompanied by a statement that it is only schematic, and that the magnitudes of the effects displayed, and even relative locations of the curves, could differ from those shown.

- p. 10 l. 27ff. Either this section or somewhere else needs a statement to the effect that:

Efficiency will require full participation of the developing countries, including some forms of commitments for emission reductions. Without some form of commitment, actions by the developed countries can be partially, largely, or more than completely offset by actions in the developing countries.

- p. 10 l. 28. Discussion of costs of action versus inaction is too simplistic; there are costs of both to future generations.

Delete 1st and 2nd sentence.

- p. 10 l. 37. Population growth needs at least a mention. Suggested insert:

Total emission increases arise both from increases in emissions per capita and from increases in population. Whether emission rights are to be distributed on a per capita basis, and whether countries will be rewarded for controlling population growth, must be addressed by future negotiations.

- p. 11 l. 30 This first sentence in the paragraph should be deleted because we should not be giving recommendations about appropriateness of issues under discussion by the international negotiators.
- p. 11 l. 36. This paragraph should include a sentence such as: "However, past emissions will not have contributed much to ambient concentrations a century or more from now, when the impact of greenhouse gas concentrations are likely to be felt.
- p. 12 l. 10ff. This paragraph, which calls for increased travel budgets for the LDC representatives, seems out of place in a summary of the state of economic knowledge on climate change. Moreover, where is the scientific evidence that increasing the number of participants in negotiations insures its success? Therefore, the paragraph should be deleted.
- p. 15 l. 15. Add sentence to the effect that "most economists believe that technology standards and other command and control regulatory mechanisms are among the least cost effective ways of attaining emissions reductions."

Points to be added to Executive Summary, taken from Conclusions of Chapter 1:

- The risks of climate change are highly asymmetrical, with a large probability of a small loss, and a small probability of a large loss.
- Even in the presence of significant uncertainty, this asymmetry, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond no-regrets policies to those that incur net costs.
- Climate change demands a decision process that is sequential, can respond to new information with mid-course corrections, and can include insurance, hedging, and the

option value of alternative courses of action.

- The challenge today is to identify short-term strategies in the face of long-term uncertainty. The question is not, what is the best course over the next 100 years, but rather, what is the best course for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course.
- In an interrelated global economic system, an attempt to reduce greenhouse gas emissions in one region or one sector of the economy may be offset by increases in other regions or sectors.
- Efficiency requires that emission reductions occur where their cost is lowest, irrespective of who bears the financial responsibility.

February 17, 1995

To: J. Stiglitz
From: S. Kane
Subject: IPCC status: comments for government review and beyond

I have spoken with Ray, Randy Lyon, and Mike about preparing comments on WGIII draft chapters and executive summary. **We are striving to get comments compiled and ready for your review by cob Tuesday February 21st or Wednesday 22nd.**

Here is the current version of the executive summary and the comments that I submitted on our behalf. I have marked the comments that Jim Bruce accepted.

on the previous version.

Future Strategy for the executive summary:

Bob Watson knows about the problems with the executive summary based on comments from me, Richard Moss, and others. He suggested setting up meetings between you and Jim Bruce at the next lead authors meeting taking place next month in Paris. I believe this makes good sense.

To make the most of the interactions with the Canadians and other members of the Bureau, we should have as many wording changes and section replacements as possible.

Government Review:

Ed Haspel's office is coordinating the formal government review. Your comments will be compiled with those of all reviewers. During the week of March 6th, interagency meetings will take place to select the changes that we will be advanced in the government review.

Paris lead authors meeting:

To be prepared for the lead authors meeting, we will need to be fully conversant with the government's review package. Moreover, we will need to have additional suggestions, text changes, and strategies to share with the WGIII Bureau. One idea might be to send materials or talk with the Korean co-chair, since he seems well versed in economics and would agree with our ideas.

January Summary
Comments

January 25, 1995

To: E. Haites

From: J. Stiglitz
S. Kane

Subject: Comments on the Summary for Policy-Makers

Thanks for letting us take a look at the policymaker summary. We have combined our comments to give you the broadest response, hopefully providing useful insights based on technical expertise and institutional knowledge of the IPCC as it applies to economics.

Our recollection is that the previous draft is, in some ways, both stronger and more complete. Enriching this version of the summary with greater discussion of the no-regrets strategy (from a technical standpoint) and its place in the decision process; important research areas to help policy makers understand more fully the uncertainties in the climate and economic systems; the underlying assumptions in the emissions scenarios; the challenges and benefits from conducting research using integrated frameworks like integrated assessment; summary of abatement cost estimates in the literature; and the importance of discounting would improve the summary considerably.

A continuing problem that we have observed is the overall "tone" of the summary, which too often is normative. The summary should be simply a presentation of scientific evidence for the use of policymakers, telling policymakers what they should do. To the extent that there are explicit policy statements that need to be made, they should be of the form, "If this is your objective.....then the least cost way of addressing this problem is....."

Moreover, there are some ideas that get considerable attention in the policymakers summary which are far from the consensus view--indeed, we would describe them as explicitly rejected by 99% of all economists. We should either drop these perspectives (saying somewhere in the introduction that there are other views, discussed in the papers, but the policymaker summary focuses on the "consensus perspectives.") or introduce them briefly, with the above described caveat. Unless we say that, the report will not be taken seriously, and the entire report will be dismissed out of hand as not reflecting the overall judgment of the disciplines.

We appreciate the difficulty in summarizing material for policy makers. Please let us know how we can be of further assistance.

COMMENTS ON SUMMARY FOR POLICY MAKERS

X p. 1. par. 1.

Context for the report is the economic principles and research findings on climate change, with particular focus on topics relevant to the Convention -- not sustainable development from the perspective of the Convention.

Delete paragraph.

modified
p.2. par. 1.

Statement of intentions of the Convention should not be made.

Delete "The Convention thus implies and".

X Many considerations guide policy makers in undertaking policy actions.

Delete last sentence.

✓ p. 2 par. 2

Little of the literature assessed in the report comes from the framework of a single global decision maker. Replace beginning with second sentence:

The report identifies a number of general principles and findings that are relevant regardless of the decision making process, such as those concerning the design of cost effective policies.

X p. 2. par. 3.

Estimates of damages are rough. Concerns center on non-market effects.

Insert "non-market" before damages on line 17.

discussed
p. 2.9
(No-regrets needs to be more fully explained. Many countries are starting with these measures and should be able to see the actions in the context of decision-making.

✓ p. 2 bullet 2

There is not consensus on the desirable of the use of regulatory instruments. The sentence is too normative.

Delete last sentence.

✓ p. 3. lines 1-2

Replace sentence beginning with "Emissions" with:

Global emissions reductions of 5% to 20% have been estimated for removal of energy subsidies worldwide (chapter 11).

p. 3. bullet 5

Last sentence is very important. Begin with

The timing and availability of cost-effective non-fossil energy technologies ...

p. 3 fn. 5

First sentence does not read well. Second sentence may not be correct, because of the "sink" capacity of forests.

p. 4 par. 1, line 7-8

Replace 1st sentence with:

"Each country's approach to climate change can be represented as a portfolio of actions that reflects its objectives, economic conditions, and constraints."

The list of considerations that follow mix up conditions that are particular to a given country, and those which are more "universal" such as "international equity."

More generally, the laundry list of possible factors does not seem to say much, and does not reflect any consensus about what are the most salient factors. I suggest deleting sentence beginning on line 12-15 (it is too normative and could be used directly as an "excuse" for less developed countries not to take any action.) The last sentence should delete "will" and add "and protection of other environmental resources and human health." to the end of line 17.

p. 4. line 24

Replace "should" with "would"

p. 5 after line 4

Replace sentence lines 1-4 with

"Clearly, the dangers of significant harmful effects from global warming increase the greater the concentration of greenhouse gases in the atmosphere. The discussion below focuses on the effects associated with concentration levels in the order of magnitude of...."

p. 5. par 2.

Insert the following before "in Figure 1"

"at levels between 350-750 ppm range"

Delete the last sentence (in quotes) and add the following sentence

Studies cited here establish that the pattern of timing of reductions of emissions can have a major effect on the overall costs of mitigation. More paced emission reductions reduce the costs associated with premature retirement of capital and allow taking further advantage of technological improvements that are likely to become available in the future.

p. 5. par. 3

X Delete paragraph and Figure 2. We consider it problematic to discuss "initial commitments of Annex I parties" in the summary; another approach could be to qualitatively discuss "aims" (rather than commitments) included in the Convention under the presumption that they are extended beyond 2000 and are actually achieved. Because of the amount of discussion that would have to be added to convey this idea correctly, we do not believe it should be included in the summary (especially not with figures).

The discussion referring to alternative scenarios will not be of much use to most policymakers, who will not be apprised of the assumptions that underlie them. If one refers to them at all, one should spell out their key assumptions. The working group on scenarios has made a clear distinction between the uses of the scenarios: direct policy analysis we do not believe was condoned. Since the analysis underlying both figures 1 and 2 will attract so much negative reaction, yet not provide any indication about which levels are preferable (and how to decide), we strongly believe they should not be included in the summary. We have seen the extreme sensitivity to the discussion of the scenarios and their use in the following meetings: discussions of the work plan for the yet to be formed working group in Nairobi 1992, 1st Working Group III meeting in Montreal spring 1993, and at the plenary for the working group approving the scenarios chapter fall 1994.

We should not be recommending that 650 ppm or lower (or any other level) be a stabilization target (see p. 6 lines 2-4).

Recommended approach: Since at this point in the assessment effort, there is no accepted goal of eventual concentration levels, it would be better simply to describe the thresholds:

(a) if the eventual goal is stabilization at the level of.... then emission reductions of this magnitude are likely to be required; (b) if the eventual goal is.... then.....; (c) On the other hand, if the eventual goal is stabilization at a level of or above, then it is likely that no further substantial interventions will be required, at least before.....

p. 6 first full par.

X J. Stiglitz has criticized this par. before. His words: Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum standard." All of these standards can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. Using this kind of language would significantly interfere with the creditability of the IPCC report in the economics community and beyond, and is likely to be sharply criticized by some governments. This is particularly true, given that the term "dangerous anthropogenic interference..." is nowhere defined. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. While it is true that environmentalists often argue for the absolute standard, and it is sometimes used in establishing health standards, most economists are strongly opposed to these approaches.

Safe minimum uses two terms that few economists would find meaningful: "reduce the risks

of climate change to an *acceptable* level at an *acceptable cost*."

In the discussion of cost benefit, you should explicitly say that risk considerations can and should be brought into the cost benefit analysis.

If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that most economists do not accept these approaches and argue for the use of a cost benefit approach, with appropriate attention paid to the treatment of risk.

✓ p. 6. par. 3. line 33

... in Figures 3(a) or 3(b), where non-economic effects of climate change are brought into the analysis, but without the development of a formal way of quantifying the effects and/or valuing those effects relative to the economic impacts.

✓ p. 7 First sentence of first full par. I do not believe that there is a consensus on this conclusion. Better to say

"Because of the large uncertainties ... ~~of non-market~~ damages due to ... , it is difficult in practice to rely solely on cost benefit analysis for the selection of an appropriate stabilization objective at this time. Still, the information provided by cost benefit analysis is critical in making judgments not only about that decision, but also about the timing of emission reductions and the design of cost effective strategies."

Delete the last two sentences. The next to the last sentence is somewhat misleading. One can easily extrapolate the benefits and costs associated with different levels of atmospheric concentration (climate change) within a range, at least, based on currently available studies.

✗ p. 7 par. 4

Need to add sentence that states that the estimates of damages for many economies in the temperate and Northern climate zones are small, and in some cases possibly negative.

✓ line 25 add "a few aggregate (across all sectors)" after contains."

✗ line 27 replace "between ... (end of sentence)" with anywhere from less than 1% to 2.5% ."

✗ line 29 replace "at least 2% with a maximum central estimate of 9% for GDP for some regions" with "higher than OECD countries". Little is known about the impacts in the developing countries and the chapter on social costs rightly points out the strong uncertainty yet qualitatively describes why the impacts are thought to be higher than that found in OECD countries.

✓ p. 8 par. 2

line 25 replace "market imperfections" with "no reducible market or government induced imperfections"

✓ line 26 insert "or government induced imperfections after "market failures" ...

p. 9. lines 6-7

Replace last sentence with "Findings from a few studies suggest that secondary benefits could offset 30% to 50% of abatement costs in Norway and up to 100% of abatement costs in the United Kingdom."

p. 9 first full par.

Discussion would be enhanced by a brief discussion of the most important differences in "input" assumptions.

p. 10 1st full par.

Discussion of costs of action versus inaction is too simplistic; there are costs of both to future generations.

Delete 1st and 2nd sentence.

p. 11, 1st full par.

We should not be giving recommendations about appropriateness of issues under discussion by the international negotiators.

Delete 1st sentence.

p. 11 3rd full par.

We should not be advocating assistance.

Delete paragraph.

Somewhere in this section one needs to add:

"Issues of equity and efficiency can, however, for the most part be separated. Cost effective strategies can be developed embracing a variety of ways for sharing the burden. Efficiency will require full participation of the developing countries, including some forms of commitments for emission reductions. Without some form of commitment, actions by the developed countries can be partially, largely, or more than completely offset by actions in the developing countries."

p. 11, around full par. 1. line 8

Insert

Total emission increases arise both from increases in emissions per capita and increases in population. The extent to which "rights to emission" should be distributed on a per capita basis, and the extent to which they should reflect country's obligations given other considerations and circumstances will be questions that will also have to be addressed by future negotiations.

p. 11 Add somewhere on this page

However, the extent to which pass emissions will have contributed to ambient concentrations 100 or more years from now, when the impacts of greenhouse gas concentrations are most likely to be felt, are limited.

p. 12

Add after second par. (replacing last sentence of par.)

"It is important to bear in mind that in making choices concerning alternative policies, while the differences in consumption at different dates will be valued using the SRTP, those differences in consumption will themselves be affected by the opportunity cost of capital, which typically is in the range of 7% to 15% real. Thus, where mitigation projects displace other forms of investment yielding these higher returns, they typically will not be chosen unless the mitigation projects themselves yield returns at least equal to those on the displaced capital."

p. 12 Second par.

Replace lines 16-22 with the following text:

Two approaches have been used to derive a discount rate. As notes above, the discount rate for policy analysis may exceed zero even if the rate of pure time preference is assumed to be zero if the level of income is projected to rise, as is implicit in the emissions scenarios. The *prescriptive* (or normative) approach begins from ethical considerations, taking as zero the rate of pure time preference. The approach includes starting with the opportunity costs of capital (or market rates of interest) in calculating the cost of an investment, arrives at a new stream of changes in consumption (possibly including environmental goods) and applies a social rate of time preference to the consumption stream.

The *descriptive* (or market) approach, on the other hand, looks at returns to investments in the real world. Using a discount rate for consideration of climate policy that is lower than for other public or private investment decisions risks diverting investment away from higher-return investments in physical capital and education that would benefit future generations more than climate mitigation (which is only desirable at a lower discount rate). A wide variety of discount rates can be observed in the markets. Real return on equity in industrialized countries averages around 6 percent. For individual consumers in industrialized countries, real returns to investments in education and real costs of borrowing are significantly higher. In developing countries, required rates of return are higher than in industrialized countries because financial markets and financial intermediation are less well developed.

modified
In summary, an approach that focuses on prescriptive or normative considerations alone, assuming that the pure rate of time preference for intergenerational decisions is set at zero, supports discount rates in the neighborhood of 1.5 percent. Allowing for a positive rate of pure time preference would add to this value, in some calculations approaching 3 percent. An approach that emphasizes descriptive or market considerations in the

determination of a discount rate favors the adoption of real rates between 3 and 6 percent, with rates declining within this range as income grows.

Increasing the discount rate because of risk is generally inappropriate.

p. 13, last par line 23
Insert after "quotas."

only
1st
sentence
taken

Though there are implementation problems associated with each, both can be made consistent with equitable international burden sharing. On the other hand, most economists believe that technology standards and other regulatory mechanisms are among least cost effective ways of attaining emission reductions.

February summary
for Govt review

New Summary

JANUARY 20 DRAFT. DO NOT QUOTE. FOR REVIEW ONLY

**SUMMARY FOR POLICYMAKERS
SECOND ASSESSMENT REPORT, WORKING GROUP III**

The Context

This assessment of the socio-economic literature related to climate change has been undertaken in the context of sustainable development as reflected in the Framework Convention on Climate Change. This Convention is now a key element in the decision making framework on climate change (Chapter 2).

The ultimate objective of the Convention is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."¹

The Convention specifies that to achieve this objective the "Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures should be cost-effective ..."²

Each of the Annex I Parties is committed to "adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs."³

¹ United Nations Framework Convention on Climate Change, Article 2. The Intergovernmental Negotiation Committee (INC) requested that the IPCC assess the scientific evidence that might help policy makers interpret Article 2 of the Convention. This topic will be addressed in the IPCC's Second Assessment Report to be published in 1995.

² United Nations Framework Convention on Climate Change, Article 3.3.

³ United Nations Framework Convention on Climate Change, Article 4.2(a).

JANUARY 20 DRAFT. DO NOT QUOTE. FOR REVIEW ONLY

The Convention thus incorporates, and the literature assessed in this report (Chapters 1, 2, 8 and 9) supports a strategy of "act - then learn - then act" where the actions to address climate change are periodically adjusted in light of new knowledge and developments. The ultimate objective of stabilizing atmospheric concentrations of greenhouse gases, although not yet operationally defined, provides guidance for policymakers when considering initial actions to address climate change.

The Convention establishes a collective decision making process where actions, reflecting their common but differentiated responsibilities, are agreed upon by the Parties. The report identifies a number of general principles and findings that are relevant regardless of the decisionmaking process, such as those concerning the design of cost-effective policies. It should be recognized that a collective decision making process may not reach the same conclusions as analyses that adopt a global optimization perspective.

A Portfolio of Possible Actions to Limit Climate Change

The precautionary principle (Article 3.3) and the estimated damages due to current emissions of greenhouse gases (Chapter 6) argue for action beyond "no regrets" measures.⁴ The decisions to be taken in the near future will necessarily have to be taken under great uncertainty. However, these decisions are not very sensitive to the level at which atmospheric concentrations are ultimately stabilized and can be adjusted based on experience, new knowledge and other developments.

Actions analysed in the literature which countries can take, individually or jointly, to limit climate change and its impacts include:

- implementing low cost measures to reduce emissions of greenhouse gases. There is broad agreement that in most countries there are some measures, such as energy efficiency, that can reduce emissions of greenhouse gases at negative to slightly positive costs (Chapter 9). Achieving such reductions may require policy intervention;
- phasing out existing distortionary policies, such as some subsidies to fossil fuels, that reduce welfare and, directly or indirectly, increase

⁴ No regrets measures are those whose benefits, such as reduced energy costs and reduced emissions of conventional pollutants equal or exceed their cost, *excluding* the benefits of climate change mitigation.

greenhouse gas emissions.³ Global emissions reductions of 5% to 20% have been estimated for removal of energy subsidies worldwide (Chapter 11);

- implementing fuel switching measures, such as coal-fired generation to natural gas, to reduce emissions of greenhouse gases (Chapters 9 and 11);
- implementing measures to enhance sinks or reservoirs of greenhouse gases;⁴
- instituting forms of international cooperation to limit greenhouse gas emissions such as joint implementation and technology transfer;
- undertaking research aimed at better understanding the causes and impacts of, and adaptation to, climate change. Economic studies suggest that such research can yield high returns by reducing the uncertainty as to the most cost-effective actions to address climate change (Chapter 2);
- conducting technological research aimed at enhancing energy efficiency, minimizing emissions of greenhouse gases from continued use of fossil fuels, and developing commercial non-fossil energy sources. The timing and availability of cost-effective of non-fossil energy technologies is one of the major determinants of addressing climate change in the long run (Chapters 9 and 10);
- planning, and implementing as necessary, measures to adapt to the consequences of climate change; and
- developing institutional mechanisms, such as insurance, to share the risks of damages due to climate change (Chapters 1 and 2).

³ Energy prices that do not reflect the externalities associated with energy use can be considered a distortionary policy. Under some circumstances, kerosene subsidies to reduce fuelwood use, can increase welfare or decrease emissions (Chapters 2 and 11).

⁴ Some actions to increase sinks may have indirect effects, such as a change in albedo. In such cases the net effect of the measure should be considered.

An illustrative simulation of global options with marginal costs of up to \$50 per tonne of carbon suggests about 50% of the total reduction/sequestration would be forestry measures, 25% would be through energy conservation and efficiency improvements, and the remainder would come from a mix of renewable energy use, fuel switching, CO₂ removal and disposal, and nuclear energy. The mix of options and the magnitude of the reduction/sequestration relative to current emissions varies significantly by region (Chapter 7).

Opportunities for Action Vary by Country and Over Time

Each country's approach to climate change can be represented as a portfolio of actions that reflects its objectives, economic conditions and constraints. The actions taken by a particular country may reflect considerations such as their cost, secondary benefits, the impacts on different socio-economic groups, international equity, intergenerational equity, the expected damage due to climate change or sea level rise within the country, and economic strategies based on development of new technologies. The size of the investment will reflect the country's obligations under international agreements, adjusted for resources transferred to or received from other countries, as well as domestic goals and priorities. A country's climate change actions will also reflect other priorities aimed at sustainable development, including eradication of poverty, increased levels of education, protection of environmental resources, and improved human health.

Governments can and should *adjust* their portfolio of climate change actions in response to new information and developments. Indeed, both the investment in climate change limitation and the mix of policies will probably change over time. That does not imply complete flexibility. Many of the measures involve capital and technology commitments with long life times. Reversing such commitments could be relatively costly, however that risk would be incorporated into the analysis of the options before the commitments are made. This is particularly important for developing countries and countries with economies in transition where significant infrastructure investments will be made over the next few decades.

Stabilization of Greenhouse Gas Concentrations

Climate change impacts are related to the stock of greenhouse gases (concentration) in the atmosphere, rather than the annual emissions, hence the ultimate objective of

the Convention is to stabilize atmospheric concentrations of greenhouse gases.⁷ Currently, the atmospheric concentration of CO₂ is about 360 ppmv; the pre-industrial concentration was about 280 ppmv.⁸ The danger of significant harmful effects from climate change increase as the concentration of greenhouse gases in the atmosphere rises. The discussion below focuses on the effects associated with stabilization of atmospheric concentrations of CO₂ within the range of 350 to 750 ppmv "could be attained only with global anthropogenic emissions that eventually drop to substantially below 1990 levels."⁹

The IPCC's six emissions scenarios assume virtually no new policies specifically designed to reduce greenhouse gas emissions (Chapter 12).¹⁰ Three scenarios that span the full range (IS92a, IS92c and IS92e) are compared with the illustrative profiles of anthropogenic emissions consistent with stabilization of atmospheric concentrations at levels between 350 and 750 ppmv in Figure 1. These emissions profiles indicate that at some stage major reductions of CO₂ emissions (of the order of 50% of current emissions) will be required to eventually stabilize concentrations. The pattern and timing of reductions of emissions can have a major effect on the overall costs of mitigation. "Emissions for all stabilization levels studied are lower than those for IS92a and e, even in the first few decades of the 21st century. Emissions for the IS92c Scenario lie between the emissions [profiles] which ... achieve stabilization at 450 and 550 ppmv."¹¹

⁷ It is not clear from the Convention whether the ultimate objective is to stabilize the atmospheric concentration of each gas at a particular level or to stabilize greenhouse gas concentrations, expressed in terms of CO₂ equivalents, at a particular level.

⁸ ppmv is parts per million by volume, a measure of concentration.

⁹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 4. Analyses of emissions profiles consistent with stabilization of atmospheric concentrations of CO₂ at levels lower than 350 ppmv or higher than 750 ppmv are presently not available in the literature.

¹⁰ *The 1994 Special Report of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 7.

¹¹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 15.

Stabilization of the atmospheric concentrations of other greenhouse gases at today's levels requires lesser reductions, but nevertheless reductions, of the emissions of those gases.¹² Thus, stabilization of atmospheric concentrations of greenhouse gases will require very low population and economic growth rates (as assumed for IS92c), a major "natural" change in energy technologies, or intervention to reduce emissions and enhance sinks. The effect of the initial commitments of Annex I Parties, assuming that they are achieved and continued to 2050, is shown in Figure 2. The current commitments are not sufficient to stabilize atmospheric concentrations of CO₂, except under scenario IS92c which has emissions below current commitments (Chapter 12).

Applicability of Cost-Benefit Analysis

A stabilization objective could be based upon an absolute standard, an affordable safe minimum standard, or a cost-benefit analysis, the approach favoured by most economists. These approaches are illustrated in Figure 3. The absolute standard approach would define a maximum atmospheric concentration of greenhouse gases that is considered to constitute "dangerous anthropogenic interference with the climate system" on the basis of predicted changes to the climate system or of the predicted impacts of climate change *regardless of the cost of achieving this concentration*. Environmental standards designed to safeguard human health are often established using this approach.

The safe minimum standard approach would specify a maximum atmospheric concentration of greenhouse gases based on an assessment of the risks associated with different atmospheric concentrations and the costs of achieving those concentrations. The standard would seek to reduce the risks of climate change to an acceptable level at an acceptable cost. Cost-benefit analysis attempts to value the impacts of climate change and seeks the atmospheric concentration where the marginal value of the net impact is equal to the marginal cost of abatement.

Working Group III was specifically requested to assess whether cost-benefit analysis is applicable to climate change. Cost-benefit analysis was broadly interpreted to include traditional project level cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and decision analysis. The traditional cost-benefit approach is

¹² *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 18 and 20.

depicted in Figure 3(c). Cost effectiveness analysis seeks to find the lowest cost option to achieve a specified objective; the marginal cost of abatement curves in Figures 3(b) and 3(c) represent cost-effective options. Multi-criteria analysis is designed to deal with problems where benefits and/or costs can not be valued; it could be used for the approaches described in Figures 3(a) or 3(b), where non-economic effects are brought into the analysis, but without a formal way of valuing those effects relative to the economic impacts. Decision analysis focuses expressly on making decisions under uncertainty and conceptually could be used in any of the approaches described in Figure 3.

Cost-benefit analysis (broadly defined) *could* contribute to resolution of three questions facing decisionmakers. These are:

- By how much should emissions of greenhouse gases be reduced or sinks of greenhouse gases be enhanced?
- When should emissions be reduced or sinks be enhanced?
- What methods should be employed to reduce emissions and enhance sinks?

Because of the large uncertainties surrounding estimates of damages due to climate change (Chapter 6) and the costs of mitigation (Chapter 9) make it difficult in practice to rely solely on cost-benefit analysis for the selection of an appropriate stabilization objective at this time. Still, the information provided by cost-benefit analysis is critical in making judgements not only about that decision, but also about the timing of emission reductions and the design of cost-effective strategies. Integrated assessment models best suited to such analyses are quite new (Chapter 10).

However, cost-effectiveness analysis can and should be used to evaluate adaptation and mitigation options.

The Benefits of Limiting Greenhouse Gas Emissions and Enhancing Sinks

The benefits of limiting greenhouse gas emissions and enhancing sinks are the climate change damages avoided. Since some increase in atmospheric concentrations from the current level is virtually inevitable, some impacts and damages due to climate change seem unavoidable.

The literature contains a few aggregate (across all sectors and regions) estimates of the damages associated with a climate characterized by a globally-averaged 2.5°C warming. The estimates suggest that if such warming occurred now it would impose net damages equivalent to 1.5% to 2.5% of world GDP on the present world economy (Chapter 6). The regional variation in climate change damage would be substantial. Damage in developing countries is estimated to be at least 2% with a maximum central estimate of 9% of GDP for some regions. Small islands and low lying coastal areas are particularly vulnerable. Climate changes of this magnitude are not expected to be realized for some decades and damages in the interim would be smaller.

Most estimates of the additional damage done by CO₂ emitted *now* range from \$5 to \$25 (1990 \$ U.S.) per tonne of carbon, although a few estimates range up to \$125 per tonne of carbon.¹³ The models used to develop these estimates are simplistic and are poor representations of dynamic processes, but they reflect the current state of the art. The wide range of estimates reflects variations in models, scenarios, discount rates and other assumptions.

Climate change benefits of emissions reduction measures can be very complex to estimate. Some energy efficiency and fuel switching measures simultaneously reduce emissions of greenhouse gases and sulphate aerosols. The negative radiative forcing from sulphate aerosols is significant. "Tropospheric aerosols have a lifetime of only a few days ... So the atmospheric concentration of aerosols responds rapidly to changes in emissions. Control of sulphate emissions ... would immediately reduce the amount of aerosols in the atmosphere."¹⁴ A recent model analysis finds that replacement of fossil fuels with carbon-free energy sources leads to lower temperature increases in the long run, but higher temperatures in the interim due to the reduced sulphur emissions (Chapter 10).

Costs of Response Options

What matters from a policy perspective is the net cost (total cost adjusted for secondary benefits and costs) of a mitigation or adaptation option apart from its

¹³ A tonne is a metric ton or 1,000 kg. \$5 per tonne of carbon corresponds to approximately 0.35¢ per litre of motor gasoline.

¹⁴ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC, Summary for Policy Makers, IPCC, 1994, p. 24.*

climate change benefits (Chapter 8). A wide range of estimates of the costs of response options is found in the literature. The wide range is due in large measure to differences in assumptions. Alternative views of the costs of emissions reduction are shown schematically in Figure 4. Curve A assumes that there are no reducible market or government induced imperfections; thus there are no "no regrets" options. Curves B, C and D all assume market failures or government induced imperfections exist in one or more sectors that can be corrected by policies that reduce costs and also lower greenhouse gas emissions. Curve B includes only measures whose direct benefits yield net cost savings. Curves C and D incorporate secondary economic and environmental benefits into the calculation of the net cost of the option.

The potential for "no regrets" policies is represented by the line OD₁. The area OD₁D₂ is the potential net benefit to society of implementing all "no regrets" measures. Some analysts have argued that measures with a positive cost should be implemented to the point where the total net cost to society is zero, i.e. to a point D₃>D₂, such that the area under curve D between D₂ and D₃ is equal to that area OD₁D₂.

Despite significant differences in views, there is agreement that some energy efficiency improvements (perhaps to 10% to 30% of current consumption) can be realized at negative to slightly positive costs in many countries, depending on the baseline assumptions and the time frame (Chapter 9). Measures to reduce greenhouse gas emissions often yield additional economic benefits (such as reduced traffic congestion) and/or environmental benefits (such as reduced emissions of acid rain and urban smog precursors). The magnitude of these secondary benefits depends on local circumstances. Studies for Norway, the U.K. and some other countries indicate that secondary benefits could offset 30% to 100% of abatement costs (Chapter 6).

The long run costs of addressing climate change will ultimately be determined by the rate of capital replacement, the discount rate and the effect of research and development. Implementation of "no regrets" measures will increase the time available to learn about climate change and to bring new technologies to the market. Infrastructure decisions are crucial because they can enhance or restrict future options and different choices can lead to very different cost outcomes.

Estimates of the costs of stabilizing CO₂ emissions vary widely as a result of differences in the baseline scenario, the estimated long run costs of mitigation measures, and the date for achieving the stabilization objective. Differences among models are less significant than differences in the underlying assumptions. Indeed widely differing methods can produce quite similar results when calibrated to the

same set of input assumptions, such as the cost and availability of different energy sources.

Top-Down and Bottom-Up Models

In the jargon of modelers "top-down" models are aggregate models, often macroeconomic models, that analyse how changes in one sector of the economy affect other sectors and regions. Early top-down models tended to have little detail on energy consumption, especially at the technology-specific level, but explicit treatment of behaviour and economic interactions. In contrast, "bottom-up" models tended to describe energy consumption in detail, however consumer behaviour and interactions with other sectors of the economy tended to be down played.

This simple characterization of top-down and bottom-up models is increasingly misleading as more recent versions of each approach have tended to provide greater detail in the areas that were less developed in the past. This convergence means that differences in model results are increasingly driven by differences in input assumptions rather than model structure. Most results available in the literature do not reflect the effects of this convergence of model structure since the evolution in model structure is a relatively recent occurrence.

Nevertheless, differences in model structure remain important as different models are best suited to answer different types of questions.

Equity and Social Considerations

Equity considerations are an important aspect of climate change policy and feature prominently in the Convention. Inaction is likely to impose costs on future generations and on regions where damages occur, often regions with low greenhouse gas emissions. Action to address climate change is likely to impose some costs on the present generation. Since actions to address climate change are deliberate, explicit decisions can be made as to how to share these burdens.

The Convention recognizes the differentiated responsibilities of the Parties, but it does not include an explicit formula for sharing the costs of addressing climate change. It also lists factors to be considered in determining how the burden should be shared and provides for development of mechanisms for sharing the burdens. Issues of equity and efficiency can for the most part be separated. Cost-effective strategies can be developed embracing a variety of ways for sharing the burden.

Equity issues involved in addressing climate change may be divided into four categories:

- distributing the costs of adaptation;
- distributing future emissions rights;
- distributing the costs of abatement; and
- ensuring institutional and procedural fairness.

The Convention offers some guidance on all of these issues, but doesn't resolve any of them.

A variety of ethical principles, including the importance of meeting people's basic needs, are relevant to sharing the burden of addressing climate change. No single rule will command universal agreement. Furthermore, any arrangement may need to change over time to continue to be perceived as equitable and to take new developments into account. Analysts can not prescribe how the burden of addressing climate change should be shared, they can only clarify the implications of different principles (Chapter 3).

Countries differ in terms of current greenhouse gas emissions (see Figures 5 and 6), vulnerability to climate change (Chapter 6), wealth, resource endowments, and institutional capacity to respond effectively. The Convention provides that these circumstances be reflected in differentiated responsibilities. Developed countries have undertaken commitments through the Convention for technology transfer and contributions to the financial mechanism.

A rigid "north-south" delineation of equity issues is inappropriate and may be highly damaging in the long run, although it permeates much of the debate at present. The implications of climate change for developing countries are different than those for developed countries because the former are generally poorer, have contributed much less to past emissions and still emit much less per capita, have shorter policy time-horizons, often weaker institutions, other urgent priorities, and are generally more vulnerable to climate change. However, there are substantial variations within the "north" and within the "south" in terms of absolute and per capita emissions, the likely impacts of climate change, institutional strengths and preferences, and endowment of natural resources that may be affected by mitigation. Similarly, over the next century some developing countries will continue to make marginal

contributions to the problem, while emissions from others may well start to dominate it.

Countries (such as low lying coastal regions and islands or drylands) and special groups within society (such as the poor, and sometimes women or children, or specific occupations or regions) that are especially vulnerable to climate change — those on whom the costs of abatement and coping would be especially burdensome — merit special attention.

All Parties have equal status under the Convention. Procedural equity also requires that all Parties be able to participate effectively in international negotiations related to climate change. Assistance to enable developing country Parties to participate effectively in negotiations would increase the prospects for achieving effective, lasting and equitable agreements on how best to address the threat of climate change.

Intergenerational Equity

Climate policy raises particular questions of equity among generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being and because it might conceivably not be possible to compensate future generations for reductions in well-being that might be caused by current policies.

Sustainable development and the concept of an environmental trust have been proposed to address intergenerational equity. Sustainable development would meet "the needs of the present without compromising the ability of future generations to meet their own needs." An environmental trust, as proposed by Brown-Weiss, would require each generation to ensure that the next inherits "a planet and cultural resource base at least as good as that of previous generations."

Discount Rate

The discount rate is the analytical tool economists use to compare economic effects that occur at different points in time. Identifying the proper discount rate is probably the single most important analytical step in economic analysis of global warming. The choice of discount rate is important in climate change analyses because the time horizon is extremely long and the abatement costs tend to come earlier than the benefits of avoided damages. It is also the most profound ethical question, since it

inherently confronts present pain of abatement cost against damages suffered by future generations if no action is taken.

The literature on the appropriate discount rate for climate change analysis can be divided into two approaches. The prescriptive approach asks whether a particular action would make society better off, given a plausible social welfare function. The discounting rules specify how consumption at different dates should be valued to provide the correct answer to that question. The descriptive approach focuses on intertemporal efficiency and opportunity costs.

The prescriptive approach discounts consumption accruing to different generations using the "social rate of time preference" (SRTP). The SRTP is composed of two components, "pure time preference" and the incremental welfare derived from future consumption:

- Pure time preference is a reflection of impatience. Although there is debate in the literature, values tend to range from zero to 1%
- The incremental welfare of future consumption accounts for rising per capita income over time and the resulting decline in the incremental welfare (marginal utility) derived from the higher future consumption.

Depending upon the values assumed for the different parameters, values for the SRTP on a global basis tend to fall between 0.5% and 3.0% per year. Developing countries may have much higher (10% to 20%) rates of SRTP due to high rates of per capita income growth or high elasticities of marginal utility for small increases in per capita income from subsistence levels.

It is important remember that in making choices concerning alternative policies, that while differences in consumption at different dates will be valued using the SRTP, those differences in consumption will be affected by the opportunity cost of capital, which typically is in the range of 7% to 15% real. Thus, where mitigation projects displace other investments yielding higher returns, the mitigation projects typically will not be chosen unless they yield returns at least equal to those on the displaced capital.

The descriptive approach to the discount rate looks at returns to investments in the real world. Market rates of return usually exceed the values estimated for the SRTP. Conceptually, funds could then be invested in projects that provide a higher return with the proceeds being used to increase future consumption. In the context of

climate change, however, society is not likely to be able to set aside investments over the next three centuries and earmark the proceeds the eventual compensation of those adversely affected. Determining the discount rate on the basis of descriptive or market considerations yields a global rate in the range of 3% to 6% real, with rates declining within this range as income rises.

Increasing the discount rate because of risk is generally inappropriate.

Policy Instruments

A clear distinction needs to be drawn between actions to reduce the impacts of climate change and actions to reduce emissions. The former also involve consideration of adaptation policies.

Policy instruments designed to mitigate climate change need to be assessed at the international and domestic levels. Such instruments can help participating countries comply with multilateral commitments on climate change abatement, including international transfers of resources and technology. The international and domestic policy instruments need not be the same, but international agreements may constrain the choice of domestic policy instruments.

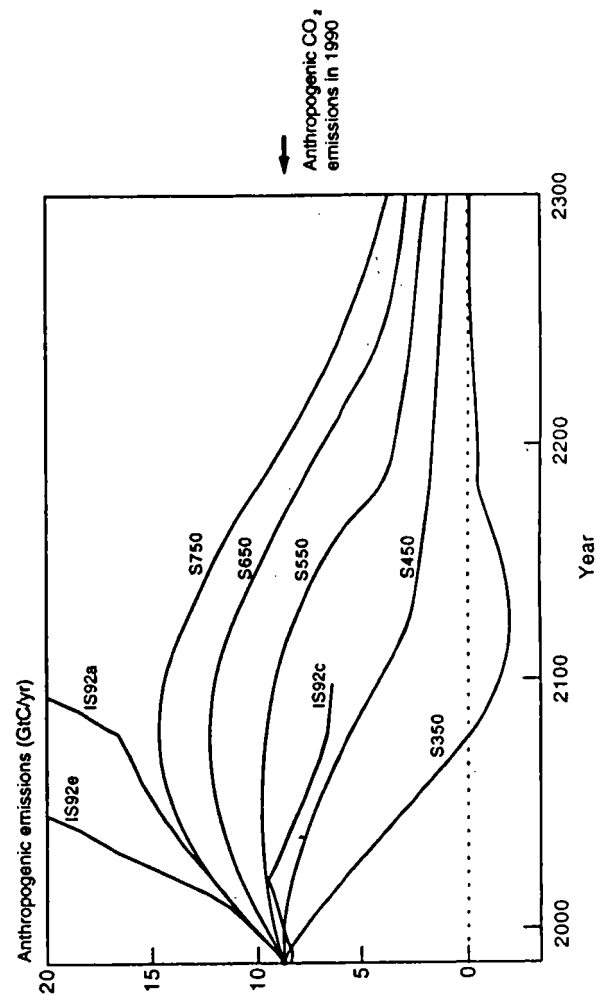
The policy instruments available internationally and for adoption by groups of countries include: non-tradeable quotas, tradeable quotas, joint implementation, harmonized domestic carbon taxes, international carbon taxes, various international standards and technology transfer. Domestic policy instruments include carbon taxes, tradeable permits, deposit-refund systems, technology standards, performance standards, product bans, voluntary agreements, energy taxes, energy efficiency subsidies, non-fossil fuel subsidies, and removing existing market distortions.

Among the criteria that governments can consider when selecting from among the available policy instruments are: distributional (including intergenerational) equity, flexibility in the face of technological change and new information, efficiency or cost-effectiveness, compatibility with the institutional structure and existing policies, and understandability to the general public. A mix of instruments may be needed to achieve the best results. Governments may apply different criteria with different weights to the selection of international and domestic policy instruments.

Cost-effectiveness should always be a criteria for selecting policy instruments, but it becomes more important at both the international and domestic levels as the abatement effort becomes more stringent. The economic literature suggests that the

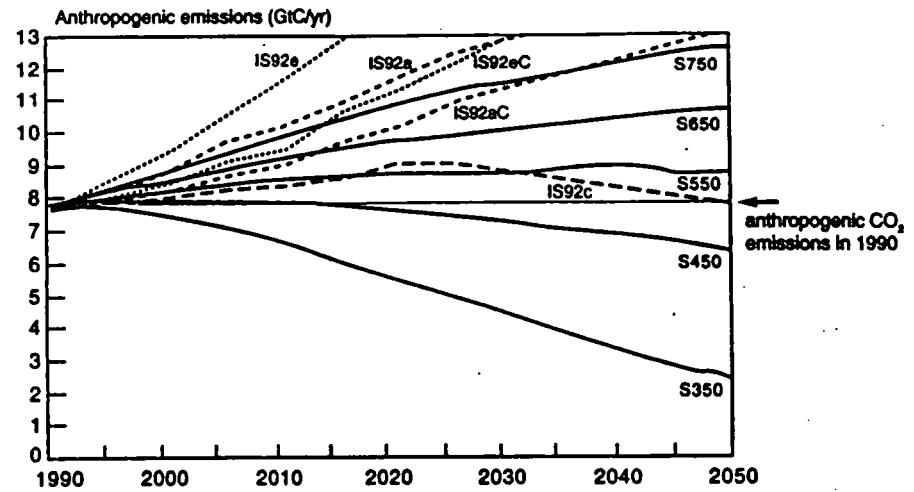
more economically efficient instruments include carbon taxes and tradeable quotas. Although there are implementation problems associated with each, both can be made consistent with equitable international burden sharing. The consequences of climate change policy will be determined by the choice of policy instrument as well as the design and implementation of those policies. The effectiveness of policies will also depend on their acceptability to the public and to governments.

Figure 1
Illustrative Anthropogenic Emissions Profiles of CO₂ Leading to Stabilization at Concentrations of 350 to 750 ppmv Using a Mid-range Carbon Cycle Model and CO₂ Emissions for the IS92a, c and e Scenarios



Source: 1994 Special Report of the IPCC

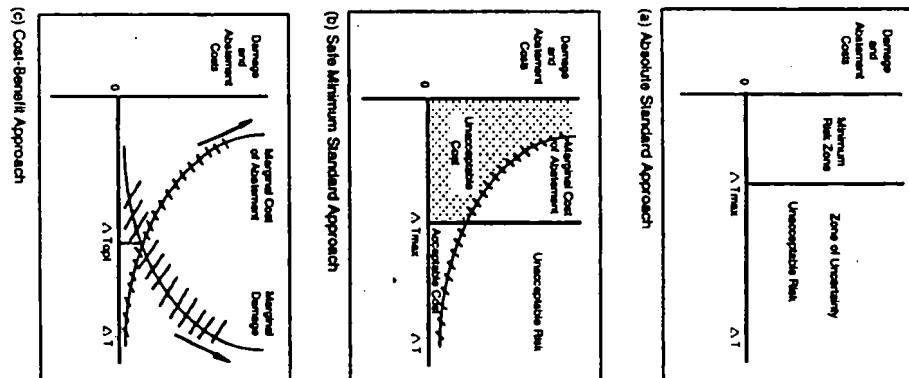
Figure 2
Comparison of IPCC Emissions Scenarios Adjusted for Current Commitments and Emissions Profiles Consistent with Stabilization of Atmospheric Concentrations of 350 to 750 ppmv



Legend: IS92aC (IS92eC) is scenario IS92a (IS92e) +
Source: Based on Chapter 12 adjusted for current commitments by Annex I Parties extended to 2050

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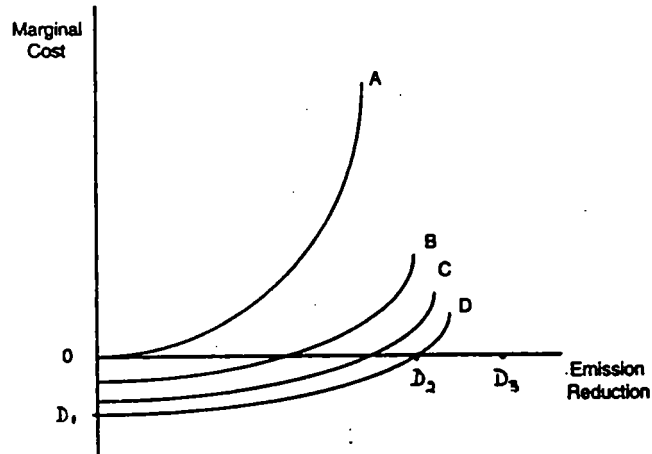
Figure 3
Global Warming, Cost-Benefit Analysis and Sustainable Development



Source: Chapter 6

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Figure 4
Alternative Views on Costs of
Emission Reduction

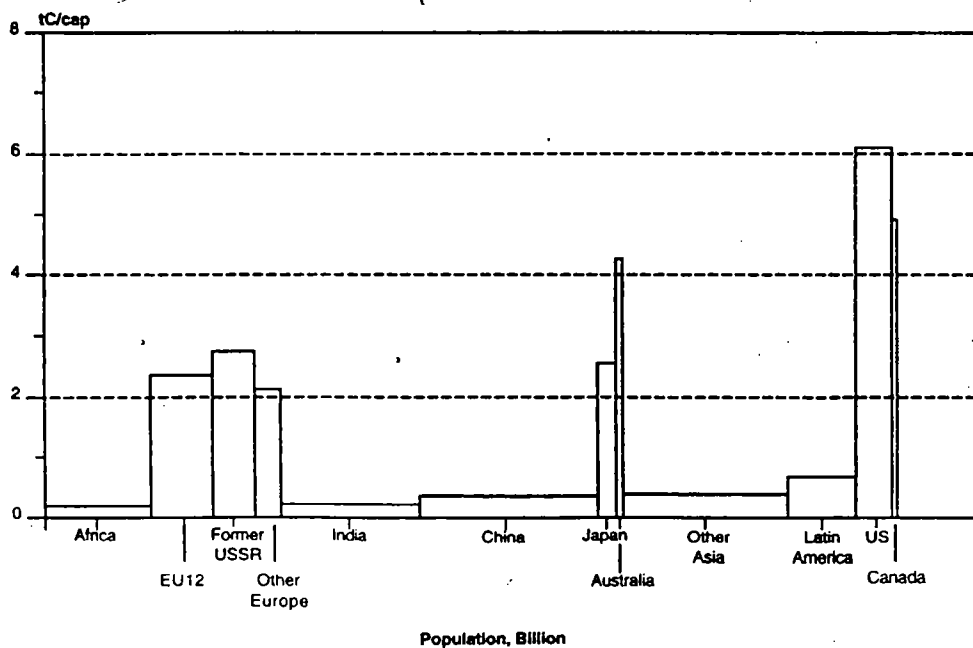


- A - No reducible market imperfections *and/or distortion*
 B - "Negative cost potential" achieved
 C - Curve B plus "economic double dividends"
 D - Curve C plus "environmental double dividends"

Source: Chapter 8

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Figure 5
Carbon Emissions per Capita and Population, 1993

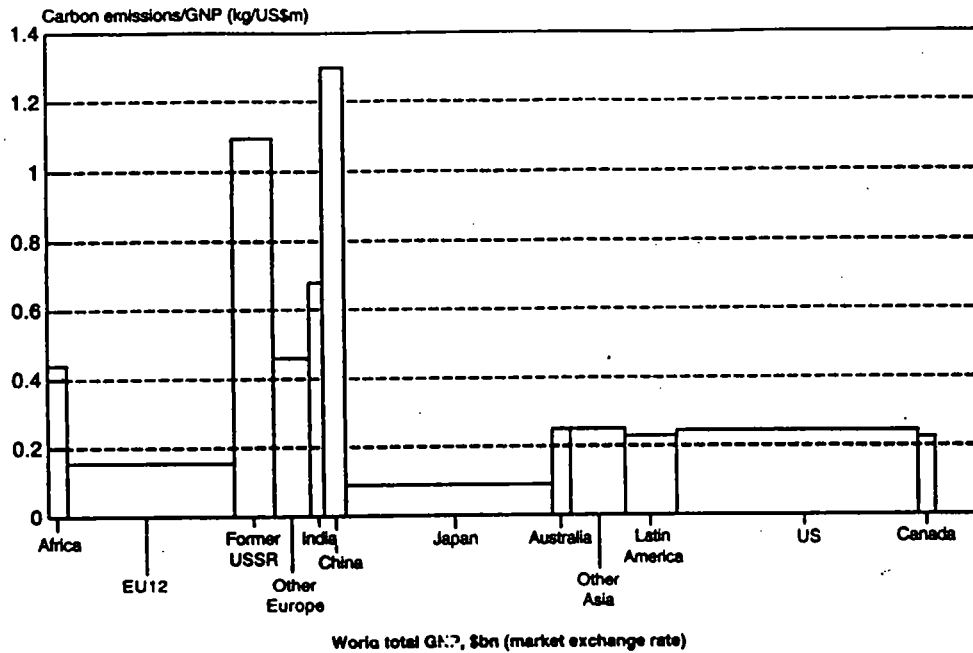


Source: Derived by M. Grubb from BP Statistical Review of World Energy 1994 and World Population Prospects, UN

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Figure 6

Carbon Emissions/GNP and Total GNP, 1992



Source: Chapter 3

WILLIAM V. ROTH, JR.
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JOINT ECONOMIC COMMITTEE

October 18, 1993

*File Enron
CIPCC*

Dr. Joseph E. Stiglitz
Council of Economic Advisors
Old Executive Office Building, Room 345
Washington, DC 20500

Dear Dr. Stiglitz:

I am writing to recommend Dr. John Byrne, Director of the Center for Energy and Environmental Policy at the University of Delaware, as coordinating lead author for Working Group III of the International Panel on Climate Change. I have known Dr. Byrne for over eight years during which I have grown to depend upon his advice in energy and environmental policy matters.

Dr. Byrne's economic and policy expertise is well established not only in the U.S. but abroad. He has been advisor to the governments of Britain, China, Finland, India and Korea in energy and environmental matters. He has outstanding knowledge of the areas of energy efficiency, renewable energy development, external valuation and equity considerations in greenhouse policy analysis. I understand that Dr. Byrne has also worked extensively with researchers at the Chinese Academy of Science, the Tata Energy Research Institute (India) and the Korea Energy Economics Institute. I believe as a coordinating lead author Dr. Byrne would make valuable contributions to Working Group III's institutional capacity building needs and in assessing existing research on the effectiveness of different policy instruments in the context of the Climate Change Convention.

I support Dr. Byrne's selection for coordinating lead author and recommend him highly and without reservation. If you have any questions concerning this recommendation, please do not hesitate to call me.

Sincerely,

Bill Roth

William V. Roth, Jr.
U.S. Senate

*What do
we
do with
this -
Can you
update?*

WVR/pck

cc: Mr. Rafe Pomerance

He's an outstanding scholar.

WILLIAM V. ROTH, JR.
DELAWARE

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Fax Transmittal

Date: 10/21/93

To: DR. STIGLITZ , CEA

Fax Number: 395-6947

From: ~~FROM~~ SEN. ROTH.

Office Number: 224-2441

Total Pages (including cover sheet):

Comments:

Recommendation for John Byrne.

MAR 1 1994

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PNCE



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



No. 30513/M/IPCC/FORTALEZA.2

Geneva, 17 February 1994

Annexes: 2

COPY

Sir/Madam,

I have the honour to bring to your attention the First Special Workshop of the Intergovernmental Panel on Climate Change (IPCC) to be held from 11-15 April 1994 in Fortaleza, State of Ceará, Brazil at the kind invitation of the Government of Brazil through its Ministry of Science and Technology.

You may recall that IPCC has been jointly established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to carry out periodic scientific and technico-economic assessments of various issues related to climate change and to respond to the need for objective scientific and technical advice in accordance with Article 21 of the United Nations Framework Convention on Climate Change (UNFCCC).

The purpose of the workshop is to examine from the scientific and technico-economic standpoint issues related to achieving the ultimate objective of the UNFCCC. That objective, it may be recalled, is to be found in Article 2 of the Convention:

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

The workshop is the first in a series of IPCC workshops on Article 2. The subject would be further discussed at the IPCC workshop on droughts and desertification under climate change

To Ministers of Foreign Affairs of Members of WMO and UN.

- 2 -

(tentatively scheduled in Victoria Falls, Zimbabwe for August 1994) and at the Second Special IPCC Workshop planned for early 1995. A list of IPCC and related meetings is attached for your reference. These workshops will be used by the IPCC to develop the scientific-technical information for Article 2, which will be summarized in the IPCC Second Assessment Report expected to be completed in late 1995.

The workshop will be held in the Marina Park Hotel, Avenida Presidente Castello Branco 400, Fortaleza, State of Ceará, Brazil. It is suggested that participants stay in the same hotel since there are no plans for transportation from other hotels to the workshop venue. The hotel charges are \$ 62 plus tax per day for single or double occupancy. Simultaneous interpretation in English, French and Spanish will be available during the workshop.

It is with great pleasure that I extend this invitation to your Government to participate in the workshop. Given the scientific-technical nature of the workshop, it would be helpful if your Government can nominate representatives with appropriate expertise and technical background. This would also facilitate fruitful discussions within the task groups which are planned during the workshop. As you may note from the attached provisional programme, the first two and a half days would be devoted to presentations by IPCC lead authors and other invited scholars on key issues. Critical themes emerging from these presentations will then be selected by the IPCC Officers for discussion and analysis in task groups for the next day and a half.

I should be grateful if you designate the representative(s) of your Government to the workshop and communicate the name(s) and full contact information (official position, area of expertise, address, available phone/fax/telex numbers) to Dr. N. Sundararaman, the Secretary of IPCC at the IPCC Secretariat, World Meteorological Organization, P.O. Box 2300, 41 av. Giuseppe Motta, CH-1211 Geneva 2, Switzerland (phone: +41 22 7308 215/284; fax: +41 22 733 1270; telex: 414199 OMM CH). This would facilitate pre-registration of the participants.

Limited financial support is available through the IPCC Trust Fund for representatives from the developing countries and from countries with economies in transition, one per country. It is not expected that more than about 15 such participants can be supported. The allocation of support will take into account the following factors, in the order mentioned:

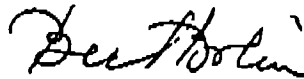
- * expertise;
- * balanced geographical representation;
- * chronology of the requests received.

- 3 -

Nominations for financial support should be sent so as to reach Dr. Sundararaman no later than 21 March 1994

Copies of this letter are being sent to the IPCC Principal Delegate and Contact Point(s), if any, the Permanent Representative with WMO and the UNEP Focal Point(s) of your country for information.

Accept, Sir/Madam, the assurances of my highest consideration.



(Bert Bolin)
Chairman,
Intergovernmental Panel on Climate Change

Richard

PROVISIONAL PROGRAMME

Monday, 11 April: Morning

OPENING CEREMONY

Session 1: Overview of the terms and concepts in Article 2

Paper 1: Interplay of Science and Politics in the Framework Convention on Climate Change

Paper 2: Scientific Issues, Knowns and Unknowns - Working Group I of the IPCC

Paper 3: Climate Change Sensitivities and Vulnerabilities - Working Group II of the IPCC

Paper 4: Social and Economic Aspects - Working Group III of the IPCC

Discussion

Monday, 11 April: Afternoon

Session 2: Sensitivity of ecosystems to climate change

The papers in session 2 will take as their starting point the initial results of the literature review with respect to maintenance of the structure and function of ecosystems and related socio-economic systems. Issues to be addressed include thresholds, effect of "multiple stresses", sensitivity to changes in extremes, and sensitivities to different rates of change.

Paper 5: Tropical forest system

Paper 6: Temperate/boreal forest systems

Paper 7: Tropical and temperate grasslands/rangelands

Paper 8: Coastal zones, including fisheries

Paper 9: Freshwater systems

Paper 10: Agriculture: Rice, Wheat and Corn

Discussion

Tuesday, 12 April: Morning

Session 2: continued

Discussion

Session 3: Regional climate simulation and prediction

Paper 11: Regional climate

Paper 12: Future climate - current status of climate modelling and predictions

Paper 13: Future climate - changes in extremes in a doubled CO₂ world (droughts, tropical cyclones, floods, winds, temperatures; relationship between changes in extremes and mean changes)

Paper 14: Recent record and impacts of climate extremes

Paper 15: Impacts of ENSO and improved ENSO forecasts

Discussion

Tuesday, 12 April: Afternoon

Emission
Scenarios



Session 4 - Linking greenhouse gas emissions and their atmospheric concentrations

Paper 16: Stabilization of carbon-dioxide for various emission scenarios

Paper 17: Feasibility and costs of achieving alternative emission scenarios and atmospheric concentrations

Paper 18: Scenarios with focus on land use implications

Discussion

Session 5: Impacts of climate change on global resource systems

Paper 19: Global ecosystem view

Paper 20: Biodiversity

Paper 21: Global and regional food production

Paper 22: Potential health impacts

Paper 23: Water resources

Paper 24: Methodological approach to Article 2: importance of regional considerations

Paper 25: Maintaining sustainable development while restricting climate change

Paper 26: Equity and socio-economic issues

Discussion

Wednesday, 13 April: Morning

Session 5: continued

Discussion

Wednesday, 13 April: Afternoon

Task Groups

Form task groups to address issues identified during the first part of the workshop. Define the "output" for the task groups. A tentative list of potential task groups is listed below:

- Natural ecosystems and biodiversity
- Food production - global and regional
- Health
- Water
- Sustainable development, equity and socio-economic issues

Thursday, 14 April: Morning

Task Groups: continued

Thursday, 14 April: Afternoon

Reports from task groups

Friday, 15 April: Morning

Considerations of the subject matter to be included on Article 2 in the IPCC Second Assessment Report



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



145 King Street West, Suite 1002, Toronto, Ontario M5H 3X6 CANADA
Tel: (416) 369-0900 Fax: (416) 369-0922

November 29, 1993

Dear Lead Author:

A concern is being expressed about the work outlines of Working Group III. It is that because of the dominance of western industrialized countries in the "main-stream" economics literature that must be assessed, a number of important social and economic issues related to global warming, and of particular concern in developing countries, may not be adequately addressed in the WG III report. If the body of published work from the industrialized countries is the only one thoroughly covered in our assessment, we would fail to present a truly global picture. We would also be in danger of losing the support of developing countries in attempting to gain world-wide intergovernmental acceptance of our report.

In particular, we must ensure that publications on some key issues of importance to developing countries are adequately addressed. These issues include:

- the disproportionate burden borne in developing regions of the potential impacts of global warming. This is most starkly evident in the case of climatically related natural disasters (storms, floods, droughts) where significant proportions of annual GNP (50% or more) or several years economic development can be obliterated in one disaster in a number of developing countries. But the disproportionately large burden is also a problem in fields of agriculture, water resources, tourism, and other economic sectors.
- recognition of the regional social, environmental, and economic benefits of existing eco-systems and ways of life that are threatened by climate change and sea level rise (e.g. in coastal communities).
- the high costs proportionally to developing countries of climate change, adaptation, and mitigation measures.

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To Joseph Stiglitz	From J.P. Bruce	
Co.	Co.	
Dept.	Phone #	

Lead Author

Page 2

November 29, 1993

These issues are discussed in many papers and publications. They should be reflected in the work of all of the writing teams, but are a particular concern of :

- Writing Team 1 - Scope of Assessment
- Writing Team 2 - Decision-Making Framework
- Writing Team 3 - Applicability of Cost-Benefit Analysis
- Writing Team 4 - Equity and Social Considerations
- Writing Team 5 - Social Costs of Climate Change (Benefits of Responses)
- Writing Team 6 & 7 - Costs of Mitigation Measures

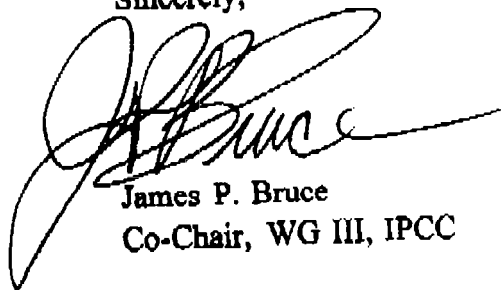
Dr. Erik Haites of the Technical Support Unit, with the assistance of members of the Bureau, the Global Commons Institute, and others, is compiling a basic bibliography of key publications in these matter and will forward them to lead authors shortly.

In addition, UNEP has now agreed to support a Workshop, July 18-23, 1994 in Kenya on Equity and Social Considerations.

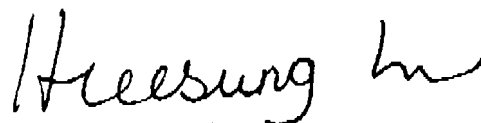
Vice-Chair Richard Odingo and Writing Team 4 will be most concerned with the organization but we urge at least one lead author from each writing team to participate.

The Bureau of WG III and the Chairman of IPCC, Dr. Bert Bolin, urge you to make special effort to reflect the above concerns in your writing work.

Sincerely,



James P. Bruce
Co-Chair, WG III, IPCC



Dr. Hoesung Lee
Co-Chair, WG III, IPCC



GLOBAL CLIMATE COALITION

*Copy to Sally sent 2/7
- Envision
File in (IPCC) 1063
This should be included in
analysis of Chapter*

Friday, February 25, 1994

Mr. Joseph Stiglitz
Council of Economic Advisors
O.E.O.B.
Room 3145
Washington DC, 20500

Dear Joseph:

As you may know, the Global Climate Coalition represents a wide range of business interests who have been actively engaged in the domestic and international economic, scientific and policy debates concerning global climate change issues. GCC member companies and associations have been involved domestically in assisting in the development of the President's Climate Change Action Plan and internationally in the Intergovernmental Negotiating Committee meetings. The GCC realizes the impact climate change policies will have on the competitive future of U.S. industry and will continue to be a voice in the development of these policies.

U.S. Industry has been a world leader on the environment and in designing new techniques for using energy more efficiently. Perhaps most illustrative of the progress industry has made in these areas are the publication of two reports:

Energy Efficiency in U.S. Industry: Accomplishments and Outlook:

This study displays U.S. industry's ability to reduce carbon dioxide intensity by using energy more efficiently, while continuing to increase production. The report demonstrates that energy efficiency improvements can be achieved through cost effective voluntary programs that do not rely on government mandates. Displayed in the report is U.S. industry's reduction of carbon emissions in all areas studied, while they performed better than the rest of the U.S. economy. The report looks at nine selected industries, including: petroleum refining, iron and steel, aluminum, paper, chemicals, cement, automobile manufacturing, electric utilities, and railroads. The U.S. improvements in energy efficiency were accomplished while lagging Japan and Germany in gross domestic investment.

The United States versus European Community: Environmental

Performance: This study shows that the United States is outpacing countries of the European Community in setting tough environmental

standards, spending on environmental protection and achieving significant environmental improvements. The report shows that in many cases U.S. emissions standards are more stringent than comparable standards in Europe under the Clean Air Act. The study also outlines a wide range of selected indicators which show that the U.S. has achieved a cleaner environment and lower levels of industrial and municipal discharges than Europe highlighting the difficulties Europe may have in reducing emissions levels to 1990 levels by the year 2000. The study further shows that the U.S. spends a greater percent of its gross domestic product on environmental protection than the European Community.

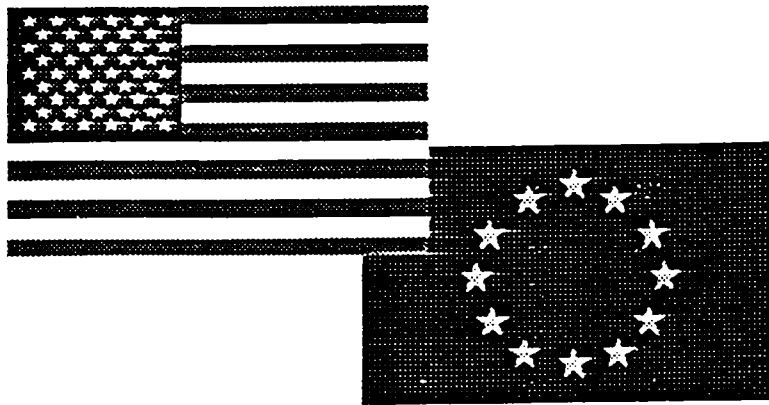
As the economic, scientific and policy debates continue both internationally and domestically, the GCC will be an active voice for U.S. industry; these issues being debated are extremely important to our economy and to our global competitiveness. Please contact me if you desire additional information, or would like to pursue this issue further.

Sincerely,

A handwritten signature in black ink, appearing to read "J Shlaes", written over the printed name and title.

John Shlaes
Executive Director

The United States
versus
European Community
Environmental Performance



The Global Climate Coalition
Revised August 13, 1993

Introduction

In the international discussion on the Framework Convention on Climate Change, the European Community (EC) and others argued that the U.S. was not taking a leadership position on global environmental issues. On April 21, 1993, in announcing the Administration's commitment to reducing emissions of greenhouse gases to their 1990 levels, the President sought to firmly establish U.S. leadership on this issue. The President stated that: "We also must take the lead in addressing the challenge of global warming that could make our planet and its climate less hospitable..."¹

All those interested in global environmental issues are closely following the activities of the developed countries as they formulate National Action Plans for Climate Change mitigation. While these plans will be an important measure of the leadership of the developed countries, it is critical that these actions be examined within the broader context of national programs to address all environmental quality issues.

To provide such a context, this discussion paper² examines and compares the environmental programs of the U.S. and the member countries of the European Community. The paper discusses differences in environmental policies and standards, as well as the actual environmental impacts resulting from the implementation of these programs. Because there are substantial differences in standard-setting, monitoring and testing procedures and enforcement mechanisms, it is not possible to provide a comprehensive, quantitative assessment of U.S. and EC environmental programs. This paper highlights a number of the

major differences across all environmental media.

Summary of Findings

The principal findings from this comparison include the following:

- **Investments in Environmental Protection:** The U.S. is allocating a substantially greater share of its GDP to environmental protection than the EC – 1.7 percent vs. 1.2 percent – a difference of 40 percent. U.S. environmental expenditures as percent of GDP are projected to grow to at least 2.7 percent by the year 2000. This estimate does not include the full cost for implementation of the Clean Air Act Amendments of 1990 and does not include the costs for any major new climate change mitigation program. The U.S. GDP projection has been adjusted to reflect the impact of the Clinton Economic Plan.
- **Air Quality:** U.S. emissions standards for stationary and mobile sources are in many cases more stringent than the EC, while ambient air quality standards are generally comparable. Actual emission levels in the U.S. will be significantly lower under the Clean Air Act Amendments of 1990 (CAAA). For example:
 - The U.S. and the EC generally have comparable standards for ambient air quality. Differences in measurement often make reported standards difficult

to compare.

- Emissions standards for new sources generally appear to be comparable between the U.S. and the EC.
- There are significant differences in the regulation of emissions from existing sources. Under the Clean Air Act Amendments of 1990, the U.S. has a stringent, new program for substantially reducing SO₂ and NO_x emissions from major existing sources. The EC has no comparable program.
- The U.S. will have reduced its emissions of sulfur dioxide to one half the level of the EC, per unit of GDP, as a result of the Clean Air Act Amendments of 1990.
- The U.S. has more stringent standards for automobile emissions and motor fuels, resulting in substantial decreases in emissions of carbon monoxide, nitrogen oxides and lead.
- **Water Quality:** For a wide range of selected indicators, the U.S. has achieved a cleaner environment and also has achieved lower levels of industrial and municipal discharges. Examples of these include:

- The U.S. has better water quality levels than the EC in major selected river systems.
- The U.S. has achieved lower levels of discharges of oxidizable material into inland water bodies.
- The U.S. has achieved higher levels of municipal waste water treatment. Almost three-fourths of the U.S. population is served by wastewater treatment facilities, higher than the EC.
- **Waste Management:** The U.S. has a more stringent and more comprehensive regulatory program for hazardous waste management.
- **Preliminary EC CO₂ Projections:** Published reports of preliminary projections of carbon dioxide emissions indicate that the EC will have difficulty in meeting a goal of stabilizing of carbon dioxide emissions by the year 2000. These preliminary projections show that estimated year 2000 emissions would be above 1990 levels.

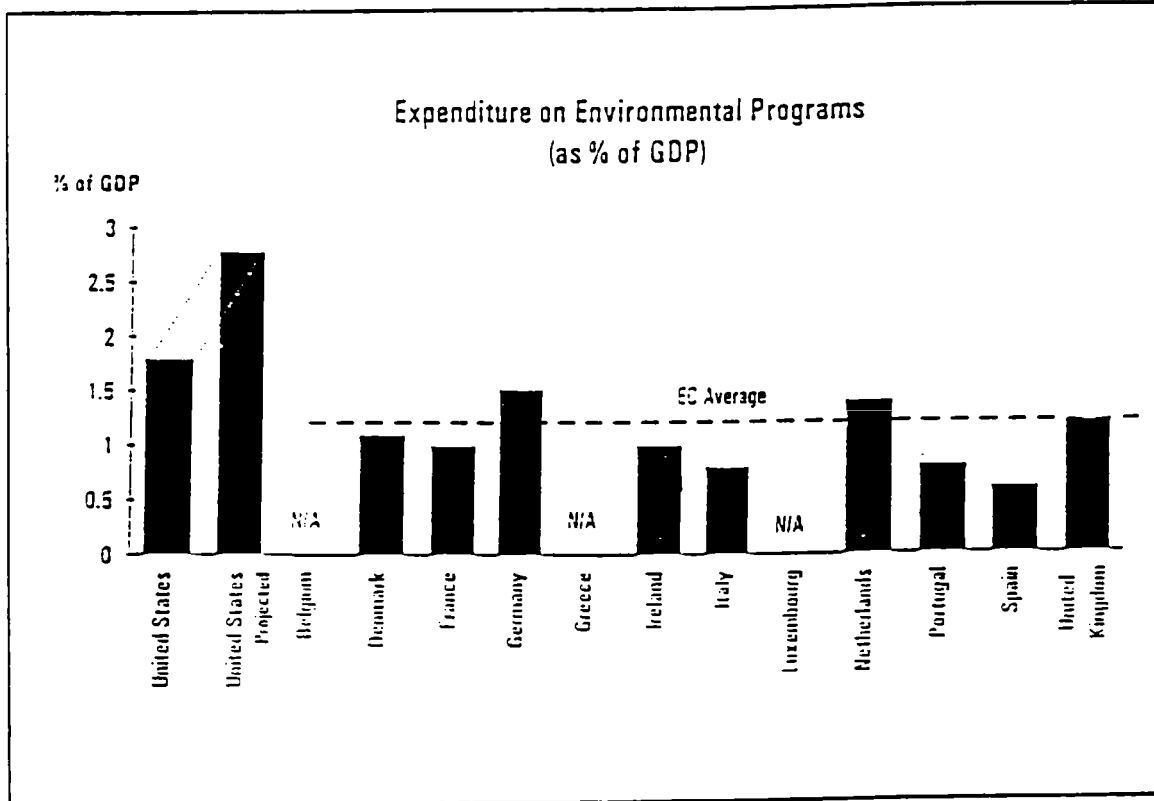


Figure 1

Sources: The State of the Environment in the European Community, 1992
Environmental Impact, EPA, 1991

Investments in Environmental Quality

Perhaps the most significant measure of a nation's commitment to environmental quality is its willingness to allocate a portion of its national wealth to investments in environmental quality. Total national expenditures for environmental quality, measured as a percent of each nation's Gross Domestic Product (GDP), illustrates both the national emphasis on environmental quality and the level of activity in improving environmental quality.

As illustrated in Figure 1, the U.S. is investing a substantially larger share of its GDP in environmental quality programs than are the European Countries. The

figure shows that the U.S. invests 1.7 percent of GDP in pollution control, substantially greater than the EC average of 1.2 percent of GDP.^{6,7,13}

In addition, based on cost estimates developed by the U.S. EPA, the level of U.S. investments in environmental quality is projected to increase to nearly 2.8 percent of GDP by the year 2000, adjusted for the new economic growth estimates contained in Clinton Economic Plan.^{7,13}

This estimate, however, may be understated, because it does not account for the full cost of the Clean Air Act Amendments of 1990. Imposition of any new requirements for curbing greenhouse gas emission also would add to this estimate.

The U.S. cost projections were prepared in 1990 and were based on the requirements of the CAA of 1977 and the amendments proposed by the Bush Administration in 1989. The costs of the 1990 Clean Air Act Amendments (CAAA), as finally passed by Congress, will be higher than the original Bush Administration proposal and are not included in these estimates.

Section 811 of the 1990 CAAA requires that: "the President shall submit to the Congress a report-

(A) identifying and evaluating the economic effects of -

(ii) the differences between the significant standards and controls required under this Act and similar standards and controls adopted and enforced by the major trading partners of the United States manufacturers.." ¹⁵

This report has not yet been issued.

Air Emissions from Stationary Sources

Ambient Air Quality Standards: The U.S. and the EC member countries have established national standards for ambient air quality. Several studies, including an analysis by the U.S. EPA, have compared the ambient standards for SO₂ and NO_x and concluded that U.S. standards were generally comparable with those of other countries. ^{2,3} The EPA study noted that differences in the way these air pollutants are measured often make reported standards difficult to interpret. ² U.S. ambient air quality standards were not modified by the CAAA of 1990, so this comparison likely will be unaffected.

Emissions Standards: Both the U.S. and the EC have adopted national standards for emissions from new facilities. A comparison of the new source standards for the United States and the European Community reveal that the standards are generally similar. ¹⁶

Table 1
Range of National Emission Standards
for Particulates, SO₂ and NO_x
(New Sources)

	EC	US
Particulates (mg/m ³)	50 - 100	40 - 125
Sulfur Dioxide (mg SO ₂ /m ³)	400 - 2000	1480
Nitrogen Oxides (mg NO _x /m ³) [*]	—	555 - 615

Notes:

^{*} No EC-wide standards; Standards are regulated by individual EC member countries.

Source: IEA, Emission Standards Handbook

The regulation of existing sources varies greatly between the U.S. and the EC. In the U.S., regulation of existing sources is generally at State and local level, although the Clean Air Act Amendments of 1990 (CAAA) established a national program for regulating the two main contributors to acid rain, namely SO₂ and NO_x. ¹⁵ In the EC, emissions from existing facilities are regulated separately by each EC member country. The EC has no regulatory program for existing sources that is comparable to the U.S. acid rain control program.

Emission Levels: Comparing actual emission levels reveals a significant

difference between the U.S. and the EC, particularly after implementation of the CAAA of 1990. This comparison is illustrated in Figure 2.

An analysis of sulfur dioxide emissions per unit of GDP shows that, as of 1989, emissions levels in the U.S. were about on a par with the EC (actual differences were less than 10 percent, within the range of accuracy of the data).¹⁸ The U.S. achievement is notable considering that the U.S. is more heavily dependent upon fossil fuels than the EC. For example, 72 percent of U.S. electricity generation capacity uses fossil fuels, compared with

57 percent in the EC.⁸

It is projected that, a result of implementation of the acid rain provisions in the CAAA, U.S. emissions will decline to about 1.9 metric tons of sulfur dioxide per \$million of GDP, which is about half the current EC levels.¹³

Forest Damage: While comparable quantitative measures are not available for all countries, the national reports submitted to the United Nations Conference on Environment and Development (UNCED) indicate that forest

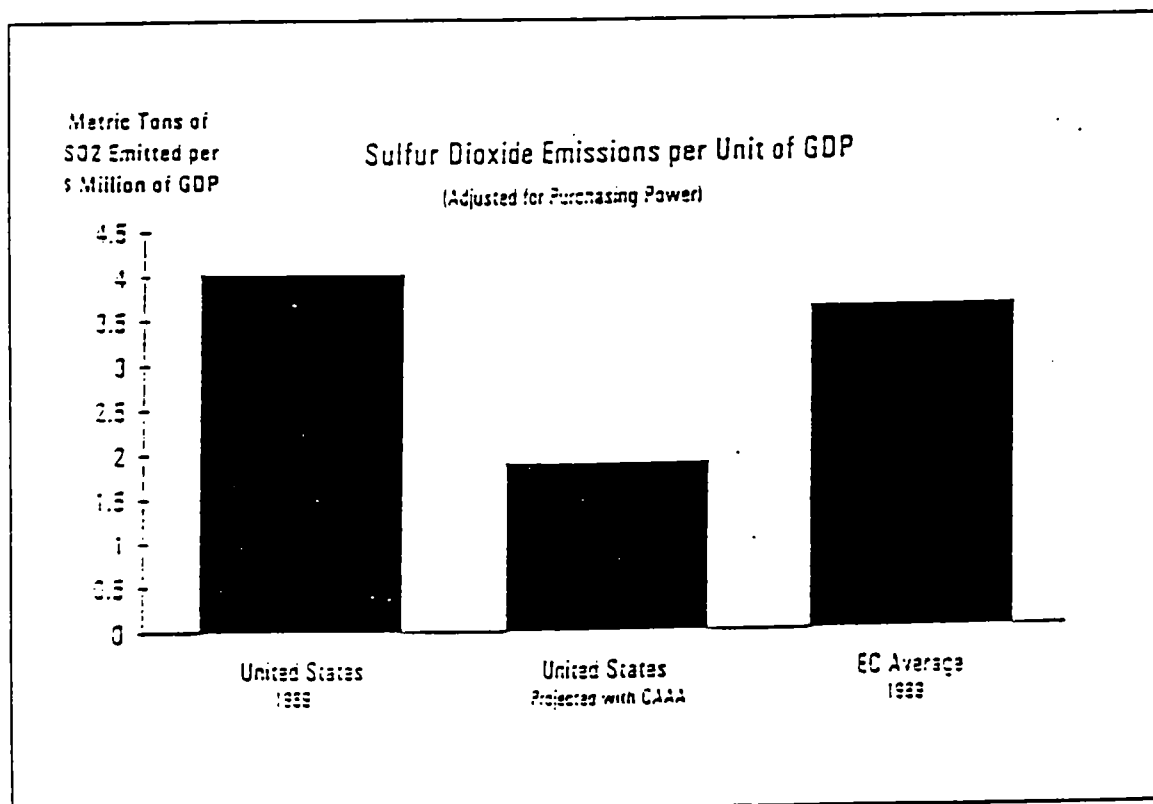


Figure 2

Source: World Resources 1992-1993: World Resources Institute
U.S. Budget, Fiscal 1994
OECD

damage from air pollution is a significant problem in Europe. Limited forest damage has been documented in the U.S. as part of the National Assessment Program for Acid Precipitation, but substantially less in scope and magnitude than Europe. In Europe, for example:

- The German National Report to UNCED noted that a 1991 forest damage survey showed significant to moderate damage to 65% of forests¹².
- The National Report from the Netherlands indicated that one third of all trees are dying¹².

Air Emissions from Mobile Sources

The United States has led automobile emission regulations in two respects:

- Emission limits are lower; and
- Testing procedures are more stringent;

Standards: Since the early 70's, the U.S. and most EC countries have adopted mobile source emissions standards. However, there has been a significant difference in the level of regulation of mobile source emissions between the U.S. and the EC. The United States established stringent mobile source emissions standards that led to the introduction of catalytic converters in new cars beginning in 1974. At the same time, the U.S. imposed stringent automobile fuel economy standards that led to a doubling of corporate average fuel economy levels

over a 15-year period. As of 1990, the United States is the only country to have a mandatory fuel efficiency requirement.⁹

Until 1989 European Community standards were much less stringent and could be met without the use of catalytic converters. In 1990 the EC adopted a new consultative directive that would require more stringent standards to take effect in 1993.⁹ These standards would require the adoption of three-way catalytic converters in most cars. At the same time, enactment of the U.S. Clean Air Act Amendments of 1990 mandated even more stringent emission standards for U.S. cars, beyond those adopted by the EC, to take effect beginning in 1994.¹³

In addition, the U.S. has adopted regulations to limit evaporative hydrocarbon emissions; the EC has not.

Testing: It is extremely difficult to quantitatively compare mobile source emissions standards, because testing procedures are significantly different. The U.S. test procedure focuses more on the urban driving cycle, while the EC test procedure places more emphasis on highway driving, which results in lower levels of emissions.⁹ Furthermore, the U.S. is imposing additional new test procedures for cold-start conditions; the EC does not have a comparable procedure.^{9,15} Achieving emission standards under cold start conditions is much more difficult than after engine warm-up has been attained.

Fuels: In addition to more stringent regulation of emissions, the U.S. also has more stringent controls over motor fuel specifications. The U.S. has led in

regulatory action to require the use of unleaded fuels as well as reduce the lead content of leaded gasoline. A 1985 analysis by EPA showed that the removal of lead from gasoline would result in substantial net benefits in improved health of children, reduced vehicle maintenance and improved fuel economy.¹⁹

Unleaded fuels were introduced in the U.S. in 1974, in conjunction with the introduction of catalytic converters. Currently, the United States has achieved 99 percent market penetration of unleaded gasoline.²³ The EC established a community-wide directive requiring the introduction of unleaded gasoline beginning in 1989,⁹ although several member companies, such as Germany, took action earlier. As shown in Table 2, market penetration of unleaded gas in the EC ranged from 0.5% to 44.5% in 1988.⁶ By comparison, by 1988, unleaded gasoline constituted 82 percent of the U.S. market¹⁷.

For the remaining supply of leaded gasoline in the marketplace, the U.S. has adopted a standard of 0.03 grams of lead per liter. By comparison, the EC standard for the maximum lead content for leaded gasoline is 0.15 grams-per-liter⁹.

Both the U.S. and the EC have established standards for constituents of diesel fuel as well. The EC has established a standard limiting the sulfur content of diesel fuel to 0.2 percent by 1994. The U.S., by comparison, requires that the sulfur content of diesel fuels be less than 0.05 percent by October 1993.¹⁴

Table 2
Market Penetration of Unleaded Gasoline in the EC (1988)

Country	% of Retail Outlets Selling Unleaded Gas	Unleaded Gas as % of Total Gas Mkt
Belgium	15	0.5
Denmark	90	33.0
FR of Germany	100	44.5
Greece	4	0.0
Spain	2	0.1
France	4	0.2
Ireland	13	0.0
Italy	15	0.7
Luxembourg	94	10.2
Netherlands	100	26.0
Portugal	3	0.0
United Kingdom	21	1.1
United States	100	82.0

Sources: *The State of the Environment in the European Community, Volume III, p. 73*
EIA Annual Energy Review

Water Quality

Standards: The United States adopted very stringent standards for controlling effluents from industrial and municipal "point sources". Since 1972 more than \$75 billion has been spent to upgrade waste water treatment facilities and minimize industrial effluents¹⁰. The EC member countries also have adopted extensive water pollution controls.

However, a detailed comparison of the two regulatory regimes is not readily available.

Ambient Water Quality Levels: The OECD has compiled selected data on ambient water quality levels for selected river systems. Table 3 displays data for four major river systems in the U.S. and selected EC countries.

The data show that for most of the pollutants measured, the Mississippi river had significantly lower levels of pollutants than major European river systems. However, it is difficult to generalize this data into national conclusions because of the wide variability of water quality levels in different river systems, as well as differences in monitoring and measurement procedures. This limited comparison does show that water quality levels in the U.S. are at least comparable, if not better, than the major EC countries.

Table 3
Water Quality for
Major River Systems

	Mississippi (U.S.)	Seine (Fr.)	Rhine (Ger.)	Thames (U.K.)
Biological Oxygen Demand (mg/l)	1.5	3.2	2.8	2.5
Nitrates (mgN/liter)	1.1	5.96	3.8	7.67
Phosphates (mgP/liter)	.23	0.84	0.25	-
Ammonium (mgN/liter)	.037	0.83	0.28	0.34
Lead (ug/liter)	4.57	20.00	2.8	1.5
Cadmium (ug/liter)	1.0	-	0.3	0.35

Source: OECD Environmental Data, 1991
Estimates taken from average of 1980's

Effluent Discharge Levels: The OECD also compiles selected statistics on total national effluent loadings into receiving waters. The data for effluent levels of oxidizable matter, known also as Biological Oxygen Demand, is shown in Table 4.¹¹ Oxidizable matter reduces the level of dissolved oxygen in rivers and streams, making them less habitable for fish. Certain high-value species of fish, such as salmon, require aquatic environments with high levels of dissolved oxygen.

The data show that average effluent levels of oxidizable matter, from all sources, and adjusted for GDP levels, are two times higher in five EC countries, for which data are available, than in the U.S. This result reflects not only differences in

Table 4
Oxidizable Matter Discharged
into Inland Waters
(Tons/Unit of GDP)

Year of Data	Country	Oxidizable Matter/Unit of Adjusted GDP
1985	United States	0.60
1986	France	1.99
1987	Germany	0.55
1982	Ireland	.65
1987	Netherlands	1.14
1985	Spain	1.86
	EC Average	1.28

Source: OECD Environmental Data Compendium,

standards, but also the effectiveness of implementation actions by industry and

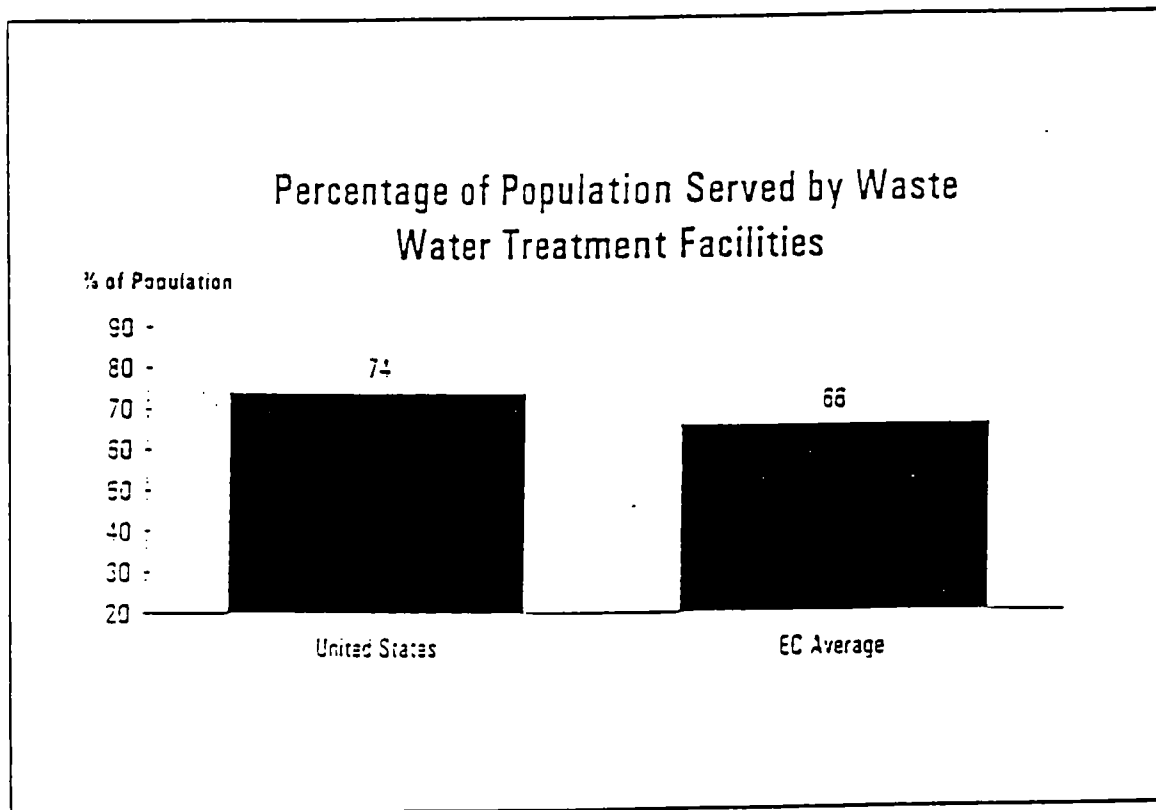


Figure 3

Sources: *The State of the Environment in the European Community.*

municipalities, as well as the effectiveness of government monitoring and enforcement programs.

Municipal Wastewater Treatment: The proportion of the population served by waste water treatment facilities is another important indicator of the national priority assigned to pollution control.

Figure 3 shows that the total percentage of the population served by primary, secondary and tertiary water treatment facilities in the United States is greater than in the European Community.⁶ Overall, 74 percent of the U.S. population

is served by wastewater treatment facilities, while in the EC, 66 percent of the national population is served. Regional differences appear to be even more striking. For instance, it's reported that about 90 percent of the sewage discharged from the southern shore of Europe into the Mediterranean Sea is completely untreated.¹⁴

Non-Point Source Run-off: Another indicator of the effectiveness of controls over water pollution is the control of "non point sources". Principal non point sources of pollution include runoff from agricultural land, construction activities

and other land disturbance practices that alter drainage patterns. As a result of improved U.S. agricultural practices, as well as utilization of more productive land resources, the U.S. currently uses fertilizer and pesticides less intensively than the EC, resulting in a lesser potential for runoff into receiving waters.³ A comparison is shown in Table 5.

Table 5
Comparison of Fertilizer and
Pesticides Use
(Tonnes per sq. km of Arable Land)

	Nitrogenous Fertilizers	Pesticides
U.S.	5	0.2
EC	12	0.6

Source: OECD Facts and Figures

The table shows that use of fertilizer in the EC is over twice as intensive as the U.S., while the use of pesticides is three times as intensive.

Waste Management

The differences in hazardous waste management practices between the United States and the European Countries are substantial. In the United States, hazardous waste is governed by two major

statutes.

The first is the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or Superfund, and the second is the Resource Conservation and Recovery Act (RCRA). While both statutes are concerned with hazardous wastes, their purposes are distinctly different. CERCLA governs the cleanup of existing hazardous waste sites. RCRA regulates the generation, transportation, treatment and disposal of newly created waste.

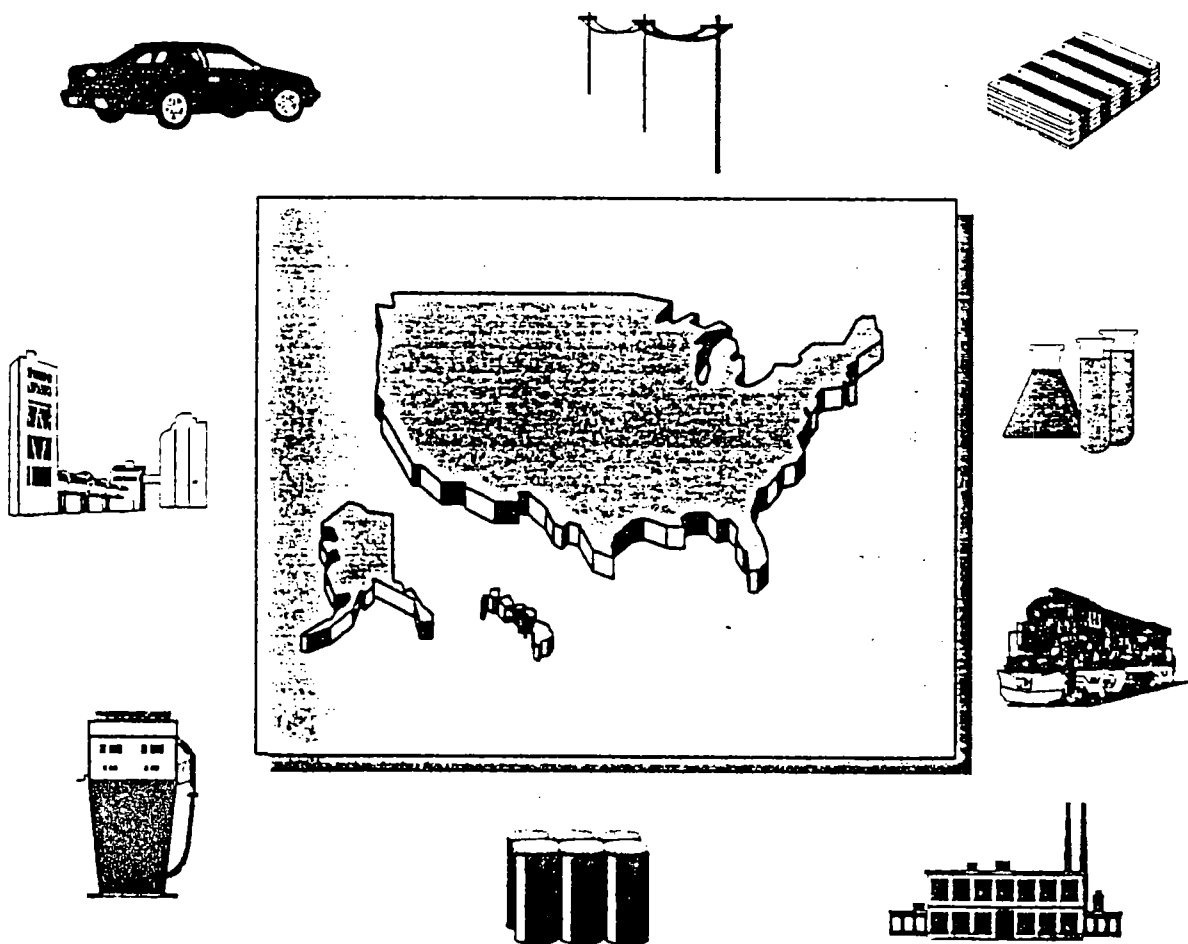
In essence, CERCLA is backward-looking and RCRA is forward-looking. A recent comparative analysis of hazardous waste management regulation in the U.S. and the EC noted that, while many European countries have legislation similar to RCRA, none are as restrictive as in the U.S.³ In addition, no European country has adopted a statute similar to CERCLA. The assessment concluded that U.S. firms are faced with higher compliance costs for hazardous waste management than firms in other major industrialized countries.³ A forthcoming study by the Business Roundtable will provide a detailed comparative analysis of waste management regulation in the U.S. and Europe.²²

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Energy Efficiency in U.S. Industry: Accomplishments and Outlook



A Report for:
The Global Climate Coalition

Prepared by:
The EOP Group, Inc

October, 1993

EXECUTIVE SUMMARY

INTRODUCTION

This report examines past and current energy performance and the effect on carbon dioxide emissions in nine selected industries: petroleum refining, iron and steel, aluminum, paper, chemicals, cement, automobile manufacturing, electric utilities and railroads.

- Seven of the nine industries are in manufacturing, and six of the seven are energy-intensive manufacturing industries.
 - The six energy intensive industries—petroleum refining, iron and steel, aluminum, paper, chemicals and cement—consume a substantial share of energy relative to their contribution to the GDP (i.e., they account for almost three-fourths of manufacturing energy consumption while providing over one-third of value-added in manufacturing).
 - The seven manufacturing industries fall into six industry sectors under the standard industrial classification (SIC) code.¹
- The remaining two industries—electric utilities and railroads—are infrastructure industries that support and contribute to the U.S. industrial base.

These industries were selected for in-depth examination because they help form the backbone of the U.S. economy, are energy intensive, and could be significantly affected by any climate-change mitigation plan.

¹ In the report, certain information is presented at the level of individual industries (three-digit SIC code), while other data is only available at the industry sector level (two-digit SIC code). For example, the chapter on automobile manufacturing discusses the automobile manufacturing industry (SIC code 371), while also presenting information at the broader industry sector level, transportation equipment (SIC code 37). Similarly, the chapter on the primary metals industry sector presents information at that level, followed by more detailed discussions of the iron and steel and aluminum industries.

- They account for nearly half of U.S. energy consumption.
- They account for nearly half of U.S. carbon dioxide emissions.
- They are large, high-wage industries. They employ almost 5.7 million workers, or 6.3 percent of total U.S. private employment. Average weekly earnings are 1.7 times the national average for the private sector.

MAJOR FINDINGS

Although there is considerable diversity among the industries examined, a number of generic issues and findings emerged in the course of the analysis.

Total energy consumption declined in eight of the industries studied. Energy consumption for electricity generation increased, due to the increased demand for electricity in a growing economy, as well as increased electrification of industrial processes. Increased electrification appears to have net benefits in improving industrial energy efficiency and reducing carbon dioxide emissions.

- Energy consumption for the seven manufacturing industries examined decreased by almost 22 percent from 1974 and 1988.
- By comparison, energy consumption for all U.S. manufacturing industries declined by 17 percent over this period.²
- The demand for electricity has increased at a faster rate than GDP and a faster rate than other energy sources, reflecting increased substitution of electricity for other fuels. The increased efficiency that occurred in other industry sectors resulted in part from increased electrification. According to the Office of Technology Assessment, "the growth is the result of electricity's superior quality, flexibility and environmental cleanliness at the point of use."

² Since 1988, total energy consumption in industry has not changed significantly. The Energy Information Administration reports that 1992 industrial energy consumption, including manufacturing, mining, construction, fisheries, agriculture and forestry, was about 5.6 percent above 1988 levels.

Energy intensity, measured as the level of energy consumption per unit of output, has declined significantly in all of the nine industries examined.

- All nine industries reduced energy intensity, the consumption of purchased energy per unit of output, by amounts varying from 6 to 41 percent between 1974 and 1988, the most recent year for which comprehensive data are available. This reduction reflects improvements in energy efficiency.
- The average energy intensity reduction for the seven manufacturing industries studied was 34.7 percent between 1974 and 1988.

Six of the industries studied reduced carbon dioxide emissions between 1974 and 1988, two industries had virtually no change, and one industry with substantial production increases had increased carbon dioxide emissions.

- Six industries—petroleum refining, iron and steel, aluminum, chemicals, cement, and railroads—reduced carbon dioxide emissions in total by 17.5 percent, or 36.7 million metric tons of carbon, between 1974 and 1988, the most recent year for which comprehensive data are available.³
- The paper and automobile manufacturing industries had virtually no change in carbon dioxide emissions.
 - In automobile manufacturing, total emissions in 1988 were 0.3 million metric tons higher than 1974 levels, even though production, as measured by the Federal Reserve Board (FRB) Index, increased by over 50 percent.
 - In the paper industry, 1988 carbon dioxide emissions were 0.01 million metric tons lower than 1974 levels, while output increased by 36 percent.
- The electric utility industry increased carbon dioxide emissions, but at a significantly lesser rate than production increases, as a result of improvements in energy intensity. Total carbon dioxide emissions increased because the use of electricity increased at a rate greater than the economy as a whole. The increased substitution of electricity for other fuels appears to be the result of a variety of economic, environmental and efficiency factors. Even though total emissions increased, the level of carbon dioxide emissions per kilowatt-hour sold decreased.

³ In this report, all data on emissions of carbon dioxide are reported as million metric tons of carbon, consistent with U.S. and international conventions on emissions reporting.

All nine industries reduced carbon dioxide emissions intensity, the emissions of carbon dioxide per unit of production. Reductions ranged from 6.2 percent to 37.4 percent between 1974 and 1988.

- The average reduction in carbon dioxide emissions intensity for the seven manufacturing industries was 29.8 percent between 1974 and 1988.
- If the seven manufacturing industries had not both improved their energy efficiency and reduced their carbon dioxide emissions intensity, then total carbon dioxide emissions for the seven would have *increased* by 96.3 million metric tons of carbon. Instead, the combined total of carbon dioxide emissions for the seven manufacturing industries *declined* by 33.8 million metric tons.
- Even though electric utilities increased total emissions of carbon dioxide, emissions intensity, the emissions of carbon dioxide per unit of production, declined by almost 7 percent between 1974 and 1988.

The nine industries examined, and manufacturing as a whole, have performed better than the rest of the U.S. economy in improving energy efficiency and reducing carbon dioxide emissions.

- The U.S. manufacturing sector, as a whole, reduced carbon dioxide emissions from 1974 to 1988 by 24.9 million metric tons of carbon, or 2.1 percent—even with a 55.8 percent increase in production. This reduced carbon dioxide emissions intensity by 41 percent.
- By comparison, total U.S. carbon dioxide emissions increased by 6.7 percent, from 1,231.1 million metric tons of carbon to 1,313.8 million metric tons of carbon.⁴

Each industry examined has implemented extensive energy efficiency improvements and is actively pursuing new initiatives today. Manufacturing industries are strongly cost-driven to improve energy efficiency wherever cost effective to do so. The specific approaches taken by each industry vary greatly. There is no "one size fits all" approach to energy efficiency improvements. In some cases, industry improvements in energy efficiency have been offset by environmental and other policy measures.

- The **petroleum refining** industry has implemented many energy conservation measures, as well as a wide range of process refinements on a continuing basis, but progress in recent years has slowed because new environmental requirements, changes in crude oil quality, and shifts in product demand are causing increased energy use in petroleum refining.

⁴ Since 1988, total U.S. carbon dioxide emissions changed only slightly. Estimated 1990 U.S. carbon dioxide emissions were 1,367 million metric tons of carbon.

- The **iron and steel** industry has implemented many energy conservation measures, as well as fundamental process changes—use of electric furnaces and continuous casting. Future improvements are dependent upon R&D for a new generation of processes, such as near-net-shape casting and direct steelmaking. These improvements have large unresolved technological uncertainties and will require significant capital investment.
- The **aluminum** industry has achieved improved energy efficiency through the implementation of a series of process refinements and improved process controls. In addition, the increased use of recycling also will result in reduced energy use and lower carbon dioxide emissions. Future changes in the U.S. aluminum industry will be extremely sensitive to the global competitiveness of U.S. electricity prices.
- The **paper** industry has achieved substantial energy efficiency improvements through the increased energy utilization of by-products and wastes and increased use of cogeneration. Residues and spent liquors comprise an increasing share of the energy used in the paper process. In addition, an increasing proportion of the electricity used in paper mills is provided by cogeneration facilities.
- The **chemicals** industry has implemented a continuous program of process refinements that have led to improved energy efficiency. Fundamental changes have been implemented in several chemical processes, substantially improving energy efficiency. Shifts in product demand, however, have had a mixed effect on overall energy consumption.
- The **cement** industry has achieved substantial improvements in energy efficiency through increased utilization of waste heat and significant process changes. Further improvements are underway to increase the utilization of waste materials (generated by other industries) as a fuel source.
- The **automobile manufacturing** industry has achieved a significant reduction in the amount of energy consumed per vehicle produced, while at the same time implementing steps to improve vehicle quality and achieve greater market share.
- The **electric utility** industry has improved the efficiency of electricity generation and reduced the level of carbon dioxide emitted per kilowatt-hour sold. In addition, the industry is implementing a major effort to improve the end use efficiency of electricity consumption through demand-side management (DSM) programs. Increased electrification of the economy, while increasing the demand for electricity, appears to have net benefits in improving energy efficiency and reducing carbon dioxide emissions.
- The **railroad** industry has achieved substantial energy efficiency improvement through more efficient operations, technology refinements, and improved system management.

From an international perspective, the achievements of U.S. industry have been substantial. U.S. industry has achieved greater improvements in energy efficiency than the manufacturing industries in the other industrialized countries, with lower levels of capital investment, and while being subject to stricter environmental standards.

- The energy intensity of U.S. manufacturing, measured as energy consumed per dollar of value-added, has declined by 50 percent from 1974 to 1988. By comparison, manufacturing energy intensity in Germany (the former Western Sector) and Japan declined by 33 percent 49 percent respectively.
- When the data are adjusted to eliminate the effects of any structural shifts (e.g., shifts from energy intensive to light manufacturing), the U.S. and Japan were about equal in energy intensity reductions. The U.S. achieved a 32 percent reduction, while Germany and Japan achieved reductions of 23 percent and 34 percent respectively.
- From the period 1970 to 1990, the U.S. lagged Japan and Germany, as well as many of the other industrialized countries, in gross domestic investment. U.S. gross domestic investment averaged 18 percent of GDP, while Germany achieved a level of 21 percent and Japan achieved a level of 30 percent.
- The U.S. has stricter standards for SO₂ and NO_x emissions and hazardous waste management than the European Community (EC). In addition, the U.S. allocates 42 percent more of its GDP to environmental protection than the EC. (The U.S. allocates 1.7 percent of GDP to environmental protection versus 1.2 percent in the EC.)

Even with the substantial improvements in energy efficiency, U.S. industry and the U.S. economy remains heavily dependent upon the cost effective use of fossil fuels.

- In 1988, 89 percent of total U.S. energy consumption was derived from fossil fuels.
- The electric utility industry sector derived nearly 70 percent of its energy requirements from the use of fossil fuels in 1988.
- In the manufacturing industries examined in this study, 85 percent of purchased energy was derived from fossil fuels in 1988.

Because fossil fuels are the predominant source of energy, any new policy measures to reduce or replace the use of fossil fuels, if not cost effective, could significantly increase costs to industry and the economy.

The improvements in energy efficiency and the reductions in carbon dioxide between 1974 and 1988 were the result of actions undertaken by industry because they were cost effective for other business purposes. They were not mandated by government standards. When energy markets are permitted to function freely and efficiently, and when government policies encourage capital investment and economic growth, industry is best able to act quickly and effectively.

- All of the industries examined improved energy efficiency and reduced carbon dioxide emissions through major capital investments in new process technologies—e.g., continuous casting, cogeneration, waste utilization, process controls, and nuclear power generation.
- Future energy efficiency gains also will be heavily dependent upon capital investment in process technology improvements. Examples identified in this report include direct steelmaking, ion-exchange membranes and low pressure oxidation.

Achieving these process technology improvements will require significant R&D investments, followed by even more substantial investments in new plant and capital equipment once the new technologies are ready for commercialization.

IMPLICATIONS FOR CLIMATE CHANGE MITIGATION PLANNING

Industry circumstances need to be carefully considered in the formulation and implementation of the Administration's Climate Change Mitigation Plan.

- Administration planning efforts need to provide flexibility to account for the wide diversity among U.S. industry sectors.
- Climate Change mitigation policies need to be carefully coordinated with other environmental, energy and economic policies to minimize any potentially conflicting requirements.
- The economic significance of U.S. energy-intensive manufacturing and infrastructure industries should not be discounted in the Administration's emphasis on information technology and other "high tech" industrial policies. Manufacturing remains a major contributor to the U.S. economy and is the source of a large number of high-wage, high-skill jobs.

- The potential for future improvements in energy efficiency in many industries is dependent upon the development and commercial deployment of new technologies, which cannot be mandated through targets and timetables.
- All of the industries examined have ongoing energy efficiency initiatives and will continue to achieve economically efficient improvements. However, the pace of industry efforts will be affected by government economic and environmental policies that constrain the availability and application of private capital investment.
- The industries examined face strong international competition in global markets. U.S. Climate Change mitigation policies must be cognizant of their impacts on international trade.
 - Actions that disproportionately increase the operating costs of U.S. industry will erode the nation's global competitive position.
 - Emissions caps or other restrictions could effectively cap U.S. manufacturing production, and lead to the export of U.S. industries (and U.S. jobs), with no diminution of global carbon dioxide emissions. Instead, a policy approach that considers carbon dioxide emissions per unit of output would avoid penalizing industry for increased production.

ADDITIONAL BACKGROUND

The analysis in this study is largely based on official government data sources, including the Department of Energy (DOE) and its Energy Information Administration (EIA), the Department of Commerce, the Department of Labor, and the Federal Reserve Board.

Data on energy consumption in manufacturing has been drawn from the DOE Manufacturing Energy Consumption Survey (MECS). 1988 is the most recent year for which MECS data is available.⁵ Where available, the MECS data has been supplemented with more recent energy data from industry trade associations.

This in-depth analysis of U.S. industry is a follow-up to previous studies for the Global Climate Coalition that provided an international comparison of the U.S. with its major competitors in the global economy.

- A previous study for the Global Climate Coalition, "Leadership in Energy Efficiency: A Comparison of the U.S. versus the Other Major Industrialized Countries", documented that the U.S. was a leader or among the leaders in energy efficiency in the residential,

⁵ Manufacturing Energy Consumption Survey, Consumption of Energy, 1988, U.S. Department of Energy, Energy Information Administration, Washington, DC, May 1991.

transportation and industry sectors. Differences in total energy consumption were often due to geographic, demographic or socioeconomic factors, and not due to differences in unit energy efficiency.

- Another study, "United States versus the European Community: Environmental Performance", documented that the U.S. generally has adopted more stringent environmental standards than the EC countries and has achieved a higher level of environmental quality.

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1 INTRODUCTION

PURPOSE AND SCOPE OF THIS STUDY

This report examines in greater detail the energy performance of U.S. industry and the resulting levels of carbon dioxide emissions. The report focuses on nine industries: petroleum, iron and steel, aluminum, paper, chemicals, cement, automobile manufacturing, electric utilities, and railroads. For each industry, the report analyzes past and current energy consumption and efficiency, provides estimates of the industry's carbon dioxide emissions, and discusses current issues and outlook.

The nine industries fall into eight industry sector categories under the standard industrial classification (SIC) code. (Two industries—iron and steel and aluminum—fall into the same SIC category—primary metals.)

- Seven of the nine industries selected for study are in the manufacturing sector, and include six industries considered to be energy-intensive industries; and
- Two of the nine industries represent infrastructure services that support and contribute to the U.S. industrial base.

The specific industries selected for study, grouped by type of industry and by Standard Industrial Classification (SIC) Code, are shown in Table 1.

The nine industries were selected for an in-depth examination because they constitute a large segment of U.S. industry, contribute substantially to the U.S. economy, and are generally considered to be energy intensive. For example:

- The seven manufacturing industries selected for study consume 74 percent of the total energy used by all U.S. manufacturers, as shown in Figure 1.
- Six of the seven manufacturing industries (contained within five SIC sectors) stand apart from the other manufacturing industries for two reasons. First, the energy intensity of

Figure 1
Manufacturing Energy Consumption
By Two-Digit SIC Industry Sector Code

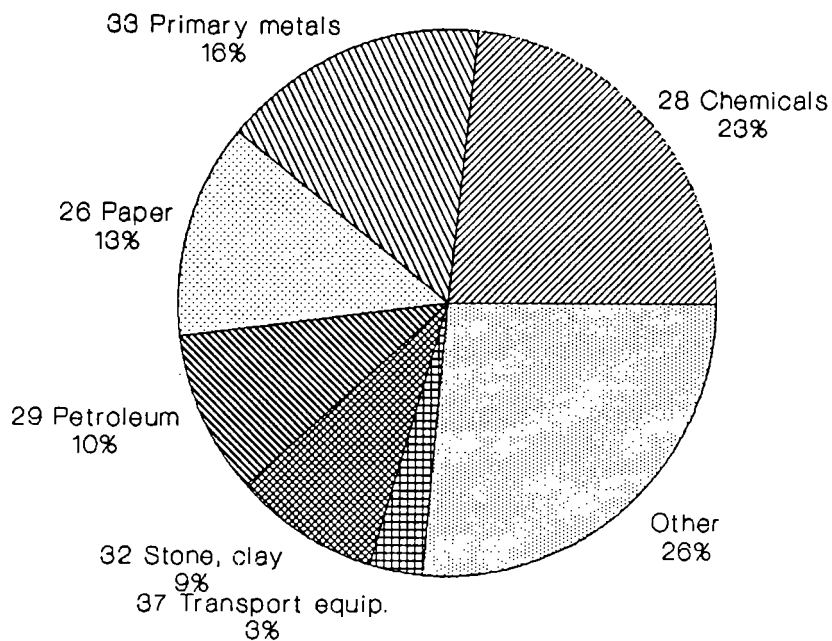
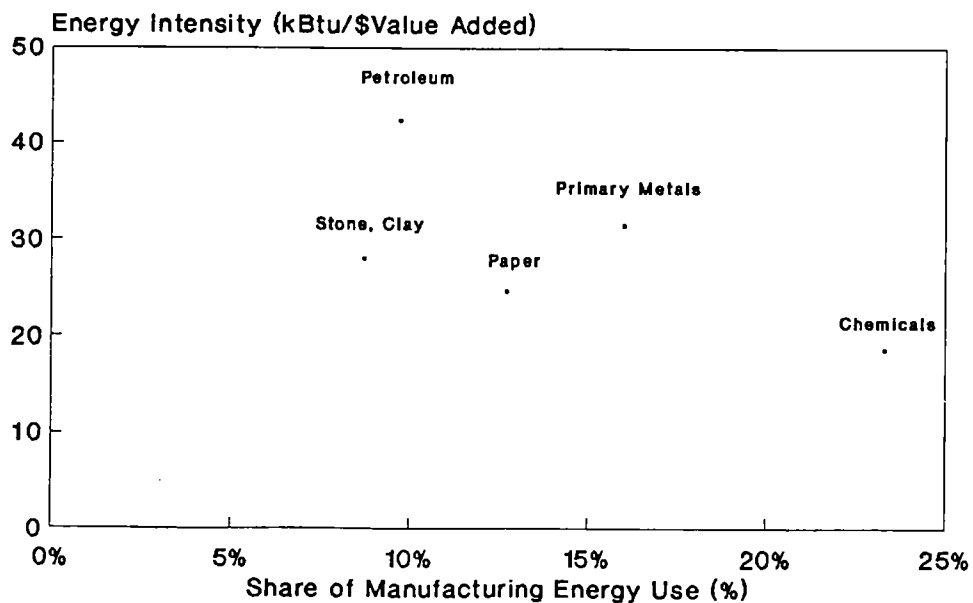


Figure 2
Energy Intensity and Energy Consumption
By Two-Digit SIC Industry Sector Code



the six industries selected is substantially greater than the others. Second, the total energy consumption of each of the six is a large share of the total U.S. manufacturing energy consumption. Figure 2 illustrates these relationships.

Table 1
SCOPE OF THE INDUSTRY SECTOR STUDY
Energy Intensive Manufacturing

<i>SIC Code</i>	<i>Industry Sector Category</i>	<i>Industry</i>
29	Petroleum & Coal Products	• Petroleum Refining
28	Chemical & Allied Products	• Chemical Manufacturing
33	Primary Metal Industries	• Aluminum • Iron & Steel
26	Paper and Allied Products	• Paper
32	Stone, Clay & Glass Products	• Cement

Non-Energy Intensive Manufacturing

<i>SIC Code</i>	<i>Industry Sector Category</i>	<i>Industry</i>
37	Transportation Equipment	• Automobile Manufacturing

Infrastructure

<i>SIC Code</i>	<i>Industry Sector Category</i>	<i>Industry</i>
491	Electric Services	• Electricity Generation
40	Railroad Transportation	• Railroads

STUDY METHODOLOGY

For each of the nine industries examined in detail, the following information and analysis was compiled:

- **ECONOMIC SIGNIFICANCE:** An overview of the industry and its economic significance (both in terms of dollars and employment).

- **HISTORICAL TRENDS:** Discussion of key historical trends in the industry, focusing on production trends, energy performance, environmental issues, and carbon dioxide emissions.
- **CURRENT ISSUES AND OUTLOOK:** A description of current issues and the outlook for the industry in terms of current energy efficiency activities, potential for future improvements, the trade-offs involved in making such improvements, and the relationship of these issues to carbon dioxide emissions.

MEASURING ENERGY PERFORMANCE: Throughout the report, energy performance is generally measured in one of two ways:

- ***Energy Consumption:*** The total amount of energy used in the industry from all fuels and electricity.
- ***Energy Intensity:*** The amount of energy used per unit of output of goods and services in the industry. (Output of goods and services is measured in terms of the value added by that industry—i.e. the value of shipments or sales, less the value of inputs to production purchased from other industries.)

CATEGORIES OF ENERGY CONSUMPTION: The information in this report on energy performance is based on two categories of energy:

- ***Purchased Energy:*** This category includes all energy purchased and delivered to the plant site. (This category of energy is referred to as "offsite-produced energy consumed to provide heat, power, and electricity" in official government data sources.) "Offsite produced energy consumed to produce heat, power, and electricity" is the most regularly available series since it was collected annually from 1974 to 1981 by the U.S. Bureau of Census in its Annual Survey of Manufactures. It was also collected by the Energy Information Administration in the Manufacturing Energy Consumption Surveys for 1980, 1985, and 1988.
- ***By-Product Fuels:*** This category includes energy that is generated on-site from non-energy sources, such as wastes and residues. It also includes the utilization of by-product from the conversion of feedstocks. (This category of energy is often referred to as "on-site energy" in many data publications.) The four major examples of by-product fuels discussed in this report are:
 - Pulp and paper residues, included in the discussion of the paper industry.
 - By-products gases from iron and steel making (e.g., coke oven gas, blast furnace gas), included in the discussion of the iron and steel industry.
 - By-products generated in the petroleum refining process.

- Waste materials from other industries used as fuel for cement kilns.

By-product fuels from other sources and in other industries are not included in this report because comprehensive data do not exist.

All data on purchased energy use generally excludes sources of energy utilized as feedstock materials to make products (e.g., the conversion of crude oil into petrochemicals).

ESTIMATING CARBON DIOXIDE EMISSIONS: All data on carbon dioxide emissions in this report are estimates based on fuel consumption data. For each industry, the various fuels used, expressed in Btus, were converted into metric tons of carbon emissions using conversion factors published by the Department of Energy. Carbon dioxide emissions are reported in one of two ways:

- *Carbon Dioxide Emissions:* Total emissions of carbon dioxide, measured as metric tons of carbon; and
- *Carbon Dioxide Emissions Intensity:* The level of carbon dioxide emissions per unit of output of goods and services in the industry. (Carbon dioxide emissions are measured as metric tons of carbon. Output of goods and services is measured in terms of the value added by that industry—i.e., the value of shipments or sales, less the value of inputs to production purchased from other industries.)

Carbon dioxide emissions for each industry include both the emissions generated on-site as well as the emissions from the generation of electricity that was ultimately consumed by that industry. The carbon emissions from the production of electricity consumed by each industry were estimated by developing an average carbon dioxide emissions factor for each Kwh of electricity consumed. This factor was developed and applied by:

- Identifying the total quantity of each fuel used to produce electricity in the U.S.,
- Calculating the total U.S. carbon emissions from each fuel using DOE published emission factors,
- Summing fuel emissions into a total of U.S. emissions for electricity generation, and calculating the carbon emissions per billion Kwh,
- Applying the standard carbon conversion factor (carbon emissions per billion Kwh) to the amount of Kwh purchased by each industry.

This approach assumes that the fuel mix in the production of electricity for each industry matches the national average mix of fuels utilized in electricity generation. This approach likely overestimates the carbon dioxide emissions from electricity consumed in aluminum production,

which largely utilizes hydroelectricity. For other industries, the differences are likely to be small.

In the discussion of industry trends, carbon emissions from the generation of electricity purchased by the industry are included in each industry's trend information. In addition, the discussion of the electric utility industry also includes data on carbon dioxide emissions in the utility trend information. Hence, carbon emissions from the utility industry cannot be added to that of the other industries without double counting.

INDEXING HISTORICAL TRENDS: Much of the data on historical trends presented in this report has been indexed to a base year, in order to highlight more clearly the relative differences in trends.

Production trends for industries are based on Federal Reserve Board (FRB) indexes of industrial production. The FRB indexes measure changes in the physical volume or quantity of output. A series such as annual tons of steel is converted into relative quantities (indexes) with the base period set at 100. Individual series of these relative indexes are combined by:

- Multiplying each series by a base-year weight factor based on the value-added for that line of production,
- Adding the year's products for each index that is being combined,
- Dividing the sum for each year by the sum of the weights.

In the presentation of production trends in this report the FRB relative index values were adjusted to a base level of 100 in 1974. This provided a standardized measure that could be used across industries.

The trends of energy intensity and of carbon intensity for each industry also were indexed in a similar manner, with 1974 values set equal to 100.

DATA SOURCES USED IN THIS STUDY: The large majority of the data presented in this study has been obtained from official government data sources, including the Department of Energy and its Energy Information Administration, the Department of Commerce's Bureau of the Census and Bureau of Economic Analysis, and the Department of Labor's Bureau of Labor Statistics. The official government data has been supplemented in selected instances with industry data compiled by the respective trade associations. In many cases, the trade association data are more recent than the government data or provide more detailed disaggregation than is contained in government databases. Data sources have been carefully documented throughout the report.

Three standard concepts of energy consumption are used in energy statistics and in energy studies, sometimes without clearly specifying which is used. This study will use the following terms:

- ***Purchased Energy*** will be used in this report as shorthand for the DOE/EIA defined concept of "off-site produced energy for heat, power, and electricity generation" which includes only energy sources produced off-site and consumed on-site. Energy sources consumed as feedstock and by-product fuels are excluded.
- ***By-Product Fuels*** will be used in this report to refer to energy from fuels resulting from the use of energy materials or non-energy material as raw materials inputs or from energy produced from non-energy materials. The combination "purchased and by-product energy" is equivalent to the DOE/EIA defined concept "total inputs of energy for heat, power, and electricity generation."

The 1974 to 1988 statistical trends presented in this report for the two-digit SIC code industry sectors are based on purchased energy, since only that category of data is available over the period for manufacturing disaggregated to that level.

The 1985 and 1988 Manufacturing Energy Consumption Surveys are the only sources which include comprehensive data on energy consumption in manufacturing. Data for 1974 through 1981 are from the Annual Surveys of Manufactures and the 1977 Census of Manufacturers. These sources only include purchased energy. Estimates for 1982 to 1984 and 1986 to 1987 are derived by DOE/EIA from the available Surveys and Censuses and only include purchased energy.

The preferable concept to use in this report would be purchased and by-product energy, since consumption of both purchased energy and by-product energy generate carbon emissions. Use of energy materials for feedstocks rather than for fuels does not generate carbon emissions.

In addition to industry purchased energy trends for 1974 to 1988, this study presents purchased and by-product energy trends for the 1985 to 1988 period for three industries where consumption of by-product energy is substantial: petroleum refining, iron and steel, and paper and allied products.

2 BACKGROUND

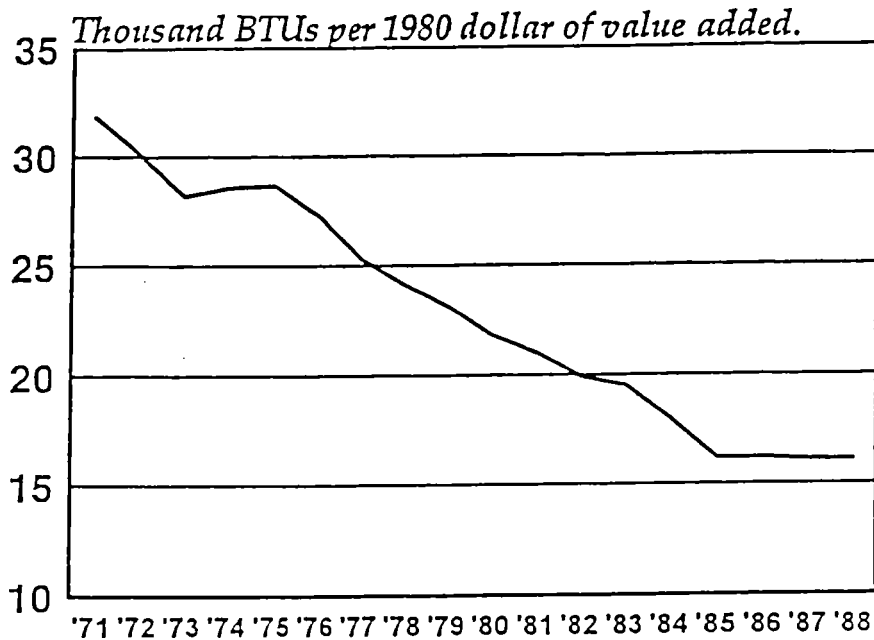
U.S. INDUSTRIAL ENERGY EFFICIENCY TRENDS

From 1970 to 1988, the energy intensity of U.S. manufacturing declined by 50 percent, as shown in Figure 3. Manufacturing energy intensity is measured as the amount of energy consumed per dollar of value added. Measuring energy intensity in this manner normalizes the data for differences in the level of industrial output, but not for structural shifts in the categories of manufacturing. Energy intensity in the most energy-intensive manufacturing industry sectors declined by 40 percent, as shown in Figure 4. The energy intensive industries included in this trend analysis include pulp and paper; chemicals; stone, clay and glass; ferrous metals; and non-ferrous metals.

This improvement was due to a variety of factors. Although some of this improvement is due to structural changes in the industrial sector towards less energy-intensive types of industry, the most significant factor affecting the rate of improvement was improvement in efficiency. According to one study, if there had been no structural change in the U.S. manufacturing industry sector during this period, U.S. manufacturing energy intensity still would have improved by about 32 percent.

Figure 3

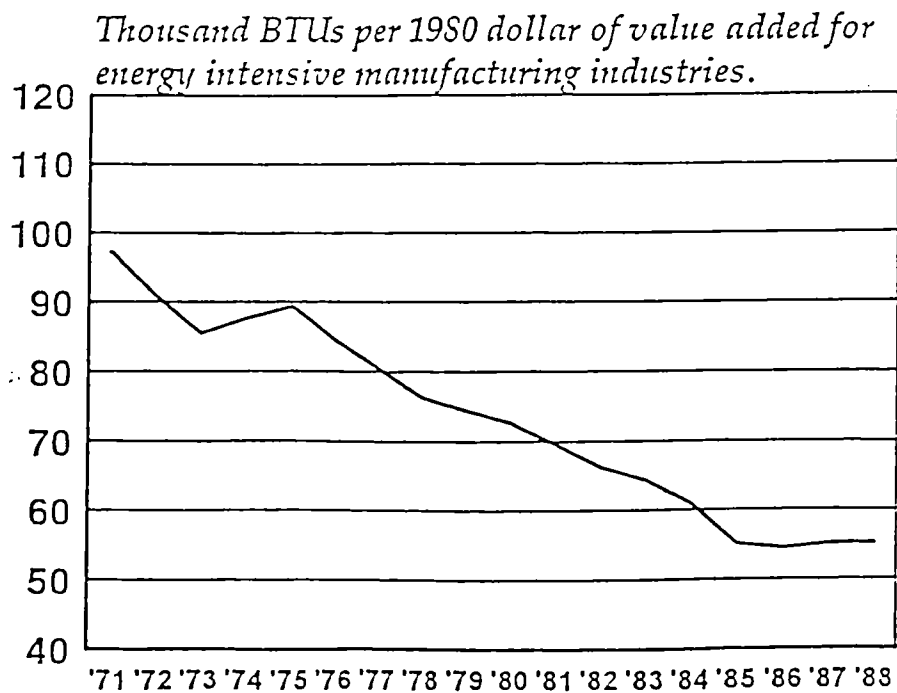
U.S. Manufacturing Energy Performance Has Improved by 50%



Source: Schipper

Figure 4

Energy Performance In U.S. Energy Intensive Manufacturing Has Improved by Over 40%



Source: Schipper

INTERNATIONAL TRENDS AND COMPARISONS

U.S. industry is operating in an increasingly competitive global environment. Changes in energy and environmental policies can have a significant impact on the competitiveness of U.S. industry. Similarly, changes in the policies of our major trading partners can also affect the relative competitiveness of their global industries.

International Industrial Energy Performance

Energy consumption in the seven major industrialized countries (the G-7) accounts for 40 percent of the world's energy. The combined 24 countries of the Organization for Economic Cooperation and Development (OECD) account for 38 percent of global net carbon dioxide emissions from all sources, including deforestation. In contrast, the United States alone accounts for 24 percent of world energy consumption but only 18 percent of global net carbon dioxide emissions. The U.S. share of global energy consumption and carbon dioxide emissions has been decreasing and is projected to decrease further.

An earlier study for the Global Climate Coalition, "Leadership in Energy Efficiency: A Comparison of the U.S. versus the Other Major Industrialized Countries", examined historical trends and current levels of energy efficiency among the G-7 countries, including (in alphabetical order) Canada, France, Germany (Western Sector only), Italy, Japan, the United Kingdom, and the United States.

The previous report analyzed separately the transportation, residential and industrial manufacturing sectors of these countries. Within the industrial sector, the study focused on manufacturing industries. International energy performance was examined in three ways: total energy *consumption*, energy *intensity* (consumption per capita or per unit of Gross Domestic Product (GDP) and *unit energy efficiency* (consumption per unit of activity, adjusted to account for geographic, demographic and economic factors unrelated to energy efficiency).

On an international basis, the U.S. achieved the greatest reduction in manufacturing energy intensity among the major industrialized countries. Japan achieved a 49 percent reduction, almost matching the U.S., while Germany achieved a 33 percent reduction. A detailed statistical disaggregation of the data showed that reductions due to efficiency improvements alone were similarly comparable. For example, on a structure-adjusted basis, the U.S. achieved a 32 percent reduction in energy intensity, compared with a 34 percent reduction in Japan and a 23 percent reduction in Germany.

CURRENT LEVELS OF ENERGY PERFORMANCE: Despite the significant improvement in U.S. manufacturing energy intensity, on an absolute basis the U.S. manufacturing sector continues to consume more energy per dollar equivalent of value added. A more detailed analysis showed

that differences in the energy intensity in the five most energy intensive sectors—pulp and paper; chemicals; stone, clay, and glass; ferrous metals; and non-ferrous metals—account for the majority of the international differences in total manufacturing energy performance. When these five industries are removed from the comparison, historical trends show a convergence among the U.S., Germany, Japan, and France. This is illustrated in Figure 5.

FACTORS AFFECTING INTERNATIONAL INDUSTRIAL ENERGY PERFORMANCE: The earlier study noted that structural differences appear to account for much of the disparity in energy performance in energy-intensive industries between the U.S. and other countries. For example, the study identified the following factors as having a significant impact on relative energy efficiency:

- ***Degree of Vertical Integration:*** The degree of vertical integration within an industry affects the energy performance of that industry. For example, in the wood products industry, Japan imports cut wood that has already gone through the energy-intensive stages of felling, stripping, cutting, etc. By comparison, the U.S. wood products industry is fully integrated, including the more energy-intensive stages.
- ***Use of Raw Materials:*** Differences in the use of raw materials can account for significant differences in manufacturing energy performance. For example, primary aluminum production from bauxite is substantially more energy intensive than secondary production, which uses aluminum scrap as feedstock. Canada and the U.S. both produce more primary aluminum than the other industrialized countries, while Japanese aluminum production is almost entirely from scrap.
- ***Waste Utilization:*** The data on total energy consumption do not account for changes due to the increased use of waste and by-products as energy sources. Data on manufacturing energy consumption often measures *total* energy consumption, regardless of the fuel source. This can be misleading. For example, the energy intensive paper industry has derived an increasing share of its energy from residues of the paper manufacturing process. Thus, the degree of energy independence in the U.S. pulp and paper industry has been much more significant than indicated by manufacturing energy intensity data alone.
- ***Availability of Investment Capital for New Plant and Equipment:*** Major energy efficiency improvements usually require significant investment in new plant and equipment. Opportunities for the deployment of new plant and capital equipment may be limited by inadequate investment capital. Overall, gross domestic investment as a percentage of GDP has been substantially lower in the U.S. than in other industrialized countries over the past two decades. As shown in Figure 6, U.S. gross domestic investment has averaged about 18 percent of GDP, compared to 21 percent for Germany and 30 percent for Japan.

Figure 5
 U.S., German and Japanese Energy Intensity Levels
 Converged in Non-Energy Intensive Manufacturing
Thousand BTUs per 1980 dollar of value added

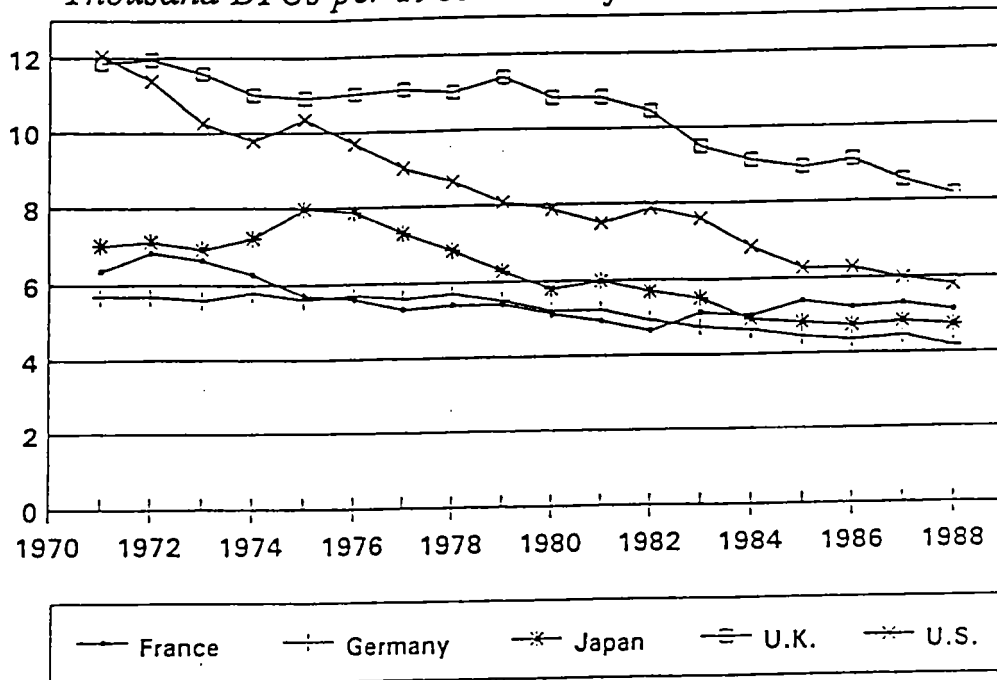
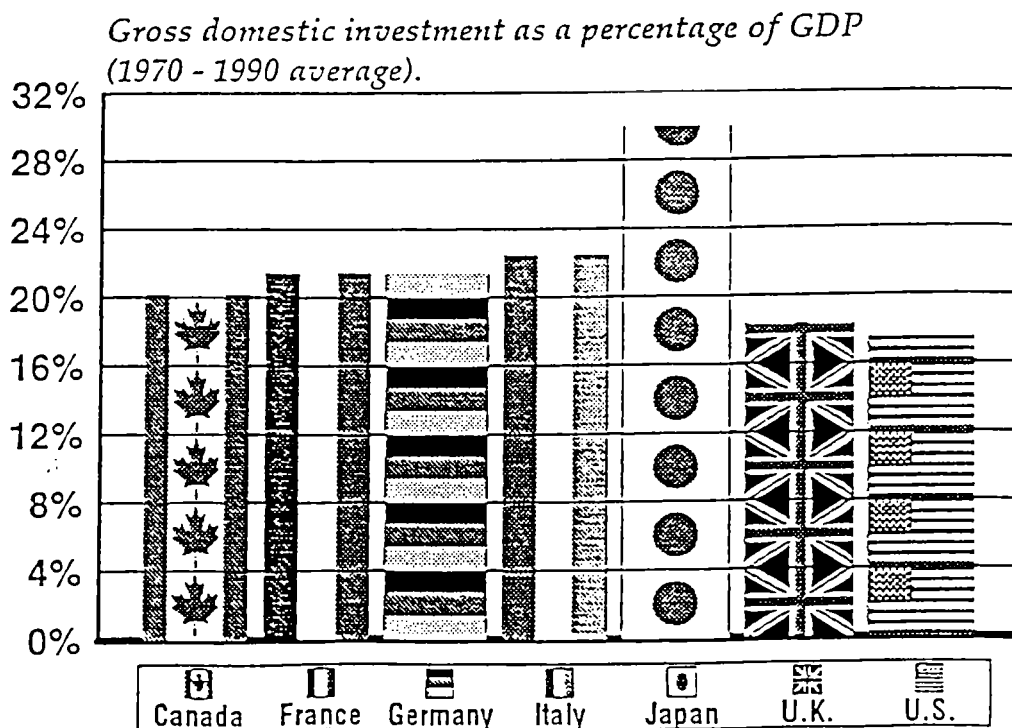


Figure 6
 The U.S. Has Lagged the Other Major Industrialized
 Countries In New Capital Investment



Source: World Tables

- **Product Mix:** Differences in consumer demand can lead to differences in product mix that affect energy consumption. For example, the both the European and Japanese automobile industries produce a much greater share of small cars than does the U.S.
- **Firm-Specific and Facility-Specific Factors:** There also may be many important firm-specific factors that affect energy consumption, such as the size and scale of facilities, age of facilities, distances to raw materials, and distances to markets.

The current study was undertaken in order to further examine these and other issues through a more detailed analysis of specific U.S. industries.

INTERNATIONAL ENVIRONMENTAL STANDARDS AND PERFORMANCE

The level of environmental standards can be an important factor affecting industrial energy performance. All of the major industrialized countries have taken significant action to protect and enhance environmental quality. As a first step toward understanding international environmental standards affecting industry, the GCC released a discussion paper ("The U.S. versus the European Community: Environmental Performance") that examined the environmental programs of the U.S. and the member countries of the European Community (EC).

The paper discussed differences in environmental policies and standards, as well as the actual environmental impacts resulting from the implementation of these programs. Because there are substantial differences in standard-setting, monitoring and testing procedures, and enforcement mechanisms, it was not possible to provide a comprehensive, quantitative assessment of U.S. and EC environmental programs. The paper highlighted a number of the major differences across all environmental media, including the following.

- **Investments in Environmental Protection:** The U.S. allocates a substantially greater share of its GDP to environmental protection than the EC—1.7 percent versus 1.2 percent—a difference of 40 percent. U.S. environmental expenditures as percent of GDP are projected to grow to *at least* 2.7 percent by the year 2000. This estimate does not include the full cost for implementation of the Clean Air Act Amendments of 1990 (CAAA) and does not include the costs for any major new climate change mitigation program. The U.S. GDP projection has been adjusted to reflect the impact of Clinton Administration economic and budget proposals.

- **Air Quality:** U.S. emissions standards for stationary and mobile sources are in many cases more stringent than the EC, while ambient air quality standards are generally comparable. Actual emission levels in the U.S. will be significantly lower under the CAAA. Thus:
 - The U.S. and the EC generally have comparable standards for ambient air quality. However, differences in measurement often make reported standards difficult to compare.
 - Emissions standards for new stationary sources generally appear to be comparable between the U.S. and the EC.
 - There are significant differences in the regulation of emissions from existing stationary sources. Under the CAAA, the U.S. has a stringent, new program for substantially reducing SO₂ and NO_x emissions from major existing sources. The EC has no comparable program.
 - The U.S. will have reduced its emissions of sulfur dioxide to one half the level of the EC, per unit of GDP, as a result of the CAAA.
 - The U.S. has more stringent standards for automobile emissions and motor fuels, resulting in substantial decreases in emissions of carbon monoxide, nitrogen oxides, and lead.
- **Water Quality:** For a wide range of selected indicators, the U.S. has achieved a cleaner environment and also has achieved lower levels of industrial and municipal discharges. Examples of these include:
 - The U.S. has better water quality levels than the EC in major selected river systems.
 - The U.S. has achieved lower levels of discharges of oxidizable material into inland water bodies.
 - The U.S. has achieved higher levels of municipal waste water treatment. Almost three-fourths of the U.S. population is served by wastewater treatment facilities, higher than the EC.

- ***Waste Management:*** The U.S. has a more stringent and more comprehensive regulatory program for hazardous waste management and prohibits co-disposal and waste mixing, which are permitted in some EC countries.

The current study examines in more detail selected environmental issues affecting U.S. industrial energy performance.

3 FINDINGS AND CONCLUSIONS

This chapter summarizes the major findings and conclusion of the study. Although there is considerable diversity among the industries examined, a number of generic issues emerged in the course of the analysis. The generic issues are discussed here.

ECONOMIC SIGNIFICANCE OF THE INDUSTRIES EXAMINED

The nine manufacturing and infrastructure industries examined in this study, as well as U.S. manufacturing as a whole, are key both to the health of the U.S. economy and to U.S. achievement in reducing carbon emissions.

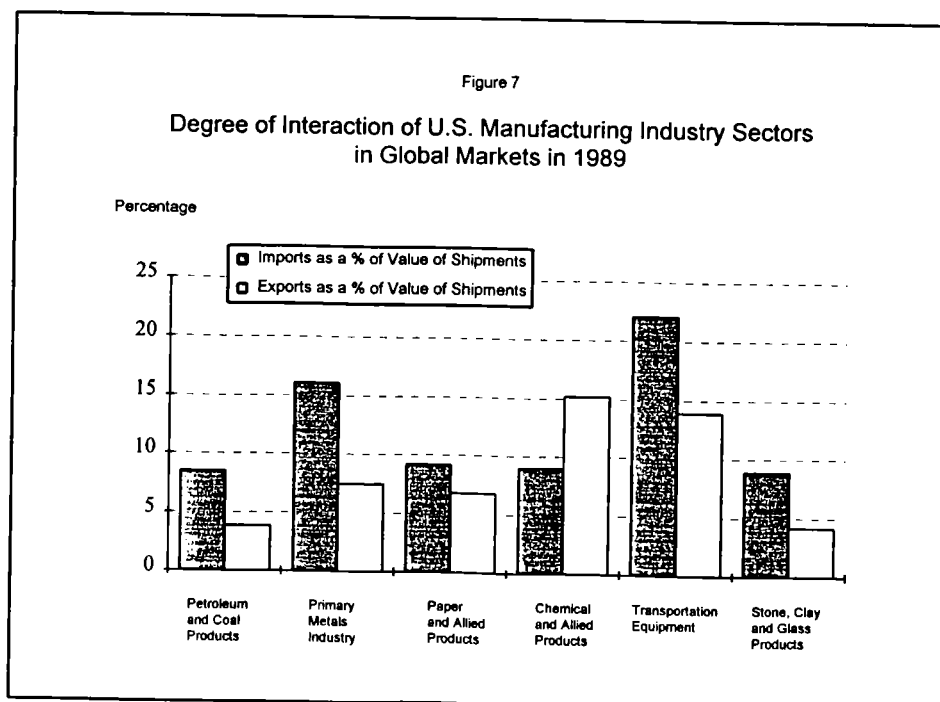
The seven manufacturing industries examined in this study:

- Are a significant share of manufacturing, accounting in 1991 for 36 percent of the 1.3 trillion dollars of value added by manufacturing.
- Used almost three-fourths (73.0 percent) of the total energy consumed by manufacturing. In 1988, the seven industries consumed 8.1 quadrillion Btus, compared to 11.1 quadrillion Btus for all manufacturing industries.
- Are heavily dependent upon fossil fuels and electricity generated from fossil fuels. These industries produce almost three-fourths (73.4 percent) of manufacturing's carbon dioxide emissions. In 1988, these industries emitted 208.3 million metric tons of carbon, compared with 283.9 million metric tons for all manufacturing. (Excluding the emissions from purchased electricity, the seven manufacturing industries emitted directly 126.1 million metric tons of carbon, or 84 percent of the 150.3 million metric tons directly emitted by U.S. manufacturing industries.)
- Are a major employer, accounting for 27.3 percent of total U.S. manufacturing employment.

Overall, the **nine industries** examined in this study—the seven manufacturing industries plus the two infrastructure industries:

- Employed almost 5.7 million workers, or 6.3 percent of total U.S. private employment.
- Accounted for nearly half (47.0 percent) of 1988 U.S. energy consumption. The nine industries in total used 35.0 quadrillion Btus, compared to the U.S. total of 74.4 quadrillion Btus.
- Accounted for almost half (48.1 percent) of the total U.S. carbon dioxide emission in 1988 (from fossil fuels and cement), consistent with the relative levels of energy consumption. They emitted 632.4 million metric tons of carbon, compared to the U.S. total of 1313.8 million metric tons of carbon.
- Are high wage industries, with weekly production worker earnings of \$618.95, which is **1.7 times** the average for all U.S. private employees (\$364.30).

The seven manufacturing industries included in this study (which are grouped into six two-digit SIC industry sectors) compete in global markets. Five of these six industry sectors have substantial net imports; chemicals, the remaining manufacturing industry sector, has a significant net export market. Any significant changes in industry costs could adversely affect the competitive position of these industries in international markets. For example, any new climate change mitigation measures that disproportionately increase the costs of U.S. manufactured products could lead to the loss of global markets, i.e., either an increase in net imports or reduction of net exports. Figure 7 summarizes the data on import and export shares for the manufacturing industry sectors, organized by two-digit SIC code.



PATTERNS OF ENERGY USE IN INDUSTRY

U.S. Industry is characterized by a diversity of processes. As a result, patterns of energy consumption, and opportunities for energy efficiency improvements, can vary greatly. For example:

- For two plants in the same manufacturing industry, there may be different processes and equipment employed, with different end-use energy consumption patterns.
- Even within a single plant, it is often difficult to accurately measure and allocate energy consumption to specific end-use categories.

A number of studies have attempted to analyze and classify energy consumption patterns within specific industries. These studies have produced different, though related, end-use classification schemes that were developed to facilitate analysis dealing with the primary objectives of each study. In the broadest sense, these studies usually addressed at least three different categories of energy use:

- Motor drives,
- Process energy, and
- Lighting and space conditioning.

These three categories, along with specific examples, are displayed in Table 2.

Table 2 CONCEPTUAL VIEW OF INDUSTRIAL ENERGY UTILIZATION	
<i>Categories of Energy Use</i>	<i>Opportunities for Future Energy Efficiency Improvements</i>
• Motor Drives	• High efficiency motors (e.g., variable speed drive)
• Process Energy (Electrolytes and Process Heat)	• Improved Maintenance
	• Improved Process Controls
	• Incremental Process Refinements
	• Fundamental Process Changes
• Lighting & Space Conditioning	• High efficiency lighting and HVAC systems

These categories provide a conceptual framework for discussion of trends in energy consumption and energy efficiency as well as for analysis of the factors contributing to those trends. However, it is not possible to quantify energy-use patterns at this level of detail. It is virtually impossible to find good quality data on energy consumption at this level of detail within industries and across industry sectors. The study by the Office of Technology Assessment, *Industrial Energy Efficiency*, August 1993, was the most recent attempt to provide estimates of energy consumption by major category of industrial energy use. These estimates are shown in Table 3. The data provide a rough guide to relative areas of energy consumption within industry sectors.

MAJOR FINDINGS

1. The nine industries examined in this study have achieved substantial improvements in energy performance in the 1974 to 1988 period:

- Eight of the nine industries examined—petroleum refining, iron and steel, aluminum, paper, chemicals, cement, automobile manufacturing and railroads—reduced the amount of purchased energy.
- Electric utilities increased the generation of electricity by 51.1 percent but increased its energy consumption by only 42.5 percent. The use of electricity increased faster than the overall rate of growth in the economy, due to the increased substitution of electricity for other fuels.
- All nine industries examined reduced energy intensity, the consumption of energy per unit of output, between 1974 and 1988 by amounts ranging from 5.7 to 41.0 percent.
- For the nine industries, the combined total for the consumption of purchased energy showed an increase of 21.1 percent over the same period.

Table 3
ENERGY CONSUMPTION BY FUNCTIONAL
USES IN SELECTED INDUSTRY SECTORS
1985
(TRILLION BTUS)

<i>INDUSTRY SECTOR (2-DIGIT SIC CODE)</i>	<i>STEAM</i>	<i>DIRECT PROCESS HEAT</i>	<i>MACHINE DRIVE</i>	<i>ELECTRO LYTIC</i>	<i>SPACE HEAT</i>	<i>FEEDSTOCKS</i>	<i>MISC.</i>	<i>Co-Generated Electric</i>	<i>TOTAL</i>
Petroleum Refining	1,100	1,300	200	---	< 50	---	< 50	< 50	2,600
Primary Metals	400	900	200	300	< 50	1,000	100	< 50	2,900
Paper	1,700	200	400	---	< 50	---	< 50	100	2,200
Chemicals	1,300	500	600	100	< 50	1,300	< 50	100	3,700
Transportation Equipment	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Stone, Clay & Glass	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source: OTA

2. **Six industries achieved lower carbon dioxide emissions. Carbon dioxide emissions in two industries were virtually unchanged. One industry had increased carbon dioxide emissions. The performance of the nine industries is shown in Figure 8.**
- Six industries—petroleum refining, iron and steel, aluminum, chemicals, cement, and railroads—reduced carbon dioxide emissions in total by 17.5 percent, or 36.7 million metric tons of carbon, between 1974 and 1988, the most recent year for which comprehensive data are available.⁶
 - The paper and automobile manufacturing industries had virtually no change in carbon dioxide emissions.
 - In automobile manufacturing, total emissions in 1988 were 0.3 million metric tons higher than 1974 levels, even though production, as measured by the federal reserve board index, increased by over 50 percent.
 - In the paper industry, 1988 emissions were 0.01 million metric tons lower than 1974 levels, while output increased by 36 percent.
 - The electric utility industry increased carbon dioxide emissions, but at a significantly lesser rate than production increases, as a result of reductions in energy intensity. During this period, the use of electricity increased at a rate greater than the economy as a whole, as a result of increased substitution of electricity for other fuels. Increased electrification of the economy appears to have resulted from economic, environmental and efficiency considerations.
 - All nine industries reduced carbon dioxide emissions intensity, the level of carbon dioxide emissions per unit of output, between 1974 and 1988 by amounts ranging from 6.2 to 37.4 percent. A comparison of the nine industries is shown in Figure 9.
 - These energy and carbon dioxide improvements were achieved despite substantial increases in industry production that usually ranged from 20 to nearly 60 percent. Two industries experience lesser production increases: petroleum and coal products increased by 11.8 percent, and primary metals decreased by 18 percent.

⁶In this report, all data on emissions of carbon dioxide are reported as million metric tons of carbon, consistent with U.S. and international conventions on emissions reporting.

3. The entire U.S. manufacturing sector, including the seven manufacturing industries examined in this study, have performed better than the rest of the U.S. economy in increasing energy efficiency and in reducing carbon emissions.

- The seven manufacturing industries together reduced carbon dioxide emissions from 1974 to 1988 by 33.8 million metric tons of carbon, 14.2 percent.
- The entire U.S. manufacturing sector, which accounted for almost one-fourth of GDP, reduced carbon dioxide emissions from 1974 to 1988 by 24.9 million metric tons of carbon, 8.1 percent, even with a 55.8 percent increase in production. This reduced carbon dioxide emissions intensity by 41 percent.
- By comparison, total U.S. carbon dioxide emissions increased by 6.7 percent, from 1,231.1 million metric tons of carbon to 1,313.8 million metric tons of carbon. (Since 1988, total U.S. carbon dioxide emissions have changed only slightly. Estimated 1990 emissions were 1,367 million metric tons of carbon.)
- Table 4 summarizes trends in carbon dioxide emissions for the industries examined in this study, for all manufacturing, and for the entire U.S.

Figure 8

Change in Production and Carbon Dioxide Emissions in Selected Industries, 1974- 1988

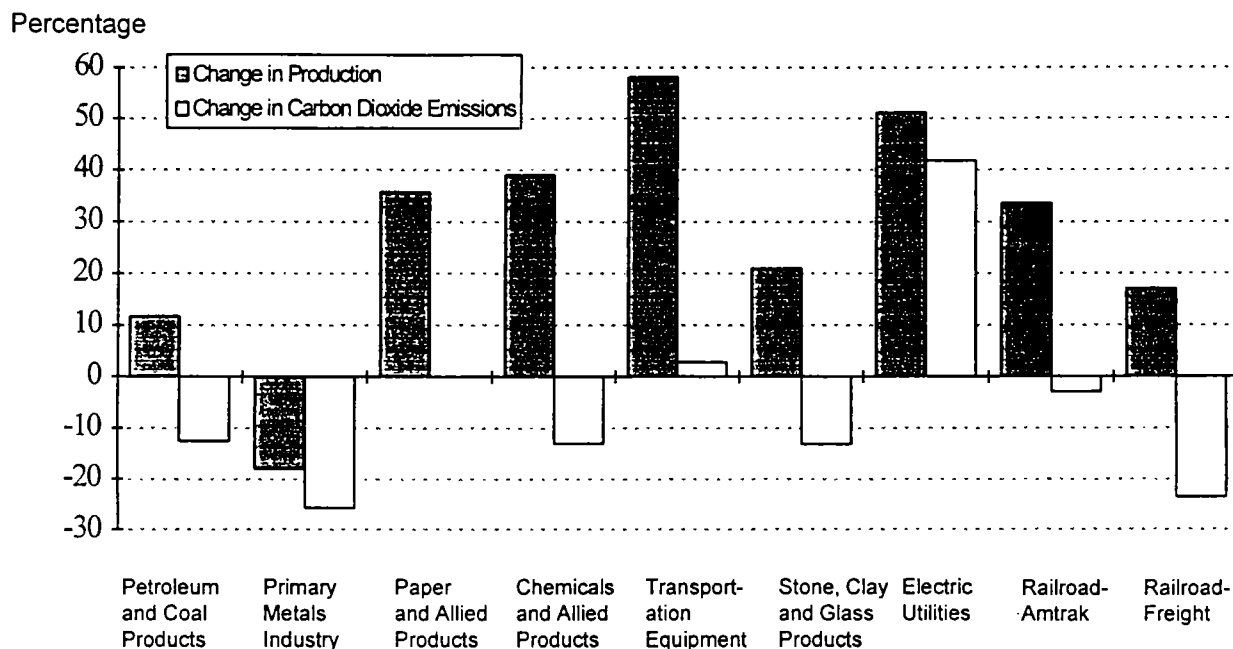


Figure 9

Reduction in Carbon Intensity, 1974- 1988 (Carbon Dioxide Emissions Per Unit of Output)

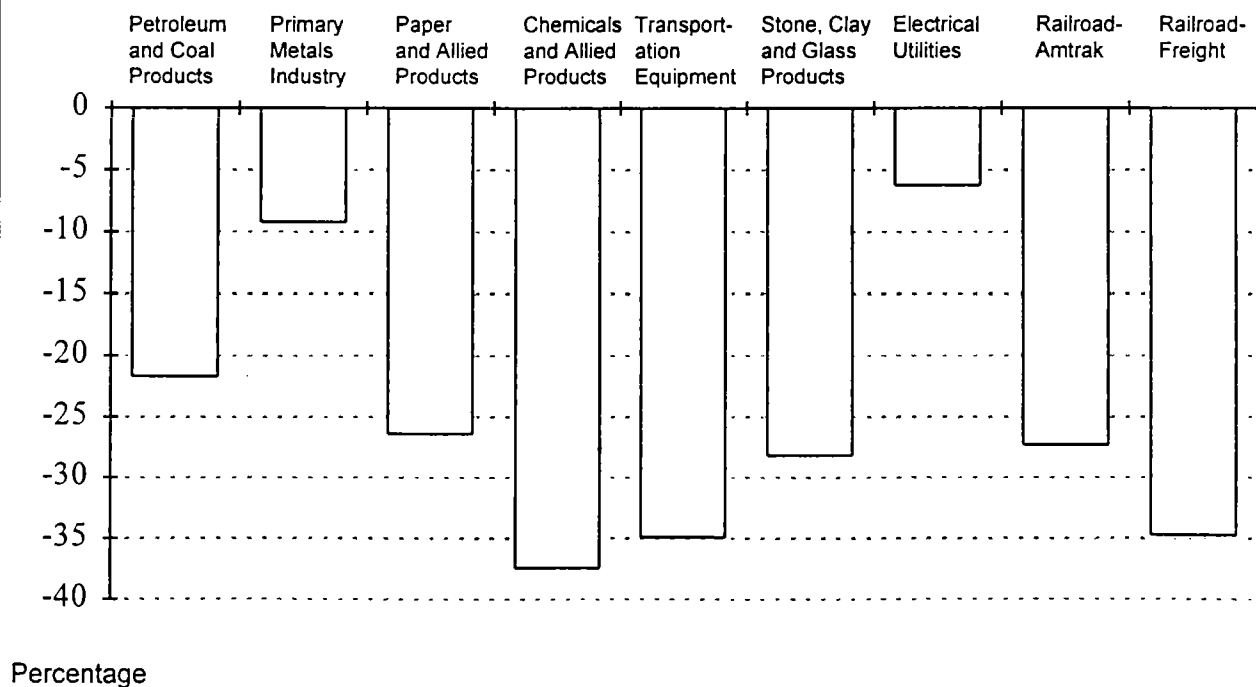


TABLE 4
SUMMARY OF CARBON DIOXIDE EMISSIONS FOR SELECTED INDUSTRY SECTORS

<i>SIC</i>	<i>Industry</i>	<i>Million Metric Tons of Carbon</i>			
		1974	1980	1985	1988
33	Primary Metal Industries	68.7	64.2	45.6	51.2
28	Chemicals & Allied Products	66.2	61.2	53.6	57.6
26	Paper & Allied Products	30.5	31.4	32.3	34.2
29	Petroleum & Coal Products	26.1	22.5	18.7	22.9
32	Stone, Clay, & Glass Products	36.5	33.9	30.5	31.7
37	Transportation Equipment	10.4	10.2	10.0	10.7
	Subtotal	238.4	223.4	190.7	208.3
	Other Manufacturing	70.4	75.0	63.2	75.6
	TOTAL Manufacturing	308.8	298.4	253.9	283.9
	Total Manufacturing (without purchased electricity)	187.4	168.1	130.8	150.3
491	Electric Services	333.6	414.9	437.4	473.0
40	Railroad Transportation	11.7	11.3	8.9	9.1
	Other U.S.	698.4	665.0	624.2	681.4
	TOTAL U.S.	1,231.1	1,259.3	1,201.3	1,313.8

4. Even with the substantial improvements in energy efficiency, U.S. industry and the U.S. economy remains heavily dependent upon the cost effective use of fossil fuels.
- In 1988, 89 percent of total U.S. energy consumption was derived from fossil fuels.
 - The electric utility industry sector derived 70 percent of its energy requirements from fossil fuels.
 - In the manufacturing industries examined in this study, 85 percent of purchased energy was derived from fossil fuels.

Because fossil fuels are the predominant source of energy, any new policy measures to reduce or replace the use of fossil fuels, if not cost effective, could significantly increase costs.

5. **The market share of electricity consumed has increased substantially over the 1974 to 1988 period in all of the manufacturing industry sectors examined.** This is also the case in manufacturing as a whole. The data are shown in Table 5. The adoption of electrotechnologies in manufacturing, due to economic, environmental and efficiency considerations, appears to be correlated with reduced levels of carbon dioxide emissions.

An analysis by the Edison Electric Institute (EEI) noted that, from 1973 to 1990, overall U.S. energy demand (including electricity) increased less than 10 percent. At the same time, GNP grew about 52 percent and electricity use increased by more than 58 percent. The EEI analysis concluded that, without this growth in electricity, energy demand would have been much greater. The correlation between increased electrification and reduced emissions has been exhibited for 70 years. A workshop on electricity use in industry, sponsored by the Electric Power Research Institute, reached a similar conclusion. The workshop report noted that "electricity use by industry appears to be a key factor in the productivity gains of the last quarter century."

TABLE 5
ELECTRIFICATION OF MANUFACTURING

Selected Sectors (SIC 2-digit code)	Electricity Share of Purchased Energy		
	1974	1988	Percent Increase
Petroleum & Coal Products	6.0	10.9	81.7
Stone, Clay, & Glass Products	7.5	12.1	61.3
Paper & Allied Products	10.6	14.8	39.6
Chemicals & Allied Products	14.9	17.3	16.1
Primary Metal Products	21.0	29.0	38.1
Transportation Equipment	25.9	37.1	43.2
Manufacturing Total	15.9	22.5	41.5

6. **While it is generally true that improvements in energy efficiency generally lead to reduced environmental emissions, including reduced carbon dioxide emissions, the reverse is not true. More stringent environmental requirements can cause increased energy consumption and increased carbon dioxide emissions.**

- The phase-out of lead in gasoline and requirements to produce reformulated gasolines both require additional energy consumption in petroleum refining.
- Increases in the average sulfur content of crude oil require more intensive processing to reduce product sulfur contents to permissible levels.
- Increasing paper recycling to reduce the amount of virgin wood in paper and to reduce the landfill problem increases the energy used compared to that for processing virgin pulp.
- Objections to hydropower or nuclear electricity generation based on environmental considerations increase the use of fossil fuels and carbon dioxide emissions.

7. **Shifts in consumer demand can result in increased industrial energy consumption and increased carbon dioxide emissions.**

- Increased demand for low-alkali cement increases the use of energy and carbon emissions.
- Shifts in demand for different types of plastics and petrochemicals could have a greater impact on energy use in the chemicals industry than improvements in the efficiency of chemical process technology.

8. **Market penetration of state-of-the-art energy-efficient technology could be limited by ability to invest.** Major savings in energy and major reductions in carbon emissions often require major changes in industry processes. These often mean the construction of entirely new plants or expensive retrofitting of existing facilities.

The substantial costs, which must be recovered from future revenues, and the length of time required to build or retrofit plants may mean that major new technologies take decades to implement throughout an industry. For example:

- Implementation of continuous casting and electric furnaces in the iron and steel industry is taking many years in an industry where demand is not growing and international competition is strong.

- Replacing wet-process cement making with the state-of-the-art preheater, precalciner, and long-dry process technologies are major changes that depend on their economic viability and the availability of investment resources.
9. **In many cases, significant future improvements in energy performance and reductions in carbon dioxide emissions may not be achievable without new technology.** In some cases, an industry may have few substantial opportunities to save energy and reduce emissions with existing technologies. Increasingly, research and development of major technical changes will be needed to achieve substantial further energy-efficiency and carbon dioxide emissions improvements. For example:
- A recent report by the Office of Technology Assessment noted that process efficiencies in several areas of petroleum refining are believed to be as efficient as possible with existing technologies.
 - Significant energy-efficiency improvement beyond existing conventional coal-fired electric generation is believed possible with "clean coal technologies", such as coal gasification, fuel cells, and advanced pressurized fluidized B&D combustion, but they are not expected to be commercially available until after 2000.
10. **The improvements in energy efficiency and the reductions in carbon dioxide were the result of actions undertaken by industry on a voluntary basis.** They were not mandated by government standards. When energy markets are permitted to function freely and efficiently, and when government policies encourage capital investment and economic growth, industry is best able to act quickly and effectively.
- All of the industries examined improved energy efficiency and reduced carbon dioxide emissions through major capital investments in new process technologies—e.g., continuous casting, cogeneration, waste utilization, process controls, and nuclear power generation.
 - The study identified a number of potential future process improvements, such as direct steelmaking, ion-exchange membranes and low pressure oxidation.

Achieving these process improvements will require significant R&D investments, followed by even more substantial investments in new plant and capital equipment once the new technologies are proven.

IMPLICATIONS FOR CLIMATE CHANGE MITIGATION PLANNING

The President has announced a goal of returning net greenhouse gas emissions in the year 2000 to their 1990 levels. The nature of change in major energy-using industries must be considered in applying the federal climate change mitigation policy. Energy use, energy intensity, carbon dioxide emissions, and carbon dioxide emissions intensity are driven by two kinds of developments.

- Fundamental process changes are basic departures from the existing technology of processing and manufacturing. These changes appear infrequently, but have profound effects on energy performance.
 - These kinds of changes require building an entirely new plant or shutting down part or all of a plant for long periods to replace major components. They are very capital intensive and are normally done when a plant must be upgraded or replaced to compete effectively or when new capacity is needed to meet product demand.
 - Rapid increase in product demand in an industry facilitates the implementation of major process changes by providing the opportunity for building new plant capacity with the expectation of future revenues to pay for it.
 - If economic conditions in an industry are highly favorable, either due to conditions in the general economy favoring investment or to special conditions in the industry, then the implementation of improved technology can be rapid and widespread.
 - The past implementation of continuous casting in the iron and steel industry and the replacement of the wet process in cement making with more energy efficient processes are examples of fundamental process changes.
 - Substantial research and development may be required to develop the technologies for fundamental process changes.
- Incremental process and control changes usually require relatively small changes in plant and equipment to improve either the production process or the operational control over it or to improve other uses of energy in the plant. These changes are often capital intensive, but they can be implemented incrementally.

If emission caps or similar restrictions were imposed on the energy intensive industries, without adequate consideration of technological and economic factors, then the range of options available to these industries and to the economy as a whole would be limited.

- One option for an industry would be to reduce its domestic production of energy-intensive products by either:
 - Reducing exports by U.S. industry; or
 - Increasing imports to satisfy domestic demand.
- Another set of options would be to accelerate development of new technologies or to invest in other control options that may be less economically efficient.
 - The costs of developing and implementing new technologies, before they would otherwise be economically available, would escalate sharply if the timetable for research and development were artificially compressed. This would further exacerbate the problem of capital availability in these industries.
 - In a global economy, with rapidly increasing economic capabilities in developing countries that are not required to control their carbon emissions, it would be difficult for U.S. manufacturers to increase their investment in environmental equipment. Foreign competitors would be able to gain an increasing competitive advantage over a U.S. manufacturers that were increasingly high-cost and less competitive due to narrower U.S. carbon restrictions.

4 PETROLEUM REFINING

INDUSTRY SECTOR OVERVIEW

Petroleum refining (SIC 291) is the largest single component of the petroleum and coal products industry sector (SIC 29), accounting for 82 percent of the value added by manufacture in 1991 for the entire industry sector. *(Note: This industry sector includes the coal products industry [e.g., coal tar], which is a small proportion of the SIC total. This sector does not include coal mining).*

This chapter presents data on energy performance of the entire SIC 29, petroleum and coal products sector, followed by a more detailed examination of trends and issues in the petroleum refining industry. The industries comprising the broader industry sector are shown in Table 6.

The petroleum and coal products industry sector consumed 1,070 trillion Btus in 1988, or 1.42 percent of total U.S. energy consumption, based on data compiled by the Department of Energy from its most recent energy survey. It emitted 22.9 million metric tons of carbon, or 1.74 percent of the U.S. total carbon dioxide emissions from fossil fuel burning and cement making.

PETROLEUM REFINING: The petroleum refining industry converts crude oil into fuels, such as gasoline and distillates, and other useful products, including lubricants, petrochemicals and asphalt. Crude oil is initially distilled to separate various fractions. Some of these fractions then undergo further conversion, either through "cracking", which breaks down large hydrocarbon molecules into smaller fractions, or through other conversion processes that enlarge and re-order other hydrocarbon molecule fractions. In the conversion processes, sulfur, metals and other contaminants are removed. The processed fractions are then blended into products, along with other elements such as additives to achieve special end-use characteristics.

TABLE 6
PETROLEUM AND COAL PRODUCTS INDUSTRY SECTOR (SIC 29)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	Total Employees	1992 Average Annual Employment	
				Production Workers Employees	Average Weekly Earnings
291	Petroleum refining	\$ 19,758	116,100	74,900	\$ 854.34
295	Asphalt paving and roofing materials	2,543	26,700	20,100	598.00
299	Miscellaneous petroleum & coal products (B)	1,685	a	a	a
29	TOTAL	\$ 24,024	154,500	101,300	\$ 782.71

Sources: Value-added data is from *Annual Survey of Manufactures*, Bureau of the Census, Department of Commerce, 1991 (most recent); Employment data is from *Employment and Earnings*, Bureau of Labor Statistics, Department of Labor, March 1993.

Note: a. Data omitted from source.

b. The "Coal Products" in SIC code 299 excludes coal mining.

Virtually all of the crude oil processed in refineries is used for feedstock, i.e., is converted into petroleum products. This report does not address feedstocks because they are rarely used directly to provide energy; thus, they do not produce carbon dioxide emissions during refining.

The industry is unusual in that some of the by-products from the refining process (usually hydrogen, methane, and other light gases) are used as fuel within refineries. Unfortunately, data showing the amount of by-product fuels used was not consistently recorded, so comparisons with 1974 data are not possible.

HISTORICAL TRENDS

The historical data for the petroleum and coal products industry sector shows significant swings between 1974 and 1988. Figures 10 and 11 show historical trends in production, energy consumption and energy intensity.

- *Production:* Production dropped in the 1975 recession year, grew steadily through 1978, and began a decline in 1979 that continued through the 1982 recession year. It then slowly rose to reach 111.8 percent of the 1974 level by the end of 1988.
- *Energy Consumption:* Consumption of purchased energy declined by 30.7 percent from 1,545 trillion Btus in 1974 to 1,070 trillion Btus in 1988, a reduction of 475 trillion Btus.
 - Most of the reduction in energy consumption was in the use of natural gas. Gas use declined by 390 trillion Btus; distillate fuel oils declined by 26 trillion Btus; and residual fuel oils declined by 2 trillion Btus.
 - Electricity use increased by 24 trillion Btus. Other fuels made up the remainder.
 - Some of the decrease in the consumption of purchased fuels was due to the increased use of by-product fuels.
- *Energy Intensity:* The energy intensity of the petroleum and coal products industrial sector, i.e., the amount of energy consumed per unit of production, decreased by 38.0 percent from 1974 to 1988. Taking into account the use of by-product fuels, energy intensity in petroleum refining increased slightly from 1985 to 1988, by 6.4 percent.
- *Carbon Dioxide Emissions:* Total emissions of carbon dioxide have been reduced by 12.5 percent from 1974 to 1988, a reduction of 3.3 million metric tons of carbon. The reduction in carbon emissions intensity has been even more significant. The level of carbon emissions per unit of production in 1988 represents a decline of 21.7 percent from the 1974 level.

FACTORS AFFECTING HISTORICAL TRENDS

The trend data generally show that the rate of improvement in energy efficiency has slowed during the 1980s. The Office of Technology Assessment (OTA) report noted that "The [petroleum refining] industry's energy consumption and intensity declined quickly in the 1970's

Figure 10
Petroleum & Coal Products Sector
Production, Energy, and Emissions

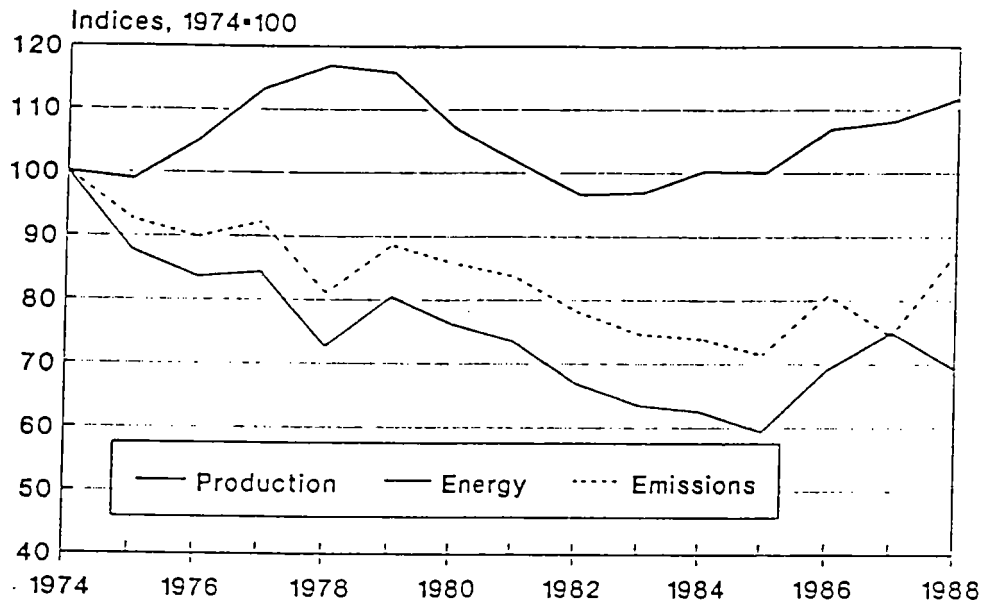
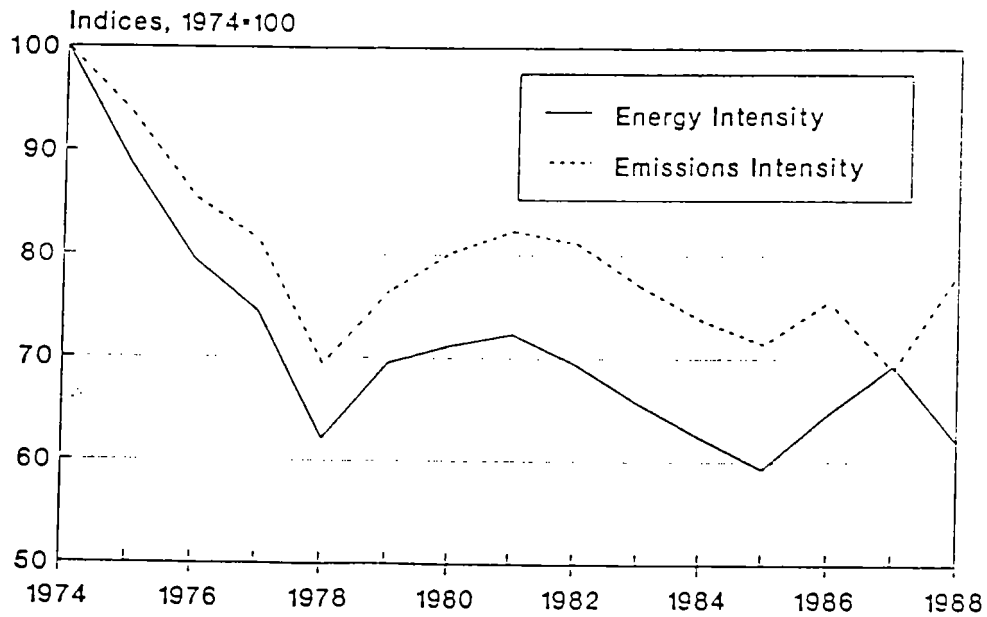


Figure 11
Petroleum & Coal Products Sector
Energy and Emissions Intensity



and more gradually in the 1980s." Major factors accounting for the slowdown included shifts in crude oil quality, increased product demand, and EPA-mandated lead phase-down; these changes required increased refinery processing and increased energy consumption.

- From 1985 to 1992, the average gravity of crude oil imports to U.S. refineries decreased from 32.46° API to 31.32° API (lower gravity means that the crude oil is "heavier", and requires more energy to process).
- Over this same period, the average sulfur content of crude oil increased from 0.91 percent to 1.16 percent, also requiring more intensive processing to reduce sulfur levels in final products in order to achieve environmental standards.
- From 1970 to 1992 consumer demand for "light" products—motor gasoline, jet fuel, kerosene and distillate—increased from 65.0 percent of all petroleum products to 69.3 percent. Virtually all of this shift took place after 1980. Producing light products requires more processing energy.
- The EPA-mandated lead phase-down began in October 1980. EPA initially set a limit on the average lead content of the entire "gasoline pool" (leaded and unleaded) of 0.5 grams of lead per gallon. EPA then set specific limits on the lead content of regular leaded gasoline. The limit was 1.1 grams of lead per gallon beginning November 1982, declining to 0.5 grams starting July 1985, and 0.1 grams beginning January 1986. As a result, in 1974, about 6.0 octane came from lead and by 1988 only 0.2 octane came from lead.

CURRENT ISSUES AND OUTLOOK

CURRENT ENVIRONMENTAL AND ENERGY INITIATIVES: The petroleum industry is continuing a major effort to improve environmental and energy performance through the STEP initiative—Strategies for Today's Environmental Partnership. STEP is a partnership among petroleum companies, their employees, neighbors and customers intended to meet the ever-rising environmental expectations of its customers. In April 1990, the American Petroleum Institute (API) Board of Directors formally adopted eleven Guiding Environmental Principles that were added to the Institute's bylaws. These principles are implemented through the STEP program. STEP includes three types of activities: those conducted through API, those conducted individually by API member companies, and those conducted by API members through activities of other industry groups. While the focus of these activities is on environmental enhancement, the program also is expected to result in additional energy efficiency benefits.

In addition to the STEP initiative, the API has adopted a specific statement of principles to guide energy efficiency activities of its member companies. The statement of principles is shown in the box at the end of this chapter.

THE ENERGY IMPACT OF STRICTER ENVIRONMENTAL STANDARDS: New overall environmental requirements on petroleum products have had a negative impact on energy consumption in the petroleum refining industry. For example, the phase-out of lead in gasoline, as well as the new requirement to produce reformulated gasolines, may have national environmental benefits but require additional energy in the refining process.

This trade-off may well intensify in the future. For example:

- The industry projects that the annual costs for environmental compliance will increase from about \$6 billion to \$15 to \$23 billion per year in the year 2000. These increased costs will divert capital investment from other productive investments, including energy-enhancing projects.
- The trend in crude oil production is toward lower quality crude while the trend in petroleum product demand is toward lighter products. These trends require increased reliance on energy-intensive process technologies, increasing the amount of energy consumed in the refining process.

PROCESS REFINEMENTS AND FUNDAMENTAL PROCESS CHANGES: New breakthroughs in process technologies are not likely for petroleum refining; thus, new production efficiencies will not be available to offset the increased energy requirements. The recent study by the Office of Technology Assessment (OTA) noted a diminished opportunity for future energy efficiency improvements. For example, in the process categories accounting for 46 percent of energy used in refining, the OTA concluded: "Little improvements in energy efficiency can be expected from using state-of-the-art technologies."

Thus, while the petroleum refining industry has made significant improvements in energy efficiency, and has achieved significant reductions in carbon dioxide emissions, a continuation of those trends does not appear likely in the foreseeable future.

API ENERGY CONSERVATION STATEMENT OF PRINCIPLES

The members of the American Petroleum Institute are dedicated to the responsible use of energy resources. The members recognize the importance of efficiently meeting society's energy needs and our responsibility to work with the public, the government, and others to economically develop and produce natural resources and to economically conserve those resources by using energy efficiently. Energy efficiency means using energy and other resources wisely and cost-effectively to meet the nation's needs, recognizing concerns about energy security, protection of the environment, and economic well-being. To meet these responsibilities, API members pledge to manage our businesses according to the following principles:

- To have management responsibility for energy conservation.
- To keep employees informed about their role in conserving energy and to reinforce the importance of efficiency goals to the firm.
- To conserve the natural resources from which petroleum products are derived by designing, operating, and maintaining our plants and facilities to optimize overall energy use in our operations.
- To develop and stay abreast of new technology for energy efficiency and to regularly evaluate the potential of new technology for our operations.
- To have energy conservation as a priority in our planning and development of new products.
- To establish a process to assess energy efficiency improvements.
- To provide information to customers, transporters and others about the efficient use of energy.
- To participate with government and others in creating responsible laws, regulations and standards to encourage the wise and efficient use of energy and other resources.

5 PRIMARY METALS

INDUSTRY SECTOR OVERVIEW

The primary metals industry sector (SIC 33) includes several industries. The iron and steel industry (SICs 331 and 332) is the largest component of the primary metals industry sector, accounting for 56 percent of the value added by manufacture in 1991 for the entire industry sector. The aluminum industry is the second largest component of the industry sector. This chapter presents information on energy performance and carbon dioxide emissions for the entire primary metals industry sector (SIC 33), followed by a more detailed discussion of the iron and steel and the aluminum industries. The industries comprising the industry sectors are shown in Table 7.

The primary metals industry sector consumed 1,773 trillion Btus in 1988 or 2.35 percent of the U.S. total energy consumption, based on data compiled by the Department of Energy from its most recent energy survey. It emitted 51.2 million metric tons of carbon, or 3.9 percent of the U.S. total carbon dioxide emissions from fossil fuel burning and cement making.

HISTORICAL TRENDS

Major changes have taken place in the primary metals industry sector during the period 1974 to 1988. Figures 12 and 13 show energy intensity and production with energy use.

- *Production:* Industrial production has been highly cyclical between 1974 to 1988, with an overall reduction over the period. Production dropped to 80 percent of the 1974 level in 1975, then slowly recovered to 99 percent by 1979. It then declined to 62 percent of the 1974 level in 1982 and slowly recovered to reach 82 percent in 1988.

Figure 12
Primary Metals Industry Sector
Production, Energy, and Emissions

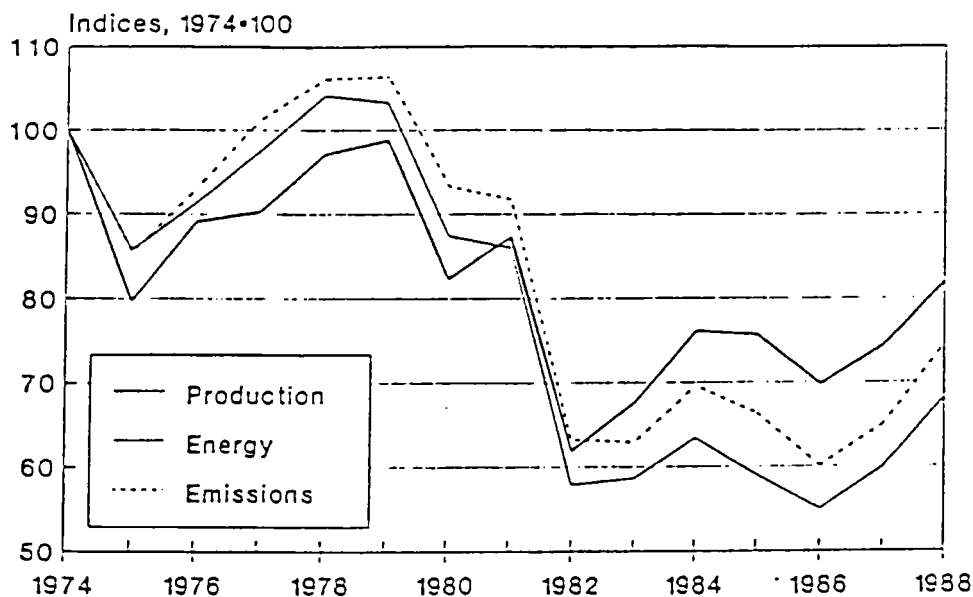


Figure 13
Primary Metals Industry Sector
Energy and Emissions Intensity

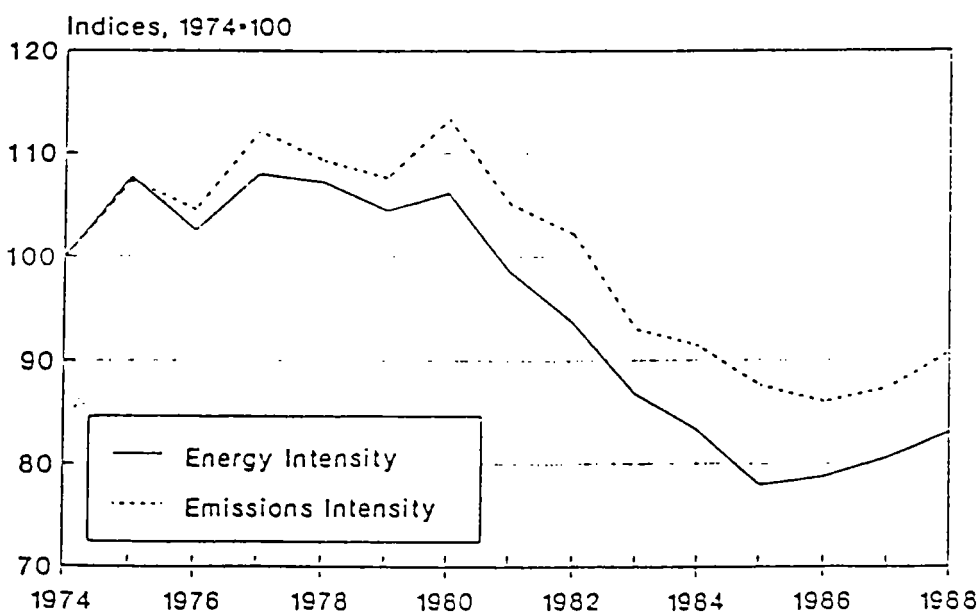


TABLE 7
PRIMARY METALS INDUSTRY SECTOR (SIC 33)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	Total Employees	1992 Average Annual Employment	
				Employees	Average Weekly Earnings
331	Blast furnace & basic steel products	\$ 19,685	253,500	191,400	\$ 691.22
332	Iron and steel foundries	6,194	121,400	97,100	525.46
333	Primary nonferrous metals	3,593	42,600	32,400	647.96
334	Secondary nonferrous metals	815	a	a	a
335	Nonferrous rolling and drawing	10,956	164,800	118,700	559.44
336	Nonferrous foundries (castings)	3,454	78,000	61,000	446.35
339	Miscellaneous primary metal products	1,909	*	*	*
33	TOTAL	\$ 46,605	703,100*	534,100*	\$ 587.*

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

Note: a. Data omitted from source.

- **Energy Consumption:** The use of purchased energy has somewhat followed the pattern of production, but with use in the 1980s declining compared with production:
 - Use of Electricity, Coke and Breeze Was Stable: in 1988, electricity and coke and breeze use, remained near 1974 levels, at 98 percent and 104 percent respectively.
 - Oil, Gas and Coal Use Declined: distillate and residual oil use decreased by 83.5 percent and 83 percent respectively. Natural gas use decreased by 30.7 percent, and coal use declined by 61.3 percent.
 - By-product fuels are not included here because data is incomplete before 1985.
- **Energy Intensity:** Energy intensity, the level of energy consumption per unit of production, declined by 17 percent from 1974 to 1988. Most of the decline occurred in the early 1980s.

- *Carbon Dioxide Emissions:* Overall, carbon dioxide emissions decreased by 17.6 million metric tons of carbon, or 25.6 percent. Compared to 1974 emissions of 68.7 million metric tons of carbon, 1988 carbon dioxide emissions were 51.2 million tons of carbon. Emissions intensity (carbon dioxide emissions per unit of value added) in 1988 was 9.6 percent below the 1974 level.

IRON AND STEEL INDUSTRY

Industry Overview

The iron and steel industry consumes large quantities of energy to produce heat. Furnaces smelt the iron ore and heat and reheat the iron and steel at several stages in the processing operations.

- Iron ore is reduced through the process of smelting to produce iron metal, which is usually further processed by heat and chemistry adjustments to produce a variety of steel grades.
- Semi-finished steel shapes are then fabricated into finished steel products by various rolling, coating, and heat treating processes.
- Most scrap is recycled to produce a wide variety of steel products.

Integrated producers both smelt iron ore and produce finished steel products at one single plant. Non-integrated producers will use semi-finished steel shapes smelted elsewhere to produce a variety of carbon and specialty products entirely from scrap. Non-integrated producers consume less energy because the scrap steel embodies the energy from the smelting process.

The iron and steel industry consumed 1,007 trillion Btus, 1.33 percent of the total U.S. energy consumed in 1988 by fossil fuel burning and cement making. In addition the iron and steel industry provides a major part of its total energy use from by-product fuels. Producing coke from bituminous coal generates coke oven gas, which is used as a by-product fuel. In addition, blast furnaces produce blast-furnace gas, which is similarly used as a by-product fuel.

- In 1985, about 30 percent of total fuel input of 1.7 quadrillion Btus was produced from these byproduct fuels.
- In 1988, about 25 percent of total energy input of 1.9 quadrillion Btus was produced from by-product fuels.
- When the use of by-product fuels is considered, energy intensity in the steel industry declined from 1985 to 1988 by about 2.2 percent.

Factors Affecting Energy Performance in the Iron and Steel Industry

A number of factors directly or indirectly affect energy consumption in the U.S. iron and steel industry and the resulting greenhouse gas impact. The factors having the most direct impact include the following:

- **Heating and Cooling of Metal.** The most dramatic energy savings are realized by improving furnace efficiencies and by reducing the number of times the metal needs to be heated, cooled, and reheated until the finished product is produced. Of greater significance has been the increased use of continuous casting, which eliminates a number of energy intensive steps and also improves product yields.
- **Energy Management.** Other significant energy savings opportunities arise from better process controls, improved management of energy, and more efficient processes.
- **Recycling of Scrap.** Recycling is another significant factor because it avoids the high energy needed to smelt iron ore.
 - Steel products are recycled more easily than other metals because they can be separated magnetically. Between 1979 and 1989, the share of iron and steel that was recycled increased from 30 percent to 43 percent; the stainless-steel rate went from 30 to 45 percent.
 - About 65 percent of all steel is produced from recycled steel.
 - Moreover, with proper scrap segregation and chemistry adjustments in the furnace, almost any steel grade can be produced from any other grade of steel scrap.

In addition, several factors have significant indirect effects on energy performance and the resulting carbon dioxide emission levels.

- **International Trade:** International trade in finished and semi-finished steel products affects energy use because they contain an embodied energy component provided by the exporting economy and avoided by the importing economy. This consideration also applies to other industries with high steel-content products, such as automobiles.
- **Product Substitution:** Another indirect factor is cross-industry substitution of products, such as plastics for metal automobile parts in recent years, and the increasing substitution of steel containers for aluminum.

- **Product Lifetimes:** The long life-cycles of iron and steel products—typically ten to thirty years—effectively create an in-service accumulation of energy. If the service life of a particular kind of product is extended, then fewer replacements are needed and less energy is used. Again, this consideration also applies to other industries with high steel-content products.

Historical Trends Affecting Energy Performance

CONTINUOUS CASTING: Continuous casting has been the most important change in recent years, and it has fundamentally changed processing in integrated plants. The molten metal is poured continuously into slabs or other steel shapes—rather than into ingot molds. The semi-finished shapes are further rolled and processed while still hot.

- Continuous casting is more energy efficient because it replaces the steps of pouring metal into individual ingot molds, cooling and removing ingots from the molds, then reheating ingots for the next processing operation. Continuous casting also yields more product, since there is less need to trim, scale, etc.
- As with most fundamental process changes in the iron and steel industry, retrofitting existing plants has been very capital intensive and has taken a number of years.
- About 80 percent of U.S. iron and steel production now uses continuous casting—compared with 67 percent in 1990 and 9 percent in 1975.

FURNACE EFFICIENCY: Second, improved furnace melting efficiency is the next most significant change in steel production. A furnace change is also a fundamental process change. Steelmaking technology has advanced from use of the open hearth process, to the basic oxygen furnace, to the electric furnace.

- Electric furnaces use less energy because they typically use 100 percent scrap and avoid the energy needed to smelt iron ore.
- Electric furnace use has increased steadily over the last two decades but has stabilized in the 35 to 40 percent range in the last five years. In 1990, 37 percent of all furnaces were electric, in contrast with about 15 percent in the mid-1970's.
- The increased use of electric furnaces has come at the expense of open hearth steelmaking, which has declined sharply. By 1992, open hearth furnaces had disappeared entirely from American steelmaking; in 1981, they had been 11 percent of all furnaces in use.

- Reliance on basic oxygen furnaces has remained essentially unchanged, accounting for 61 percent in 1981 and 59 percent in 1990.

OTHER PROCESS IMPROVEMENTS: Third are a group of process efficiencies, including:

- The heat produced by supplemental furnaces in producing finished steel products is used more efficiently by reconfiguring how product moves through these furnaces during reheating operations.
- Blast furnaces are being reconfigured, where suitable, to allow coal, natural gas, or oil to be injected directly into the furnaces as a supplemental fuel. This reduces the amount of coke required, which can reduce the total energy used by the furnace and can ease the environmental impact of converting coal to coke.

IMPROVED ENERGY MANAGEMENT: Fourth are a group of energy management improvements, including:

- Use of more exact process control systems.
- Use of computer controls in energy management systems.
- Greater utilization of gasses from blast furnaces and basic oxygen furnaces.
- More efficient motors.
- More efficient steam utilization.
- More efficient non-process energy use, such as space heating, cooling, and lighting.

Indirectly, the U.S. economy has been a net importer of semi-finished steel products (primarily from Japan) and a net exporter of finished steel products. When steel products are imported or exported, their embodied energy is also imported or exported.

- In 1990, the U.S. exported 4.3 million tons (virtually all finished steel products), about 5 percent of its 85.0 million-ton steel production. The U.S. imported 17.2 million tons, about 18 percent of its 97.8 million ton demand.
- In contrast, Japan and Canada imported about 3 percent of their steel demand, and the EEC imported 5.6 percent of its demand.

The American Iron and Steel Institute's statistics on recent energy performance of member iron and steel companies show that those companies:

- Reduced energy consumption by 8.1 percent from 1988 to 1991, from 470 trillion Btus to 432 trillion Btus.
- Reduced carbon dioxide emissions by 12.6 percent from 1988 to 1991, from 8.9 million metric tons to 7.8 million metric tons, including the emissions from the generation of electricity consumed in steelmills.

Current Issues and Outlook

Future improvements in the energy performance of the iron and steel industry will depend greatly on fundamental changes in steelmaking technology. Other process improvements may have a lesser impact.

Two new process technologies that will revolutionize steelmaking are under development in the U.S. and elsewhere—direct steelmaking and near-net shape casting. In the U.S., these technologies were jointly developed and funded by the American Iron and Steel Institute (AISI), several steel companies, and the Department of Energy (DOE). Plants incorporating these fundamental changes will be the most energy-efficient steel plants in the world. DOE estimates a 1.0 percent reduction in industry-wide energy use per year.

DIRECT STEELMAKING: Direct Steelmaking uses existing postcombustion and heat-transfer technology to increase the scrap melting capability in basic oxygen furnaces and to produce steel from iron ore in one operation. This project is jointly funded by AISI, steel companies, and DOE.

- Pilot projects have been completed, and a demonstration site is being selected for further development and commercial production.
- DOE estimates direct steelmaking and associated casting changes will save 50 trillion Btus per year when fully implemented.
- Moreover, DOE reports direct steelmaking will eliminate the production of nitrogen oxides (NO_x) by using oxygen instead of air in the combustion of coal.

NEAR-NET-SHAPE CASTING: Near-net-shape casting of low-carbon steel applies several existing technologies to the manufacture of steel sheet in conjunction with direct steelmaking. This project is jointly funded by AISI, steel companies, and DOE.

- Advanced sensors will immediately determine the chemical composition of molten steel and will provide more accurate measurements of temperature and dimensions as it is formed into sheet steel.

- DOE estimates near-net-shape casting will save 150 trillion Btus per year when fully implemented.

OTHER PROCESS IMPROVEMENTS: Other process improvements include the following:

- Better product control is expected from laser analysis of molten carbon steel, which has been successfully proved in laboratory tests. DOE estimates the energy savings potential is 10 trillion Btus per year.
- Improvements in process control and metal casting have an energy savings potential of 50 trillion Btus per year. A new on-line process-control model jointly developed by the American Foundrymen's Association and DOE promises to optimize the melting process for liquid iron. Industrial application will save coke and reduce metal losses due to oxidation.
- While the greater use of coal injection in blast furnaces is not expected to reduce energy use substantially, it will reduce carbon dioxide emissions substantially.

PRIMARY ALUMINUM INDUSTRY

Industry Overview

The primary aluminum industry consumed 246 trillion Btus or 0.33 percent of total U.S. energy consumption for fossil fuel burning and cement making in 1988. The refining and smelting processes consume 92 percent of the energy used in the aluminum industry, mostly in the form of electricity. Thus, the cost of electricity is a significant part of the total costs of refining and smelting operations. Smelters are usually located in regions where electricity is plentiful and less costly. The industry estimates that electricity for refining and smelting comes from 53 percent fossil fuels, 45 percent hydroelectric, and 2 percent nuclear.

The aluminum industry comprises three major functions. Aluminum is produced by refining bauxite ore into alumina, which is smelted into molten aluminum metal that is formed into semi-finished shapes and finished products. Secondary (recycled) aluminum accounts for nearly a third of U.S. aluminum supplied.

- First, bauxite ore is used to produce alumina through the Bayer process. Finely ground ore is added to a hot solution of caustic soda, and impurities precipitate out. Crystalline aluminum hydrate is formed and then heated in kilns to remove the water, leaving pure alumina. In 1980, the Bayer refining process used 35.5 million Btus of energy per ton of aluminum metal. This process consumes 27 percent of the energy used by the aluminum industry.

- Second, alumina is smelted into aluminum metal through the Hall-Héroult process. Since it is an electrolytic process, the primary source of energy used is electricity—averaging 7.3 kwh per pound of aluminum metal, although carbon anodes are also consumed in the process. This process consumes 65 percent of the energy used in the aluminum industry.
 - When aluminum oxide content falls too low in the electrolytic bath in a Hall-Héroult cell, an anode effect occurs. The technology does not currently exist to directly measure the aluminum oxide content in electrolytic baths and thereby completely avoid anode effects. During anode effects conditions become such that a portion of cell gas contains two greenhouse gasses, tetrafluoromethane (CF₄) and hexafluoroethane (C₂F₆). Since anode effects reduce cell productivity and power consumption efficiencies, cell control strategies that improve operations as well as minimize anode effects are critical to smelters.
 - Scrap aluminum is easily recycled. Recycling uses only about 5 percent of the energy required to produce aluminum metal from bauxite ore. Many aluminum products can be made entirely from scrap aluminum, and some producers are approaching 100 percent scrap content for can stock. Beside cans, recycled aluminum is also a major contributor in automobile and light truck manufacturing. By increasing aluminum recycling, the industry substantially reduces its energy use.
- Third, finished aluminum products are then fabricated from semi-finished shapes.

Most new, world production capacity is being built outside the U.S. Since 1980, no new smelters have been built in the U.S., ten smelters have closed, and production capacity has declined by 16 percent.

Imports and exports have process energy embedded in the material—the energy of refining, smelting, and forming. The effect of net imports is to reduce both the amount of energy needed and the carbon dioxide emitted in the U.S.

- The U.S. aluminum industry imports about half the alumina it needs and refines the remainder domestically.
- During the first five months of 1993, U.S. exported 1,067 million pounds of aluminum semi-finished shapes and mill products, a 2.5 percent reduction from 1992. In the same period, the U.S. imported 2,027 million pounds, a 40 percent increase over 1992.
- This trend is also shown during the first five months of 1993 by a slight decline in U.S. aluminum mill shipments (0.7 percent) from 1992, while U.S. primary aluminum production declined more significantly, by 4.9 percent.

Factors Affecting Historical Trends in Energy Performance

Several developments in the aluminum industry have resulted in less energy being consumed per pound of aluminum produced.

- The amount of secondary metal used in aluminum can manufacturing operations has increased significantly due to the increased popularity of can recycling.
- Aluminum cans are being manufactured with thinner walls without sacrificing the can's ability to contain soda and other liquids under pressures that typically may be fifteen atmospheres.
- The life of material used to line pots that hold liquid aluminum in the Hall-Héroult smelting process has been significantly extended. This improvement allows individual pots to remain in use for longer periods before being removed from service for relining.
- By controlling the electrolytic process more precisely, occurrence of the *anode effect* can be minimized and the cell can be operated efficiently, thereby optimizing aluminum metal production levels and avoiding both greenhouse gas emissions and excessive energy use.
 - An anode effect occurs when the alumina content decreases in the electrolytic bath. This condition impairs the process and reduces the amount of aluminum metal produced. Moreover, during an anode effect, two greenhouse gasses are released, tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6).
 - Conversely, if the alumina content is too high, the cell operates inefficiently and uses excessive energy. Current technology does not allow smelter operators to measure the alumina content in electrolytic baths, so they must maintain the proper balance of alumina content based on their operating experience.

Current Issues and Outlook

The aluminum industry is energy intensive, capital intensive, and very competitive on a global basis. The basic refining and smelting processes are common among all aluminum plants, but the specific technologies used at individual plants are often proprietary, which can make it difficult to track efficiency improvements due to specific process changes.

As in other capital-intensive industries, fundamental process changes often require costly capital improvements, and the resulting energy efficiency gains provide strong incentives to make those improvements, whether they are process-control improvements or fundamental technology

changes. This has been the case in the aluminum industry as it moved from smelting aluminum in kilns to the Hall-Héroult electrolytic cell process in past decades.

The fundamental technology change to electrolytic cells was followed in more recent years by improvements to the design of the Hall-Héroult electrolytic cell to reduce energy consumption.

- Mathematical models, based on knowledge of the physicochemical properties of the materials and processes coupled with accurate experimental data on cell behavior, provide the basis for modern designs, choice of materials, effects of mechanical forces, and process control.
- The use of point feeders has made it possible to add known quantities of alumina (and aluminum fluoride, where used), which facilitates monitoring the alumina concentrations and bath compositions more precisely, resulting in very low anode-effect occurrence (less than 0.2 per day).
- By increasing the surface area of the carbon anodes, the amount of energy needed to operate the cell could be reduced. This improvement reduces heat dissipation and, thus, the energy required by the cell.
- By improving the electrical properties of the cell to distribute the current more evenly across the electrodes, they can be positioned somewhat closer, which reduces heat dissipation and energy used.
- Modern cells operating at 175 to 300 kilo-Amperes require magnetic compensation to reduce metal and bath velocities and counteract the tendency to form non-horizontal metal surfaces.
- To control off-gas, dry-scrubbing systems are applied to reduce the emissions to less than 0.5 kg of fluorides per ton of aluminum produced. The off-gas fluorides and hydrocarbon vapors are absorbed on the alumina feed stock, which is recycled to the cell electrolyte.

In a recent report, the U.S. Office of Technology Assessment (OTA) identified several longer-term industry efforts to improve energy efficiency. OTA also suggested an expected level of energy-efficiency improvement that might be realized by the year 2010, compared with a 1980 baseline. Thus, some of OTA's expected improvement has already been realized through changes the industry has made since 1980, and the industry is continuing its efforts to realize further efficiencies. The following programs typify the industry's present efforts to achieve further energy efficiencies.

PROCESS CONTROL: Advances in computer control of smelting pots makes it easier to maintain the required temperature and minimizes the amount of slag. In the 1980s, Kaiser Aluminum & Chemical Corporation developed and marketed CELTROL®, a proprietary computer-control process for controlling the current and power efficiency in the Hall-Héroult smelting process. Similarly, Reynolds Metals has developed its own proprietary computer control system.

A case study of the use of the computerized process control technologies has demonstrated several important benefits at Kaiser's Mead smelter.

- The electricity required for smelting operations was reduced by 14.7 percent per pound of aluminum metal produced through the use of CELTROL® over the period 1987 to 1992.
- The life of carbon anodes was lengthened, resulting in an 8.9 percent reduction in dioxide emissions per pound of aluminum produced over the period 1987 to 1992.
- By better controlling occurrence of the anode effect, emissions of tetrafluoromethane (CF₄) and hexafluoroethane (C₂F₆) were reduced by 70 percent over the period 1980 to 1987. Refinements in the technology produced a further reduction of 26 percent in the emissions of these two greenhouse gasses from 1988 to 1992.
- Since 1984, Kaiser has marketed and installed its CELTROL® technology to other aluminum producers in the United States and internationally.
- (The reductions noted were measured at Kaiser's largest smelter in Mead, Washington, which produces 200,000 tons annually. This smelter was well-suited to realize substantial benefits that may be greater than some other smelters could attain.)

LONGER-TERM PROGRAMS: The longer-term industry efforts to improve energy efficiency are focused in the following areas.

- Improvements in the Bayer process could reduce the energy needed for refining by 24 percent (to 27.0 million Btus per ton) by the year 2010.
- Since about 55 percent of the energy used in the Hall-Héroult smelting process is dissipated in the form of heat, process improvements are usually intended to reduce heat dissipation. For example, less heat is produced when the electrodes are moved closer together; however, current technology limits the spacing to 1.75 inches. When electrode spacing is reduced, the electromotive force (voltage) causes the molten aluminum in the center of the cell to rise toward the anode, which further reduces the spacing causing improper cell operation.

- The most promising improvements under development would prolong anode life and allow closer anode spacing. By the year 2010, the amount of energy needed for smelting could be reduced by 16 percent (to 71.8 million Btus per ton) by the year 2010.
- A reduction of 33 percent is theoretically possible if the electrode spacing could be reduced to 0.25 inches; however, doing so requires the industry's engineers to overcome fundamental technological barriers. Solving this challenge is important to the industry, since energy is a major cost of aluminum production. Reynolds, Kaiser, and the Department of Energy have been jointly working on this problem for about fifteen years.

Current efforts have focused on adding titanium diboride to the carbon cathode, but this approach does not appear to be commercially viable. To date, the major obstacle to producing a viable titanium diboride cathode has been material failure. Full-size cathode shapes produced from titanium diboride powders and graphite have been successfully demonstrated in pilot cell tests. These cathode elements are being evaluated in cells at a commercial facility.

- A long term goal of the industry is to develop inert (non-consumable) anodes to replace carbon anodes in reduction cell. Investigations are being conducted with cermet (ceramic-metal) composition sponsored jointly by Department of Energy and aluminum industry. The anodes have a higher decomposition voltage but a lower polarization energy and carbon savings, and they generate oxygen gas during electrolysis. Non-consumable anodes have the potential to allow a closer anode-cathode distance than carbon anodes, particularly in new revolutionary cell designs.

6 PAPER AND ALLIED PRODUCTS

INDUSTRY SECTOR OVERVIEW

Paper and allied products (SIC 26) comprises an entire industry sector, as shown in Table 8 below.

TABLE 8
PAPER AND ALLIED PRODUCTS INDUSTRY SECTOR (SIC 26)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	1992 Average Annual Employment		
			Total Employees	Production Workers Employees	Average Weekly Earnings
261	Pulp mills	\$ 2,446	a	a	a
262	Paper mills	15,510	180,100	136,800	\$ 731.19
263	Paperboard mills	7,257	49,100	37,800	737.30
265	Paperboard containers and boxes	11,530	209,300	163,600	472.14
267	Miscellaneous converted paper products	21,436	235,600	169,000	485.30
26	TOTAL	\$ 58,281	688,200	518,200	\$ 570.72

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

Note: a. Data omitted from source.

The industry sector consumed 1,141 trillion Btus of purchased energy in 1988 (comprised of fossil fuels and electricity), or 1.51 percent of total U.S. energy consumption, based on data

compiled by the Department of Energy from its most recent energy survey, adjusted to eliminate DOE's "Other" category which represents biomass energy in this industry. Emissions of carbon dioxide from the use of fossil fuels resulted produced 2.3 percent of the total U.S. carbon dioxide emissions from fossil fuel burning and cement making.

The paper making process varies, depending upon the type of fiber material (wood pulp or recycled product) and the type of paper products produced.

- Virgin paper is produced by chemical or mechanical methods. Mechanical pulping involves grinding logs or wood chips, adding water, then filtering and cleaning before sending the slurry to the paper machine. In chemical pulping (the majority of papermaking capacity), wood chips are cooked in caustic chemical solutions to separate the fibers, which are then washed, cleaned, and sent to the paper machine.
 - In chemical papermaking, many process by-products (bark, spent pulping liquors, and wood residues) are used to generate 56 percent of the energy required for the production process. Most of these by-products are not produced in the mechanical or recycled papermaking processes, which generally require greater fossil fuel and purchased electricity use.
 - In recycled papermaking, recovered paper is repulped by mixing it with water and is processed to remove impurities. It is then deinked or bleached, if necessary, and sent to the paper machine.
 - The trend toward greater use of recycled fiber will not necessarily reduce energy use. If recycled fiber replaces *chemical pulp*, the by-products (bark and spent pulping liquor) will be lost as an energy source, so fossil fuel and electric use would increase accordingly. However, where recycled fiber replaces newsprint or other *groundwood pulp*, both fossil energy use and electricity use would likely decrease.
- The paper industry meets over half its energy needs with by-product biomass fuels. Both the bark and the liquor are used to produce energy for paper manufacturing operations. Since 1972, the paper industry has significantly increased the amount of these fuels that can be used for electrical generation, which dramatically reduced the environmental disposal problem of the by-products, as well. In recent years, methods have been developed to reduce the water content in the sludge produced by paper mill operations sufficiently so that it, too, can be incinerated and used for on-site electrical generation.
- The paper industry also utilizes cogeneration to meet its energy needs. In cogeneration, steam produced on-site for process applications is used for a second time for electrical generation. About half of the industry's electricity demand is met through cogeneration.

HISTORICAL TRENDS

ENERGY USE: Figures 14 and 15 illustrate energy intensity and production with energy use in the paper and allied products industry sector.

- *Production:* Production in the paper and allied products industry increased by 35.8 percent from 1974 to 1988.
- *Energy Consumption:* Consumption of purchased energy (fossil fuels) decreased by 10.5 percent from 1974 to 1988, from a level of 1,275 trillion Btus to 1,141 trillion Btus.⁷ Within the total energy consumption, a significant shift in fuel mix had occurred.
 - *Oil Consumption Decreased:* Consumption of fuel oil decreased by 58 percent, from 455 trillion Btus to 190 trillion Btus.
 - *Coal and Electricity Consumption Increased:* Consumption of electricity increased by 68 trillion Btus and of coal increased by 96 trillion Btus. The remainder of the increase was from other fuels.
- *Energy Intensity:* Energy intensity, consumption per unit of production, declined from 1974 to 1988 by 51.4 percent, to 48.6 percent of 1974 levels.
- *Carbon Dioxide Emissions:* Carbon dioxide emissions resulting from the use of fossil fuels have been virtually unchanged between 1974 and 1988, with a slight decrease of 0.01 million metric tons of carbon. Carbon dioxide emissions intensity, i.e., carbon dioxide emissions per unit of output, decreased by 26.4 percent between 1974 and 1988.
- *By-Product Fuels:* The paper industry relies heavily on by-product fuels which are not included in the data on purchased energy described above. According to industry data, hogged fuel, bark, and black liquor from the pulping process are used as by-product fuels.
 - In 1972 (1974 data is not available), 39.7 percent of the industry's total energy input of 2,092 trillion Btus was from byproduct fuels.
 - In 1988, 55.5 percent of the industry's total energy input of 2,373 trillion Btus was from byproduct fuels.

⁷ Only purchased energy supplied by fossil fuels is included in this presentation. The paper industry utilizes a large amount of renewable energy from biomass, which comes mainly from by-products and wastes generated in the paper making process. The biomass energy data is not included because it does not result in a net addition of carbon dioxide to the atmosphere. The MECS data includes both fossil fuels and renewable energy.

Figure 14
Paper and Allied Products Sector
Production, Energy, and Emissions

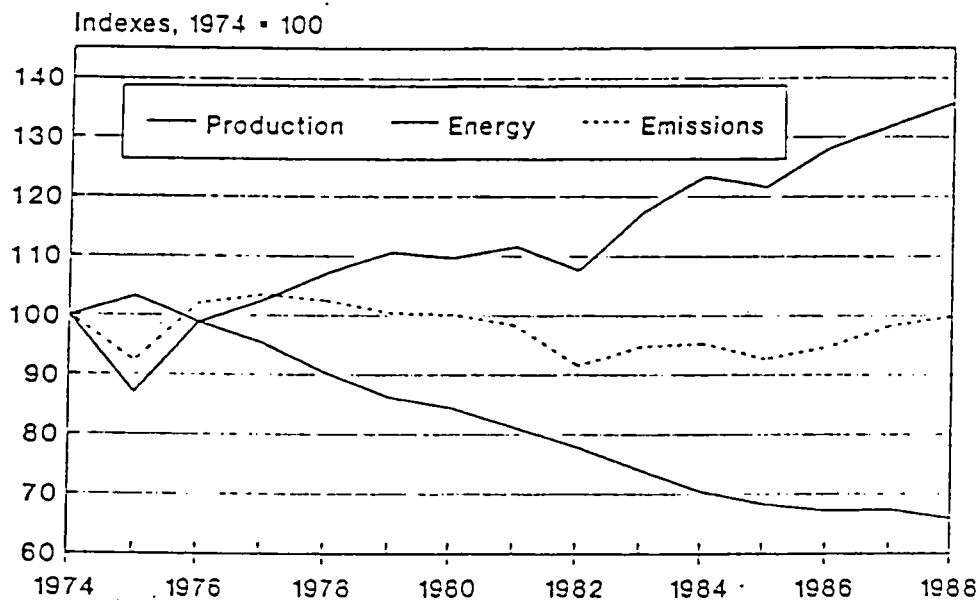
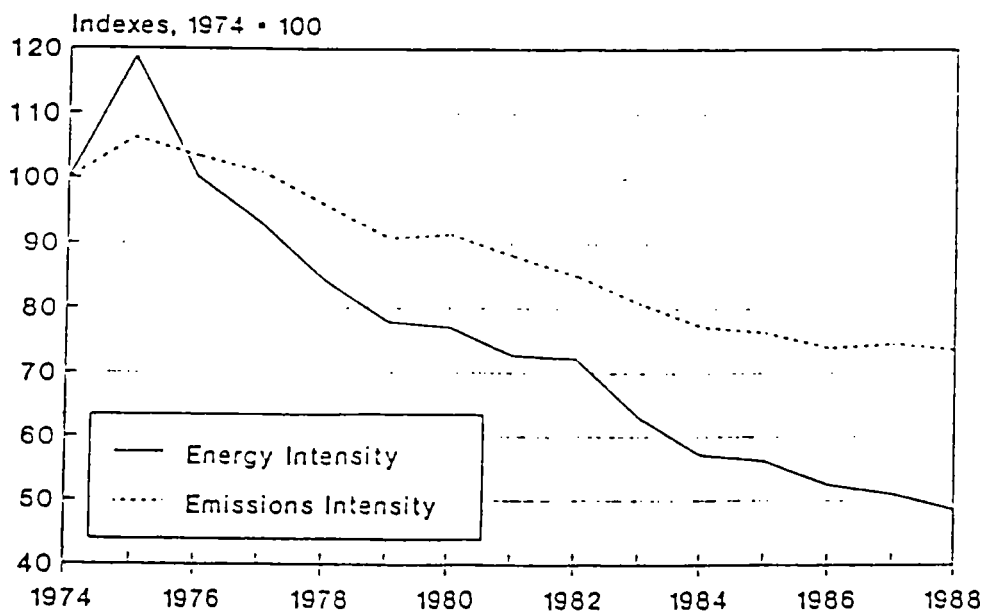


Figure 15
Chemicals and Allied Products
Energy and Emissions Intensity



- Taking into account the use of byproduct fuels, the industry's energy intensity decreased by 8.9 percent from 1985 to 1988.

INDUSTRY CARBON SINK: The industry owns about 70 million acres of forests, and leases additional private forest land. According to industry estimates, each acre of growing forest absorbs about one ton of carbon from atmospheric carbon dioxide. Most of the industry's production facilities are located on or near industry owned or leased forest land. The capacity of these forest lands to absorb carbon dioxide exceeds the amount of carbon dioxide released by the industry's production facilities, including emissions both from purchased energy and from self-generated and residual fuels.

FACTORS AFFECTING HISTORICAL TRENDS

Over the past twenty years, the industry has reduced the total amount of energy required to produce a ton of paper from 33.0 million Btus to 27.7 million Btus—a reduction of 16 percent. Over this period the industry has been increasing its cogeneration of energy.

- *Cogeneration:* The industry is a leader among U.S. industries in the production of energy from byproducts and the cogeneration of electric power. Commonly, the energy produces high-pressure steam that is used first to drive electric turbines and then is used in process applications requiring steam or heat. This dual use is more efficient than using the energy to produce only electricity.
 - In 1991, the industry cogenerated 48.8 million kwh of electricity that it used for its own production needs—an increase of 75 percent over the amount cogenerated in 1982.
 - Of total in-plant electric generation of 55 billion kwh in 1991, 89 percent was cogenerated.
 - Cogenerated electricity meets over half of the industry's electricity demand.

This trend is illustrated in Figure 16.

- *Increased Use of Renewable Fuels:* A significant source of energy savings and improvements in emission intensity has been the use of renewable fuels. Industry estimates provide a longer-term picture of such use than the government statistics on by-product fuels discussed above.

Over the 1972 to 1991 period, the industry expanded its use of renewable domestic energy sources such as wood residues, bark, pulping liquors, and hydropower by 70 percent. These renewable energy sources provided:

- 844 trillion Btus in 1972, or 40.2 percent of total energy consumption;
- 1,436 trillion Btus in 1991, or 55.7 percent of total consumption.

Without the use of these renewables, the combustion of fossil fuels would have had to be greater by an amount on the order of 126 percent. Carbon emission would also have been greater by substantial amounts. The trend in the use of wastes and residues is shown in Figure 17.

- The net result of the industry's reliance on cogeneration and on the use of renewables is that the amount of fossil fuel and purchased energy used to produce one ton of paper went from 19.1 million Btus in 1972 down to 11.9 million Btus in 1991—a reduction of 38 percent. When viewed in terms of the efficiencies gained, the adjusted reduction is 46 percent.

Figure 24

Energy Efficiency Trends in Automobile Manufacturing (Ford Motor Company Operations)

MMBTU/ Vehicle

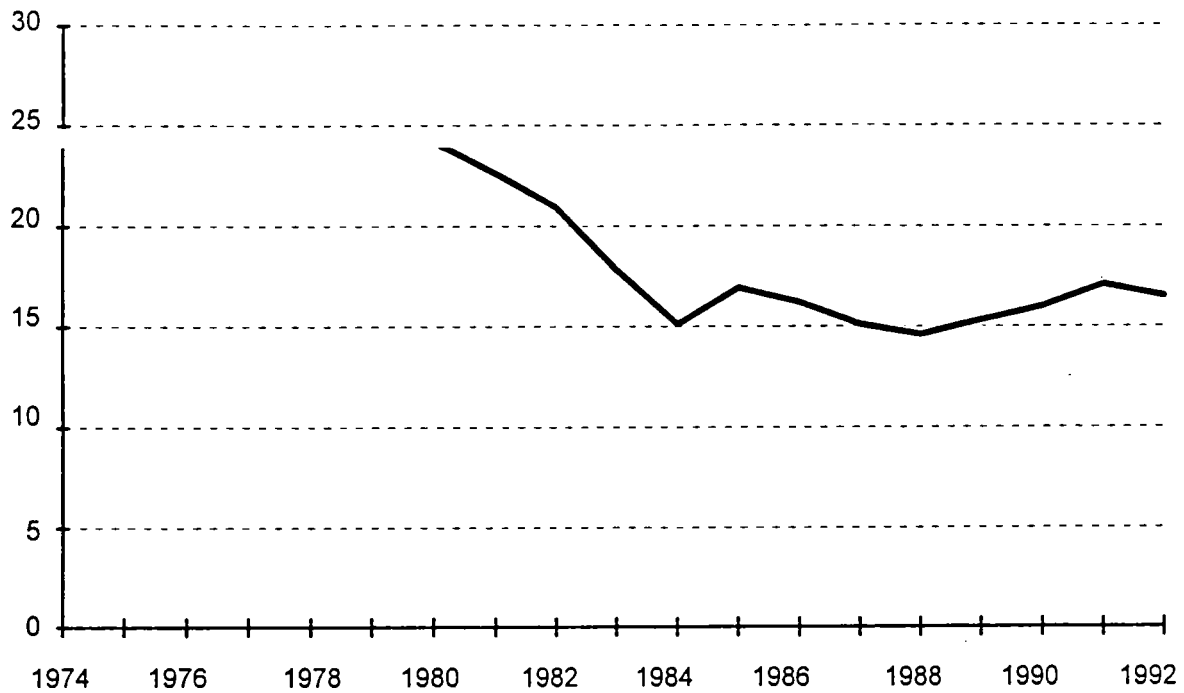
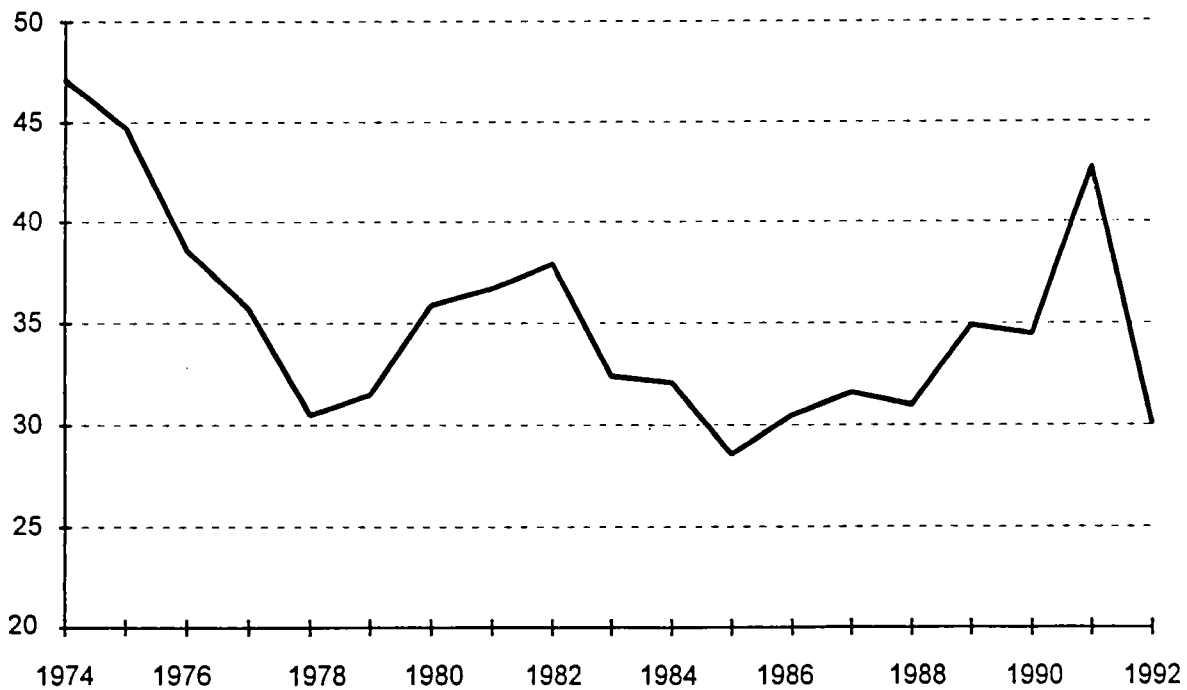


Figure 25

Energy Efficiency Trends in Automobile Manufacturing (GM North American Operations)

MMBTU/ Vehicle



Note: Ford and GM data are not directly comparable due to differences in the degree of vertical integration in automobile manufacturing

USE OF COGENERATION TO IMPROVE ENERGY PERFORMANCE AND SOLVE ENVIRONMENTAL PROBLEMS

PAPER MILL SLUDGE AND COGENERATION: Paper mill plants must dispose of the large amount of sludge they produce every day, and the standard practice has been to put the sludge in landfills.

- For example, Westvaco's North Charleston Kraft paper mill plant produces an average of 400 tons of wet sludge daily, which was being hauled to a landfill 22 miles away. This practice was undesirable because it used a large amount of the available landfill capacity and required hauling the sludge by truck—often through communities that objected.
- Earlier attempts to remove enough water to permit incineration were unsuccessful because sludge is typically about 22 percent solid matter and the remainder is water. In its North Charleston mill, Westvaco engineers designed a system using a recent Japanese technology that could remove about one-third of the water from the sludge, which sufficient to make its incineration practical when combined with bark fuel.
- Today, all of that plant's sludge is dewatered, combined with bark, and burned to produce steam, which is first used to generate electricity and is then used to provide about 16 percent of the heat needed for mill operations.
- Moreover, the process completely eliminates the need to use landfills.

CIRCULATING FLUIDIZED-BED BOILER: Scott Paper Company's Chester, Pennsylvania, tissue paper mill plant was at a competitive disadvantage because the costs of locally purchased energy were high and increasing and because the plant's forty-year old cogeneration facilities were limited, used fossil fuels, and required upgrading.

- Scott decided to build a large circulating fluidized-bed boiler fueled by limestone and anthracite culm, a coal-mining residue that is inexpensive and readily available in Pennsylvania.
- This new cogeneration facility has reduced the plant's energy costs (in real dollars) by 40 percent over six years.

- Plant engineers have been learning how to use this technology to burn sludge, and they are now able to incinerate 50 percent of the sludge produced by the plant, thereby reducing the landfill space needed by that amount.
- The anthracite culm is taken from exhausted coal mines and is acidic. After burning, the residual ash is alkaline and has a favorable neutralizing effect on mine drainage, when returned to the mines for disposal.
- The emissions from the circulating fluidized-bed boiler comply with the stringent emission restrictions of the ozone non-attainment air basin in which the plant is located.

CURRENT ISSUES AND OUTLOOK

INCREASED RECYCLED-PAPER CONTENT: Paper recycling places two environmental goals at odds. The benefits of recycling are reducing the amount of virgin wood used in making paper and reducing wastepaper delivered to landfills. In 1992, the industry achieved a recycled-paper content of 39 percent in all grades of paper by reprocessing 33.6 million tons of paper, up 28 percent from 1988. The industry is committed to reaching a 40 percent recycled-paper content by 1995.

However, reprocessing paper comes at some environmental cost. For many products, reprocessing paper uses much more energy than does processing virgin pulp to produce the same quantity of paper product. The industry is now determining the effect on energy requirements for the year 2000.

A recent study analyzing the energy life-cycle of newsprint by F. Stodolsky and M.M. Mintz of Argonne National Laboratory found two recycling scenarios that were estimated to be more energy efficient than the current pattern of utilization. Currently, about 15 percent of newsprint production is from old newsprint and about 10 percent of the supply of old newsprint is used in waste-to-energy plants. The alternative scenarios were:

- Increasing old newsprint to 33 percent of input material in newsprint manufacturing; or
- Increasing waste-to-energy use to 34 percent.

In both scenarios, the proportion of old newsprint going into landfills is reduced from the current 35 percent to 11 to 12 percent.

Both alternatives are estimated to reduce life-cycle energy consumption per ton by 7 percent. However, the authors point out that increasing the use of old newsprint as an input to newsprint

manufacture tends to increase the use of fossil fuels to replace the by-product and wood-waste renewables now used. The degree of uncertainty about the energy saving to be gained is greater for waste-to-energy use than for use as a raw material input.

The environmental implications of such future energy-saving scenarios are not necessarily simple and straight forward. They need to be examined carefully in conjunction with cost and other economic implications.

7 CHEMICALS

INDUSTRY SECTOR OVERVIEW

The "chemicals industry" comprises an entire industry sector (SIC 28), known as "chemical and allied products." This chapter presents data on energy performance and carbon dioxide emissions for the chemical industry sector, followed by a more detailed discussion of the industrial chemicals industry (SICs 281 and 286) and the agricultural chemicals industry (SIC 287). Combined, the industrial and agricultural chemicals industries account for 32 percent of the value added by manufacture in 1991 for the entire industry sector. The industries comprising the broader industry sector are shown in Table 9.

The industry sector consumed 2,568 trillion Btus of energy in 1988, or 3.40 percent of total U.S. energy consumption, based on data compiled by the Department of Energy from its most recent energy survey. Of that amount, 91.6 percent was carbon-based fuels that produced 4.38 percent of the U.S. total carbon dioxide emissions from fossil fuel burning and cement making.

The chemical industry uses heat and chemical processes to transform matter from one physical state to another (solid, liquid, gas) and from one composition to another. Some chemical reactions require enormous amounts of energy to accomplish the transformations. The industry produces over 70,000 distinct products through organic and inorganic processes.

Inorganic chemical processes produce compounds by breaking down or combining other compounds composed of the 107 natural elements. Examples of inorganic products include chlorine for bleach and water treatment, semiconductor materials, acids, and metal compounds.

Organic chemical processes use naturally occurring organic matter to produce other carbon-based substances. In 1991, the chemical industry sector processed 2,603 trillion Btus of organic feedstocks, including liquified gasses, heavy liquids, natural gas, and coal. The first step involves processing organic matter into first-level derivative chemicals, such as benzene, ethylene, and propylene. Inorganic compounds may be added in later steps to produce organic

products. Examples of organic products include nylon fiber, pharmaceuticals, latex paints, solvents, dyes, plastics, fertilizers, and tires.

TABLE 9
CHEMICAL AND ALLIED PRODUCTS INDUSTRY SECTOR (SIC 28)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	Total Employees	1992 Average Annual Employment	
				Production Workers Employees	Average Weekly Earnings
281	Industrial inorganic chemicals	\$ 15,724	125,100	56,600	\$ 681.65
282	Plastics materials and synthetics	19,673	173,200	104,300	671.89
283	Drugs	43,245	251,400	111,000	596.70
284	Soap, cleaners, and toilet goods	25,374	157,700	95,900	497.25
285	Paints and allied products	6,784	57,000	29,700	526.24
286	Industrial organic chemicals	26,441	153,300	76,100	785.69
287	Agricultural chemicals	8,120	56,300	33,500	653.71
289	Miscellaneous chemical products	9,431	96,900	57,500	556.36
28	TOTAL	\$ 154,793	1,070,900	564,600	\$ 622.80

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

The energy required to manufacture different chemicals varies significantly. A recent study by SRI International provides several examples. Methomyl pesticide requires 140 million Btus per ton of product; EDPM rubber, 50 million Btus; nylon-66, 45 million Btus; and ammonia, 6.5 million Btus. In contrast, although using some energy, the production of sulfuric and phosphoric acids provides a net release of energy.

Depending on customer demand and the nature of the chemical processes involved, some chemical products are manufactured in large-volume continuous-production facilities. Other chemicals are manufactured in small batches. The high-volume continuous operations offer more opportunities for energy efficiencies through process controls.

HISTORICAL TRENDS

During the 1974 to 1988 period, the chemical and allied products industry sector substantially increased its energy efficiency and reduced carbon dioxide emissions while substantially increasing production. Figures 18 and 19 show energy intensity and production with energy use.

- *Production:* Production in 1988 was 39.1 percent higher than in 1974. The chemicals industry is the largest export sector of the U.S. economy. In 1992 the chemicals industry exported \$44 billion and had a net trade surplus of \$17 billion.
- *Energy Consumption:* The use of purchased energy in 1988 was 12.6 percent lower than in 1974, decreasing from 2,937 trillion Btus to 2,568 trillion Btus. This reduction was the result of the following changes for specific fuels:
 - Coal, Oil and Gas Consumption Declined: Distillate use was 105 trillion Btus lower, residual oil use 66 trillion Btus lower, and natural gas use 232 trillion Btus lower. Coal use was 79 trillion Btus lower.
 - Electricity Consumption Increased: Electricity use Increased by 6 trillion Btus, and the use of other fuels increased by 91 trillion Btus.
- *Energy Intensity:* Because of these changes, energy intensity, energy consumption per unit of production, declined by 37.1 percent from 1974 to 1988.
 - In 1982 the Chemical Manufacturers' Association set a voluntary energy intensity improvement goal for members of 30 percent from 1972 levels, which the industry has exceeded.
- *Carbon Dioxide Emissions:* Carbon dioxide emissions declined by 8.6 million metric tons of carbon, or 13 percent, from 1974 to 1988. Emissions in 1988 were 57.6 million metric tons of carbon, compared to 66.2 millions tons in 1974. Carbon emissions intensity, carbon dioxide emissions per unit of production, declined by 37.4 percent from 1974 to 1988.

Figure 18
Chemicals and Allied Products Sector
Production, Energy, and Emissions

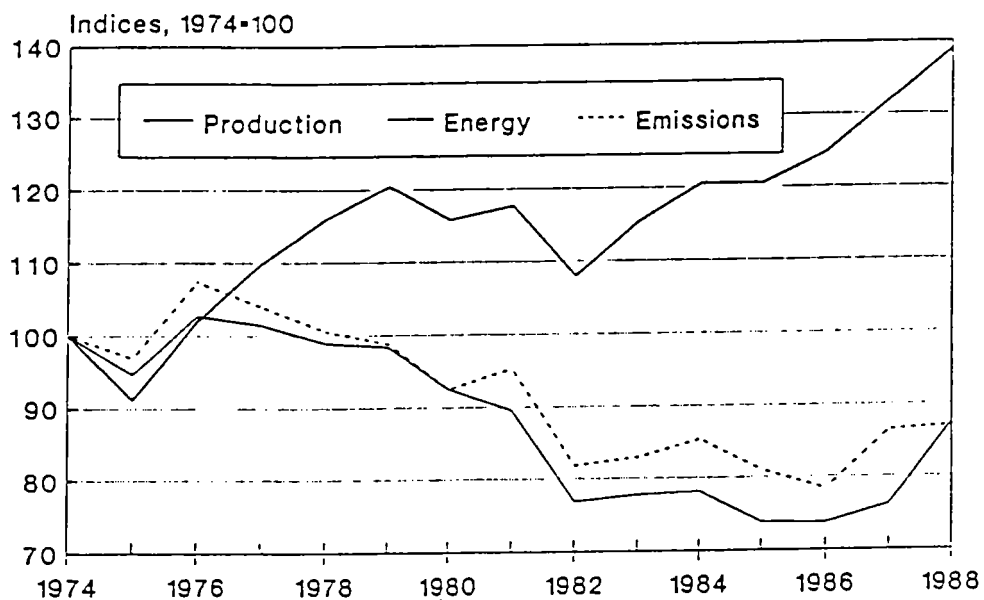
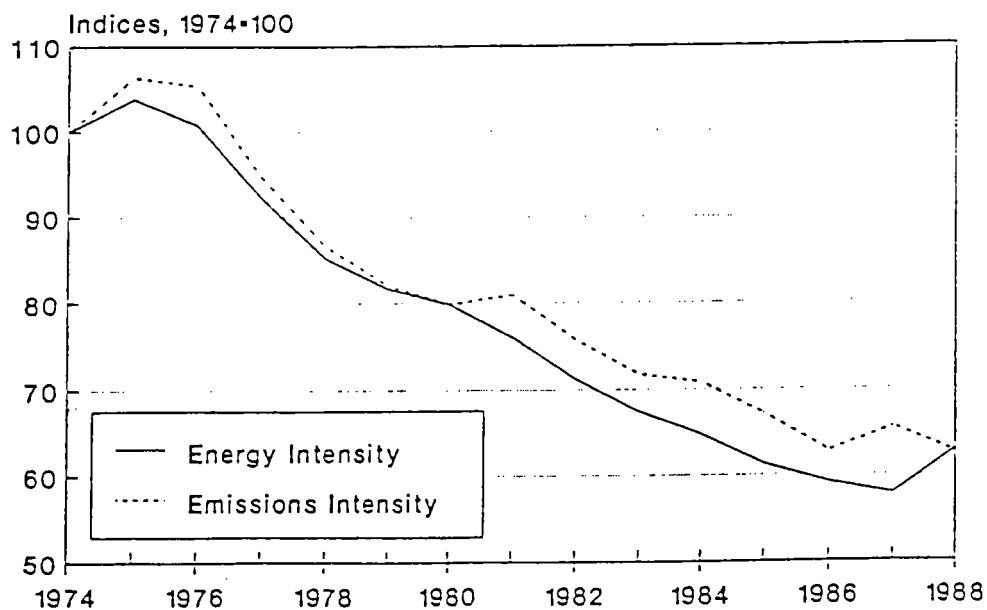


Figure 19
Chemicals and Allied Products Sector
Energy and Emissions Intensity



CURRENT ISSUES AND OUTLOOK

From one year to the next, the set of products manufactured by the chemical industry sector changes due to changes in customer needs and the development of new chemical products. In 1991 the industry spent \$13.3 billion on research and development and, in recent years, accounted for about 15 percent of U.S. patents issued. Since some chemical products are much more energy intensive than others, the product mix directly affects energy use and efficiency in the chemical industry sector. To support its members in achieving further energy efficiencies, the Chemical Manufacturers' Association (CMA) established its Energy Efficiency Continuous Improvement Program, which is described in the box at the end of this chapter.

The industry uses efficient manufacturing processes from the outset. Some products have short production lives before being replaced by other products. As production experience is gained with a product, process methods may be improved and yield further efficiencies. The production of nylon fiber is an example.

A further development in the chemical industry sector has been the globalization of the chemical industry—especially over the last three decades. U.S. manufacturers compete with foreign manufacturers to supply U.S. customers. Conversely, U.S. manufacturers supply many foreign customers. This global competition emphasizes the need to manufacture products as efficiently as possible. U.S. manufacturers have been successful in maintaining a substantial positive balance of trade in chemical products; the industry has exported more chemical products than it has imported. In 1991, total exports of chemical industry sector products was \$43.0 billion and imports were \$24.2 billion, for a net surplus of \$18.8 billion.

The following programs typify the industry's present efforts to achieve further energy consumption and energy intensity improvements and to share that technology with other countries.

- *Low-Pressure Processes.* The chemical industry has been working to replace high-pressure processes with low-pressure ones wherever possible, which also produces energy efficiencies. For example, LP-OXO is a low-pressure oxidation process for producing industrial solvents and plasticizer. LP-OXO uses 40 percent less energy than conventional processes.
- *Polyethylene Production.* Unipol is a new process for making polyethylene, a long-term staple organic chemical product. Compared with conventional production methods, Unipol uses 65 percent less energy per pound of polyethylene manufactured.
- *Ethylene Oxide and Ethylene Glycol Production.* The technology for producing ethylene oxide has become significantly more energy efficient. Olin Corporation has just completed a new plant in Venezuela to use the new technology.

- *Fibers Technology Transfer.* DuPont Chemical's Fibers Technology Transfer Division has sold DuPont's state-of-the-art technologies for producing acrylic, nylon, and polyester fibers under agreements with several developing countries, including China, India, Turkey, and Indonesia. Specifically, these technologies use energy-efficient processes, equipment, and manufacturing practices. By operating and maintaining facilities using these technologies, workers in these countries will gain experience with energy-efficient operations.
- *Ion-Exchange Membrane Cells.* Chlorine and sodium hydroxide are widely used chemicals in the plastics, paper, and other industries. They have been produced using mercury cells or diaphragm cells, which employ mercury (a health hazard), electrolytic separation (a dangerous operation), and heat for evaporation.
 - OxyChem has a pilot plant in Chile that uses ion-exchange cells, which eliminates the health and environmental hazards of the previous technology. The new technology is significantly less energy intensive, since it uses much less electricity per ton of product.
 - An OxyChem affiliate in Thailand uses the new technology to double product capacity while saving energy.
- *Self-Generated Electricity.* The chemical industry generates about 20 percent of the electricity it uses.
- *Process Control.* Computer control of production processes has been implemented in much of the chemical industry, providing a greater consistency of operations and greater energy efficiency.

CMA ENERGY EFFICIENCY CONTINUOUS IMPROVEMENT PROGRAM

A. CMA ROLE

1. CMA will provide a positive influence supporting continuously improved energy efficiency. CMA will continue to collect information on member companies' energy efficiency performance through the annual member company Energy Efficiency and CO2 Emissions Survey. This survey will also provide a means of gauging aggregate progress in improving energy efficiency.
2. CMA, using data obtained by the annual survey, will assess aggregate energy efficiency performance on the basis of both Btu/\$ of sales (Value of Shipments), corrected to constant dollars, and Btu/lb. of product. These parameters are useful in determining trends in industry performance.
3. CMA will sponsor periodic meetings/seminars for member company plant and corporate representatives focusing on energy efficiency programs, achievements, education, etc.
4. CMA will initiate and sponsor an annual Energy Efficiency Award program in recognition of individual member company performance.
5. CMA will routinely inform member companies of industry energy efficiency progress in the Energy and Feedstock Issues newsletter and other CMA publications.
6. CMA will maintain open lines of communication with DOE and EPA regarding energy efficiency performance and energy efficient technology and methodology development which could have application in the chemical industry.

B. MEMBER COMPANY ROLE: ILLUSTRATIVE MEMBER COMPANY VOLUNTARY GUIDELINES

1. Each member company should have a corporate energy policy that establishes energy management as an integral part of the corporate culture and decision-making process.
2. Upper level management should be responsible for implementing and supporting a cohesive, coordinated corporate program to implement the energy policy.
3. Each member company should track its energy use on at least an annual basis, relating that energy use to whatever base is indicative of efficiency performance.
4. Each company should establish goals for energy efficiency improvements and plans to meet those goals.
5. Companies should keep employees informed of energy efficiency performance and the importance of efficient energy use. Mechanisms should be established to encourage employees to suggest changes, to help them get ideas funded and implemented, and to recognize those responsible for improvements.
6. Individual companies should recognize the inherent interconnection of energy management and environmental control projects should also be recognized.
7. Economic evaluation procedures which consider the lifetime energy impact of equipment and processes should be used in the decision-making process, rather than methods which consider only the purchase cost or installed cost of equipment.
8. Corporate energy program progress should be regularly reported to and by executive management, either through annual reports or other means.

8 CEMENT MANUFACTURING

INDUSTRY SECTOR OVERVIEW

Cement and concrete, gypsum, and plaster manufacturing (SIC code 324) are parts of the Standard Industrial Classification for the stone, clay, and glass products industry sector (SIC 32). Together they account for 39 percent of the value added by manufacture in 1991 for the entire industry sector. This chapter presents data on energy performance and carbon dioxide emissions in the stone, clay, and glass products industry sector, followed by a more detailed discussion of cement manufacturing. The industries comprising the broader industry sector are shown in Table 10.

In 1988, based on data compiled by the Department of Energy from its most recent energy survey, the industry sector consumed 959 trillion Btus or 1.32 percent of total the U.S. energy consumption. Of this total, 97.5 percent was derived from fossil fuels and cement making (calcination), producing 31.7 million metric tons of carbon emissions, or 2.41 percent of total U.S. carbon dioxide emissions from fossil fuel burning and cement manufacturing (calcination).

CEMENT MANUFACTURING: The manufacture of cement is an energy-intensive process. Calcium carbonate and magnesium carbonate are heated, driving off carbon dioxide and leaving free lime and magnesia. This process is called calcination. These intermediate products, heated further with other ingredients, become cement clinker. Although cement comprises 10 to 15 percent of concrete, the manufacture of concrete is not an energy-intensive process.

There are two sources of carbon emissions—the emissions from combustion of fuels for process energy and heat, and the emissions from calcination of the raw materials. The calcination process generates 45 to 54 percent of the carbon dioxide emissions.

TABLE 10
STONE, CLAY, AND GLASS PRODUCTS INDUSTRY SECTOR (SIC 32)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	1992 Average Annual Employment		
			Total Employees	Production Workers Employees	Average Weekly Earnings
321	Flat glass	\$ 1,254	16,300	12,800	\$ 735.45
322	Glass and glassware, pressed or blown	5,129	82,900	70,600	553.35
323	Products of purchased glass	3,312	57,000	43,100	413.83
324	Cement, hydraulic	1,937	17,900	13,800	623.50
325	Structural clay products	1,604	32,700	25,200	406.59
326	Pottery and related products	1,758	37,200	29,100	410.86
327	Concrete, gypsum, and plaster products	10,632	187,200	141,400	480.31
328	Cut stone and stone products	582	a	a	a
329	Miscellaneous nonmetallic mineral products	5,630	75,900	56,400	508.99
32	TOTAL	\$ 31,839	519,300	401,300	\$ 491.21

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

Note: a. Data omitted from source.

HISTORICAL TRENDS

Figures 20 and 21 show energy intensity and production with energy use in the stone, clay, and glass industry sector.

- **Production:** Production in the stone, clay, and glass products industry increased by 21.0 percent from 1974 to 1988.
- **Energy Consumption:** Total energy consumption decreased by 28 percent from 1974 to 1988, from 1,332 trillion Btus to 959 trillion Btus. Within this total:
 - **Oil and Gas Consumption Decreased:** Gas consumption decreased by 231 trillion Btus, distillate by 41 trillion Btus and residual by 35 trillion Btus.

Figure 20

Stone, Clay, and Glass Products Sector Production, Energy, and Emissions

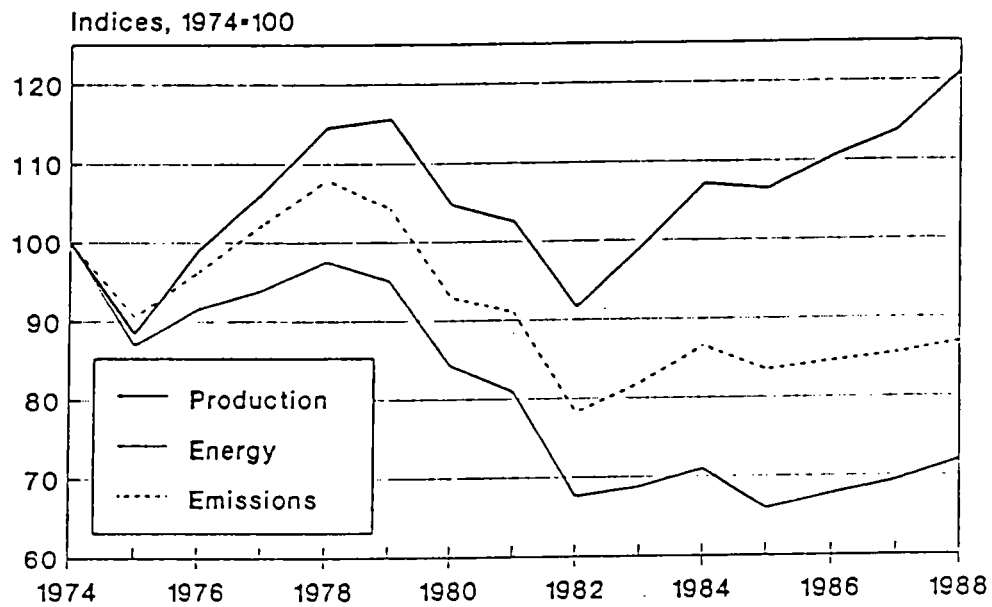
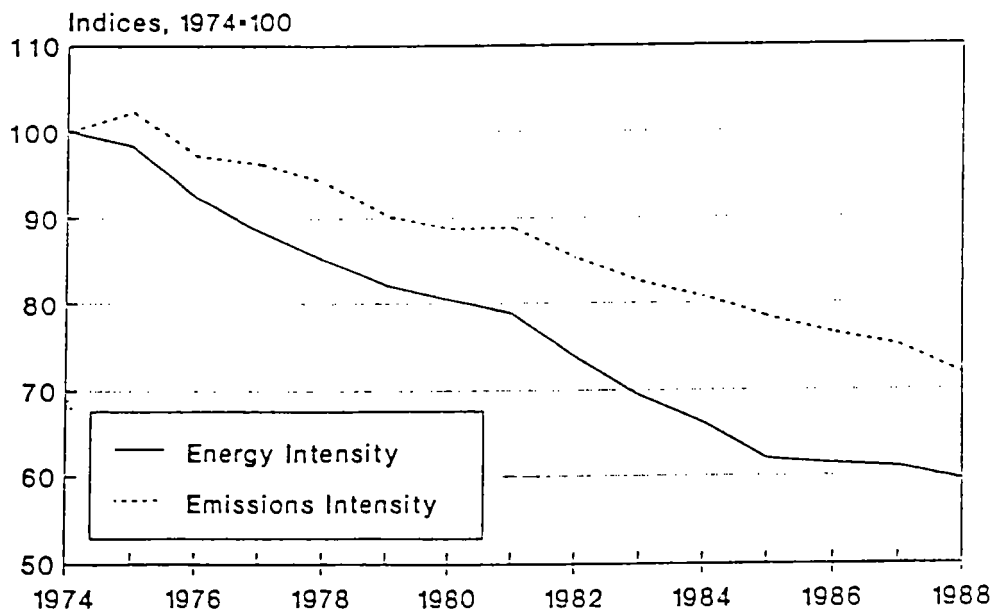


Figure 21

Stone, Clay, and Glass Products Sector Energy and Emissions Intensity



- Coal Utilization and Electricity Consumption Increased: Coal increased by 47 trillion Btus, and electricity consumption increased by 16 trillion Btus.
- *Energy intensity*, measured as energy consumption per unit of production, declined by 40.5 percent from 1974 to 1988.
- *Carbon Dioxide Emissions*: Total emissions of carbon dioxide decreased by 4.8 million metric tons of carbon between 1974 and 1988, a decrease of 13.1 percent. Emissions decreased from 36.5 million tons in 1974 to 31.7 million metric tons in 1988. Carbon dioxide emissions intensity, emissions per unit of production, decreased by 28.2 percent from 1974 to 1988.

FACTORS AFFECTING HISTORICAL TRENDS

Fuel use has changed substantially in the U.S. cement industry. In 1972, 57.3 percent of the process fuel consumed was petroleum or natural gas. By 1992, this had leveled to 11.4 percent, and coal and coke accounted for 82 percent.

In recent years an increasing trend has been the use of waste-derived fuels. Gases have long residence times in cement kilns at high temperatures of 3200°F to 3400°F, which ensures proper destruction of the waste materials while capturing their energy value. Cement plants are burning such waste materials as tires, spent solvents, and agricultural wastes, such as rice hulls and wood chips. Experiments are being done with municipal waste and biomass.

The use of such materials has the advantage that it involves no net increase in carbon dioxide emissions and may even reduce carbon dioxide emissions. Burning waste materials in cement kilns avoids the need to burn that waste material in incinerators while operating kilns with conventional fuels; this reduces total emissions. Burning waste materials also provides substantial environmental benefits by solving what is often a difficult disposal problem and conserving fossil fuels. Recycling biomass produces no net increase in emissions and avoids the emissions that would otherwise come from conventional fuels. About one-third of U.S. cement plants are now developing or using waste fuel capabilities, and more are likely to do so.

CURRENT ISSUES AND OUTLOOK

The cement industry has strong incentives to pursue ongoing efforts to reduce fuel consumption. Energy can account for 20 to 35 percent of the cost of the product, depending on economic conditions and plant age and process. Investment in improved process technology is a major source of past reductions in energy use and are likely to continue to be a major source.

The major opportunities underway currently and in the future that could further improve energy performance include the following:

- *Shift Toward More Efficient Calcination Process Technologies:* The traditional process for calcination is the so-called wet process, where slurried raw materials are mixed and pumped into the rotary kiln where they are calcinated and turned into clinker. This process has the advantage of better blending and easy handling of materials but is the least energy efficient since part of the energy used must be used to evaporate the water in the slurry. There is currently underway a trend toward more energy efficient processes, including:
 - The **long dry process**, where raw materials are fed into a long kiln in a dry state. The long kiln is necessary for sufficient heating, and is more energy efficient.
 - The utilization of **preheater** technology, which is more energy efficient than the long dry kiln. Preheater technology utilizes the waste energy in combustion exhaust gases to heat raw materials before they enter the dry kiln.
 - The use of **precalciner** technology, which adds additional efficiency to preheater equipped kilns. Precalciner technology involves the addition of a separate combustion chamber between the preheater tower and the kiln.

The Office of Technology Assessment's recent study, *Industrial Energy Efficiency*, [August 1993 (p. 109)] noted that the industry in recent years has shifted to the dry process, imposed greater environmental controls, made more extensive use of preheaters and concluded: "Advances in the preheater and precalciner process have led to significant improvements in the overall energy efficiency of cement production in recent years." This improvement is illustrated in Table 11.

TABLE 11
ENERGY CONSUMPTION OF SELECTED TYPES OF U.S. CEMENT PLANTS
(MILLION BTU PER EQUIVALENT TON*)

	1972	1991	% Change
All Plants **	6.746	4.913	-27%
Wet Process Plants	7.254	6.302	-13%
Dry Process Plants	6.254	4.471	-29%
No Preheater	6.293	5.379	-13%
Preheater		4.364	
Precalciner		3.881	
Preheater/Precalciner***	6.404	4.113	-36%

* Tons used to measure energy efficiency are an equivalent ton measure composed of 92% clinker production plus 8% finish cement production.

** Grinding Plants not included.

*** Includes Plants that are Preheater only.

Source: Portland Cement Association, "U.S. and Canadian 1991 Labor-Energy Input Survey"

In 1989, cement clinker capacity in the U.S. was 81.5 million tons.

- Preheater and precalciner capacity installed since 1971 was 41.5 million tons or about half of total capacity. Long-dry capacity was 14.1 million tons, or an additional 17.3 percent.
- The wet process capacity was 26 million tons.

Precalciner capacity in new plants is estimated to cost \$150 to \$200 per ton in 1990 dollars. Upgrading of an existing facility is estimated to cost \$90 to \$120 per ton. Costs to upgrade to industry-wide precalciner technology are estimated at \$4.4 to \$5.8 billion, compared to U.S. 1989 production value of \$3.7 billion.

Industry upgrading to the more energy efficient technologies will continue as rapidly as it makes economic sense and the necessary investment resources are available. However,

these investments are costly, and raising capital for investment is difficult even in good economic times.

- *Shifts in Raw Materials Utilization:* The industry is funding research to examine low-carbonate raw materials which could be substituted for the high-carbonate materials currently used in cement manufacture. It is also substantial technical and process issues evaluating the use of blended cements and extenders as a way to reduce carbon dioxide emissions. For example, the industry currently uses 6 million tons of fly ash as a cement extender. This represents a reduction of approximately 6 million tons of carbon dioxide, annually.
- *More Selective Specifications for Low-Alkali Cement:* Carbon dioxide emissions could be reduced by more selective practice in specifying low-alkali cements, only where they are needed. Some aggregates containing certain silicate minerals will chemically react with soluble alkalis in cement, unless the cement is low alkali. Carbon dioxide emissions can be reduced by using low-alkali cement only in these circumstances.
- *Natural Gas Conversion:* Switching to natural gas as a fuel may be a potential option for reducing carbon dioxide emissions where economic, environmental, and availability considerations are favorable. However, a disadvantage is that the switch from coal to natural gas increases NOx emissions significantly. In 1989, 10 of the 114 U.S. plants were using natural gas, 54 plants considered natural gas as an alternative fuel, and 50 plants had no practical natural gas option because of remoteness from pipeline facilities.

9 AUTOMOBILE MANUFACTURING

INDUSTRY SECTOR OVERVIEW

Automobile manufacturing (SIC 371) is the largest component of the transportation equipment manufacturing industry sector (SIC 37), accounting for 48 percent of the value added by manufacture in 1991 for the entire industry sector. This chapter presents data on energy performance and carbon dioxide emissions for the entire transportation equipment manufacturing industry sector, with a follow-up discussion that focuses on the automobile manufacturing industry. The industries comprising the broader industry sector are shown in Table 12.

The transportation equipment manufacturing industry sector consumed 350 trillion Btus in 1988, or 0.46 percent of total U.S. energy consumption, based on data compiled by the Department of Energy from its most recent energy survey. It emitted 0.81 percent of the total U.S. carbon dioxide emissions from fossil fuel burning and cement making.

HISTORICAL TRENDS

Figures 22 and 23 show historical trends in production and energy intensity in the transportation equipment manufacturing industry sector.

- *Production:* Industrial production in the transportation equipment industry increased by 58.1 percent from 1974 to 1988.
- *Energy Consumption:* Consumption of purchased energy declined by 6.7 percent from 1974 to 1988, from 375 trillion Btus to 350 trillion Btus. Within this total reduction:
 - *Electricity Consumption Increased:* The use of electricity increased by 33 trillion Btus.

Figure 22

Transportation Equipment Industry Sector Production, Energy, and Emissions

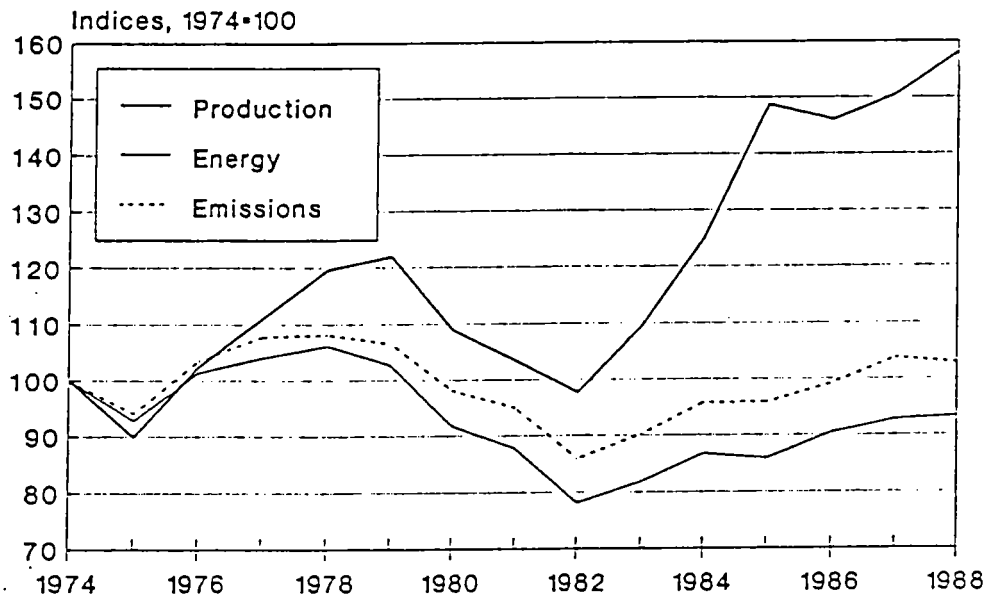


Figure 23

Transportation Equipment Industry Sector Energy and Emissions Intensity

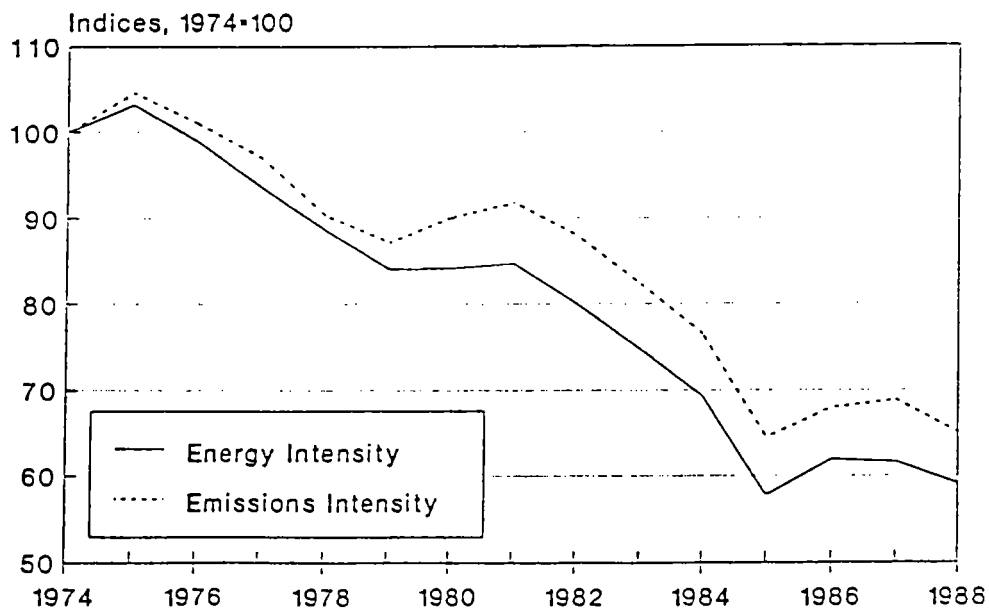


TABLE 12
TRANSPORTATION EQUIPMENT MANUFACTURING INDUSTRY SECTOR (SIC 37)
EMPLOYEES AND VALUE ADDED BY MANUFACTURE

SIC	Industry	1991 Value Added by Manufacture (\$ millions)	Total Employees	1992 Average Annual Employment	
				Production Workers Employees	Average Weekly Earnings
371	Motor vehicles and equipment	\$ 73,333	812,200	620,800	\$ 649.99
372	Aircraft and parts	49,046	617,400	293,000	691.80
373	Ship and boat building and repairing	7,959	170,100	131,100	481.19
374	Railroad equipment	1,690	28,700	21,200	587.94
375	Motorcycles, bicycles, and parts	741	a	a	a
376	Guided missiles, space vehicles, parts	17,103	140,900	38,900	651.58
379	Miscellaneous transportation equipment	2,107	41,800	27,500	434.41
37	TOTAL	\$ 151,979	1,826,900	1,144,200	\$ 633.69

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

Note: a. Data omitted from source.

- Consumption of Coal, Oil and Gas and Other Fuels Decreased: Coal use decreased by 13 trillion Btus, residual oil by 5 trillion Btus, natural gas by 7 trillion Btus, distillate and coke together by 11 trillion Btus, and other fuels by 22 trillion Btus.
- *Energy Intensity:* Energy intensity, measured as energy consumption per unit of production, was reduced by 41.0 percent from 1974 to 1988.
- *Carbon Dioxide Emissions:* Total carbon dioxide emissions were virtually unchanged between 1974 and 1988, with a slight increase of 0.3 million metric tons, or 2.9 percent, to 10.7 million metric tons of carbon. Carbon dioxide emissions intensity, or emissions per unit of production, declined by 34.9 percent from 1974 to 1988.

CURRENT ISSUES AND OUTLOOK

The automobile manufacturing industry has achieved significant reductions in energy consumed per unit of production. Information from companies' North American operations show:

- Ford Motor Company reached a reduction of 30 percent in total energy use per vehicle, from over 24 million Btus per vehicle in 1980 to almost 17 million Btus in 1992. This is shown in Figure 24.
- General Motors Corporation reached a reduction of 34 percent in total energy use per vehicle, from 47 million Btus per vehicle in 1974 to about 31 million in 1992. This is shown in Figure 25.

These data are not comparable between the two companies, because of differences in the degree of vertical integration within each company. Each company has a different proportion of parts provided by outside supplies (Ford relies more heavily on outside suppliers), and the data on energy consumption in parts manufacturers is not included in the graphs. In addition, the data excludes energy consumption by major subsidiaries, e.g., the GM data excludes EDS and Hughes and the Ford data excludes glass.

These reductions are remarkable because they took place during a period of time when the industry was engaged in substantial efforts to significantly redesign vehicles and improve vehicle quality. During this period of time, the industry made a substantial investment in new plant and capital equipment, including the greatly expanded use of robotics.

10 ELECTRICITY GENERATION

INDUSTRY SECTOR OVERVIEW

The electric services industry (SIC 491) includes the generation, transmission and distribution of electricity. This chapter presents data on energy performance and carbon dioxide emissions in electricity generation and transmission. It also discusses efforts by electric utilities to promote increased end-use energy efficiency by their customers. Table 13 shows key facts about the industry.

TABLE 13
ELECTRIC UTILITY INDUSTRY SECTOR (SIC 491)
EMPLOYEES AND VALUE ADDED

SIC	Industry	1991 Revenues* (\$ millions)	Total Employees	1992 Average Annual Employment	
				Production Workers	
				Employees	Average Weekly Earnings
491	Electric services	\$175,595	443,200	343,200	\$ 698.48

Sources: *Employment and Earnings; Annual Survey of Manufacturers.*

* Value added is not available.

According to data compiled by the Department of Energy from its most recent energy survey, in 1988 the industry consumed 28,000 trillion Btus or 35.07 percent of the total U.S. energy consumption. Of that amount, 75.8 percent was of carbon-based fuels that produced 36 percent of the total U.S. carbon dioxide emissions from burning fossil fuels and cement making.

The electric utility industry uses other forms of energy to produce electricity. The significant advantage of electricity is that, once produced, it can be transmitted to other locations on demand with only minor energy losses. Electricity is generated by several methods.

- **Hydroelectric.** Water stored at a higher elevation (e.g., behind a dam) drops across the blades of a turbine, causing the attached generator to rotate and produce electricity. This method uses no other energy and produces no carbon dioxide emissions. Hydropower is renewable because the atmosphere evaporates water from lower elevations and returns it as rain or snow to the higher elevations above the dam. About 10 percent of U.S. electricity is generated by hydroelectric plants.
- **Nuclear.** A nuclear reaction produces a great amount of heat, which is used to heat water to steam that passes over a turbine, producing electricity. Nuclear energy produces no carbon dioxide emissions.
- **Fossil fuel.** Gas, oil, or coal is burned to heat water to produce steam that passes over a turbine, producing electricity. Combustion of the fossil fuels produces carbon dioxide emissions.
- **Other Renewable Energy.** Solar, geothermal, wind and biomass sources are being developed commercially. There are 54 large-scale solar projects, one gigawatt of geothermal production in California, and _____ of wind-generated electricity.

Electricity is transmitted long distances from the generator to a local utility over high-capacity power lines; these lines may extend a few miles or over a thousand miles. Although there are no carbon dioxide emissions, there are energy losses due to the properties of the transmission lines.

- These energy losses are less at very high voltages and less for direct current, rather than alternating current. Most transmission lines in the U.S. use high-voltages and alternating current. In recent years, the technology has become available to use high-voltage direct current lines, with significant reductions in energy losses.
- Local transmission to substations is over _____ capacity lines operating at lower voltages and invariably at alternating current. Lines from substations to customers operate at still lower voltages, except to large industrial customers.

HISTORICAL TRENDS

Figures 26 and 27 show historical trends in production and energy intensity in the electric services industry.

Figure 26
Electric Services Industry
Production, Energy, and Emissions

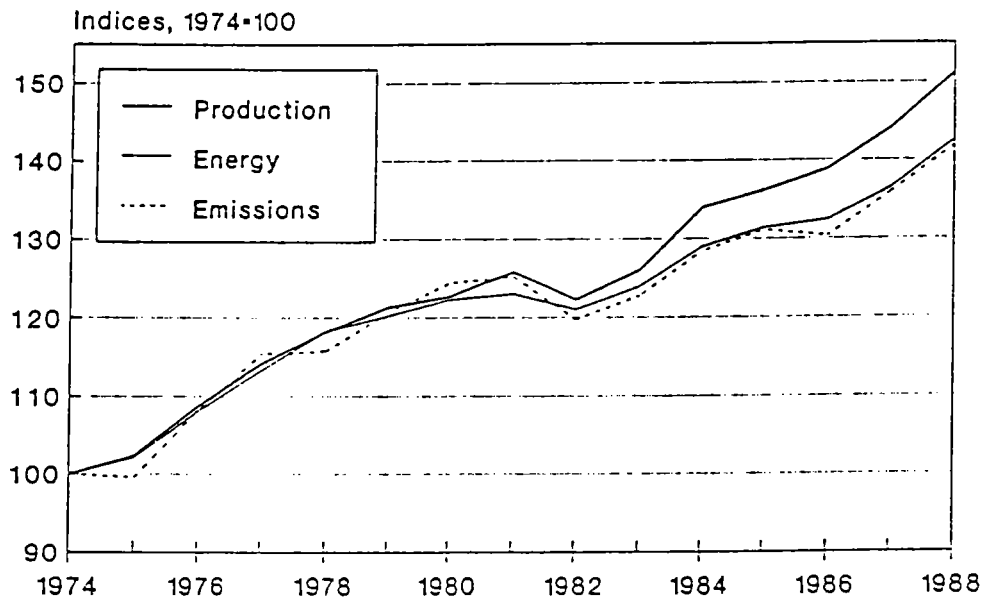
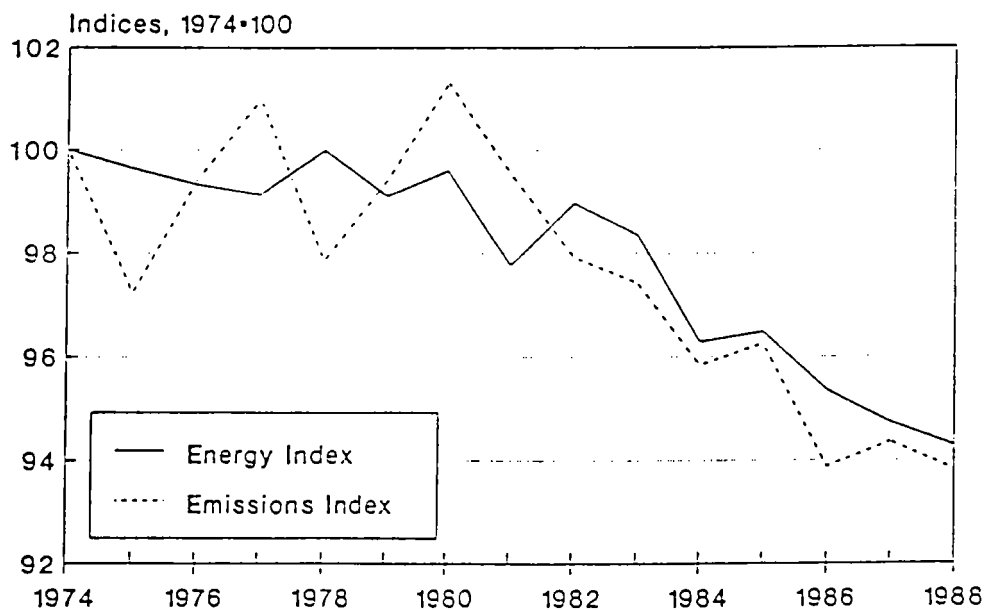


Figure 27
Electric Services Industry
Energy and Emissions Intensity



- *Production:* Total U.S. electricity generation increased by 51.1 percent from 1974 to 1988, from 1,706 to 2,578 billion kilowatt hours, or at an annual rate of 3.0 percent.
- *Energy Consumption:* Energy consumption increased by 42.5 percent, from 19.7 to 28.0 quadrillion Btus, an annual increase of 2.5 percent. This overall increase was the net result of:
 - Reductions in Oil and Gas Consumption: Oil consumption decreased 53.3 percent from 3,181 to 1,484 trillion Btus, and natural gas consumption declined 22.9 percent from 3,512 to 2,707 trillion Btus.
 - Increased Reliance on Nuclear Power: Electricity from nuclear power increased 34.5 percent, from 1,272 to 5,662 trillion Btus.
 - Increased Coal Utilization: Coal consumption increased 85 percent from 8,545 to 15,846 trillion Btus.
 - Reduced Hydro: Hydropower production decreased 26.8 percent, from 3,143 to 2,302 trillion Btus.
- *Energy Intensity:* Energy intensity, measured as energy consumption per unit of output, improved by 5.7 percent from 1974 to 1988.
- *Carbon Dioxide Emissions:* Carbon dioxide emissions increased by 41.8 percent, 139.4 million metric tons of carbon. Total emissions increased 42 percent, from 333.6 to 473.0 million metric tons of carbon, an annual rate of 2.5 percent. Coal consumption accounted for approximately 85 percent of these emissions. Although total carbon dioxide emissions increased, carbon emissions intensity, measured as carbon dioxide emissions per unit of output, improved by 6.2 percent between 1974 and 1988.

FACTORS AFFECTING HISTORICAL TRENDS

The major factor accounting for the increase in energy use and carbon dioxide emission in electricity generation was the increased demand for electricity as the fuel of choice. The recent Office of Technology Assessment Report noted that the "use of electricity grew faster than other energy sources during 1960 to 1990". The report opined that the factors that contributed to this trend were "electricity's superior quality, flexibility, and environmental cleanliness at the point of use". The increased use of electricity in the industrial sector is particularly noteworthy. For example:

- From 1974 to 1991, the demand for electricity in industry increased by 37%, while the demand for the fuels either declined or showed little change. This is illustrated in Figure 28.

Figure 28

Changes In Industrial End-Use Patterns 1975- 1991

Percentage Change
in Demand

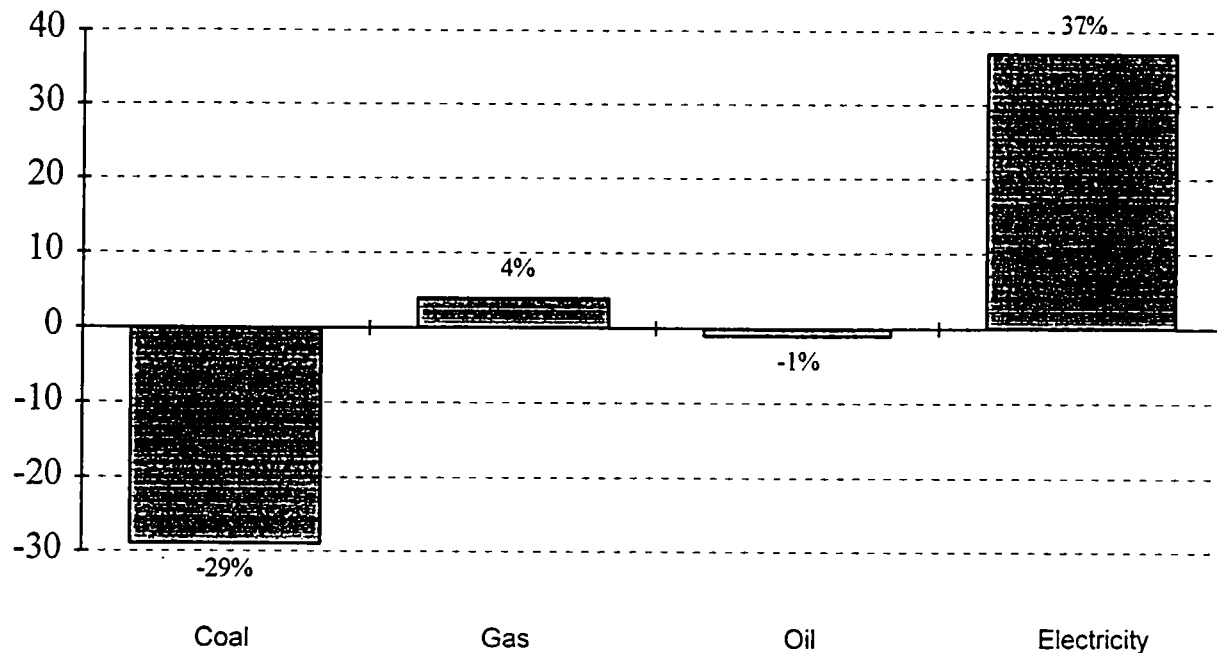
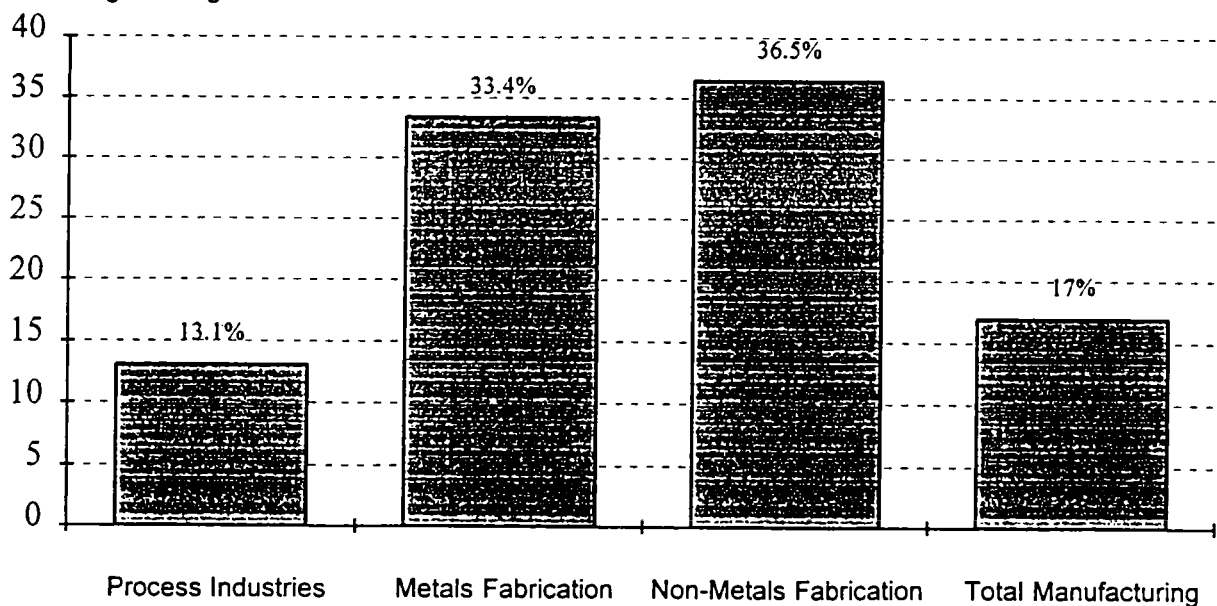


Figure 29

Change in Market Share for Electricity Selected Manufacturing Industry Sectors 1980- 1990

Percentage Change



- The change in market share of fuels in the manufacturing sector was even more striking. Over the past decade (1980 - 1990), the market share of electricity increased by almost 20 percent. The changes in market share are shown in Figure 29.

CURRENT ISSUES AND OUTLOOK

The electric utility industry currently has underway a number of initiatives to improve the efficiency of generation and transmission systems.

- *Hydroelectric Generating Efficiency.* This program replaces older hydroelectric turbines with new-generation ones that can be up to 60 percent more efficient. The additional electricity produced offsets production from fossil-fueled plants, thus avoiding the associated carbon dioxide emissions.
 - For example, one utility has a multi-year program to replace older turbine units. During the period 1991 to 2000, this utility expects to increase output by 400,000 megawatt-hours (MWh), which will avoid emitting 120,000 metric tons of carbon.
- *Clean Coal Technologies.* These technologies are being used to replace older coal-fired boiler with advanced conversion technologies such as pressurized fluidized bed combustion, coal gasification, or advanced fuel cells.
 - These technologies are expected to be 10 to 15 percent more efficient than conventional coal-fired units.
 - A joint Federal-industry Clean Coal Technology Demonstration program is supporting the commercialization of these technologies. It is funded at \$5 billion.
- *Improved Transmission Systems.* The use of extra-high voltage (EHV) transmission systems greatly reduces transmission-line losses. One 345 kilovolt (kv) line has the capacity of six 138 kv lines, and one 765 kv line can replace five 345 kv lines. A single 765 kv line can avoid about 60 MW in losses.
- *Electric Utility Boiler Efficiencies.* Increased energy efficiencies are possible at certain kinds of boilers that would improve their heat rate from 1 to 5 percent. However, in light of the efficiency gains that already have been achieved, the potential for additional improvements appears limited.
- *Clean Air Act Compliance.* Electric utilities are converting selected coal-fired generators to natural gas to comply with requirements of the acid rain provisions of the Clean Air Act of 1990. While reducing the emissions of acid rain precursors (SO₂ and NO_x), this change also reduces carbon dioxide emissions at the same time.

IMPROVING END USE EFFICIENCY

The electric utility industry has substantial efforts underway to increase end-use energy efficiency and to reduce carbon dioxide emissions through demand-side management (DSM) programs. When energy services can be provided with a smaller electricity input, then less capital needs to be invested in generating capacity, smaller quantities of fuels need to be burned, and smaller quantities of carbon dioxide emissions are released into the atmosphere. DSM programs have been increasing in popularity with electric utilities in the past few years.

According to surveys conducted by the Electric Power Research Institute (EPRI) in 1988 and 1992, the average number of DSM programs at U.S. and Canadian electric utilities had increased by 65 percent, from 2.11 programs per utility in 1988 to 3.48 in 1992. In the 1992 survey, EPRI found that DSM programs affected the following areas of end user electrical efficiency. (Some programs affect more than one area.)

- **Heating, Ventilating, and Air Conditioning (HVAC).** About 28 percent of the DSM programs affect this area. These programs encourage replacing less efficient heat pumps and air conditioners with more efficient units. Customers are also shown how to use existing equipment more effectively and how to use different kinds of HVAC equipment to reduce their energy demands during peak hours, thereby reducing the peak generating capacity needed by utilities. Depending on the equipment involved, the savings for a non-residential end user can range up to 25 mega-Watt-hours (MWh) annually. Similarly, the savings for an average residential end user can range up to 0.7 MWh annually, particularly for winter users.
- **Audit and Building Envelope.** Utility representatives conduct a walk-through audit of the end user's facilities and provide recommendations that can include weatherization improvements (e.g., better insulation), evaluations of industrial processes, and design changes for new construction. About 25 percent of DSM programs are in this area. The average energy savings from non-residential weatherization audits average 234 MWh annually per end user. Other audits save an average of 62 MWh per end user annually.
- **Efficient Equipment and Appliances.** About 20 percent of DSM programs are in this area. These DSM programs encourage with substitution of electricity for other fuels for water heating and replacement of older equipment with more energy-efficient models. The greatest savings can be realized with agricultural irrigation, averaging 16 MWh per end user annually.

- **Load Control.** About 20 percent of DSM programs emphasize the use of devices to control electrical equipment more accurately. This area includes use of electronic HVAC controls. The average air-conditioning energy reduction for a non-residential end user is 1 kwh, and the average for non-residential end users is 65 MWh. However, agricultural irrigation has the greatest potential, achieving an average load reduction of 35 kwh per end user.
- **Lighting and Lighting Controls.** About 15 percent of DSM programs show non-residential users how to illuminate areas more efficiently and how to use more energy-efficient lighting equipment. The average non-residential user saves 113 MWh annually, and can save up to 1,086 MWh annually.
- **Special Rates.** About 9 percent of DSM programs use rate structures to encourage end users to reduce power usage during periods when the peak demand on the utility is especially high, such as reductions in retail store lighting and air conditioning on very hot days. The energy reduction achieved by special rates varies depending on whether the facility is new or old and other circumstances. Special rates can produce an average load reduction of 1,180 kilo-Watt hours (kwh) for interruptable power and 1,900 kwh for economic development areas.
- **Thermal Storage, Standby Generation, and other Programs.** About 7 percent of DSM programs show end users how to use thermal storage to balance their HVAC energy demands. Standby generation programs help end users produce electricity on-site to meet part of their electric needs during peak-demand periods. The average thermal storage program reduces cooling demand by 21 kwh and heating demand by 412 MWh. The average industrial standby generation program saves 670 MWh annually per end user.
- **Refrigerator Recycling.** About 9 million households have second refrigerators, which are generally older, inefficient units with PCB-filled capacitors and CFC-charged systems. This program encourages their replacement or retirement. Each unit removed from service saves 1200 MWh annually.
 - For example, one utility has implemented a program that, in two years, collected nearly 14,000 refrigerators, incinerated the PCBs, captured the CFCs for reprocessing, and recycled the metal. This initiative saved 13,000 MWh (allowing for 25 percent replacements with more efficient units) and avoided 4,500 metric tons of carbon.
 - Nationally, recycling 75 percent of the 9 million refrigerator units would save about 8.4 million MWh and avoid about 2.9 million metric tons of carbon emissions.

THE IMPACT OF ELECTROTECHNOLOGIES ON CARBON DIOXIDE EMISSIONS

One of the major issues in the electric utility industry today is the increased use of electro-technologies in industry. Electrotechnologies replace traditional industrial process technologies that use fossil fuels directly with ones that utilize electricity as their energy source. There appear to be opportunities for electrification in a number of industries, due to a combination of environmental, energy policy, and technology trends. A recent study for the Edison Electric Institute discussed a number of electrotechnologies and their possible application in industry. A summary of these technologies and their possible market penetration is shown in Table 14. The table shows that electricity consumption for electrotechnologies could triple between 1980 and the year 2000.

The increased efficiency of many electrotechnologies has a favorable effect on U.S. carbon dioxide emissions. Although the increased use of electrotechnologies will increase electricity consumption, the growing commitment by the electric industry to non-polluting renewable generation sources helps to electrify U.S. industry with minimal environmental impacts. Currently, the generation and transmission of electricity is heavily dependent upon fossil fuels (about 72 percent), and the increased use of renewable energy reduces reliance on fossil fuels. The generation and transmission processes have an overall efficiency of 30 to 35 percent (i.e., only about one-third of the energy content of the fuel is ultimately delivered to the customer in the form of electricity); however, this efficiency can improve for industrial customers able to accept high voltage interconnections. The net impact on carbon dioxide emissions must be determined on a case-by-case basis through a complete analysis of the electricity required and its source and of the fossil fuels being replaced.

A recent study of electrification prepared for the Edison Electric Institute (EEI) presented national data documenting that, electrification was correlated overall with lower emissions of carbon dioxide. The analysis showed that, over the 1970 to 1991 period, the U.S. economy (excluding the transportation sector) performed as follows:

- Gross domestic product (GDP) increased by 70 percent;
- Electricity consumption increased by 98 percent;
- The trend-line of carbon emission increased by only 4 percent over the two decades;
- Carbon intensity (emissions per dollar of GDP) declined by 36 percent. Measured in 1982 dollars, a dollar of non-transportation GDP in 1970 was associated with emissions of 0.999 pounds of carbon. By 1991, this had fallen to 0.63 pounds of carbon. This implies an emissions saving in 1991 of about 600 million metric tons of carbon.

Table 14
ELECTROTECHNOLOGIES' ELECTRICITY CONSUMPTION
By Category and Industry Sector
1980 ESTIMATIONS AND PROJECTIONS TO 2000

(Million Kilo-Watt Hours)	1980	1990	2000
1 Adjustable-Speed AC Drives (A)	20,700	175,300	350,100
2 Electrochemical Synthesis	1,380	1,850	2,490
3 Electrolytic Separation	32,600	38,900	50,900
4 Freeze Concentration	1	740	2,360
5 Heat Pumps	350	740	1,470
6 Membrane Separation	1	140	340
TOTAL PROCESS INDUSTRIES	55,032	217,670	407,660
1 Direct-Arc Melting	17,100	19,400	26,600
2 Electronavigation	250	930	1,250
3 Electrolytic Reduction	84,700	69,700	72,600
4 Electroslag Processes	200	520	850
5 Induction Melting	3,050	3,330	3,790
6 Ladle Refining	80	500	610
7 Plasma Processing	0	0	3,600
8 Vacuum Melting	140	210	310
TOTAL METALS PRODUCTION	105,520	94,590	109,610
1 Electric Discharge Machining	200	270	530
2 Electrochemical Machining	100	120	220
3 Electromagnetic and Electrohydraulic Forming	2	25	100
4 Electron Beam (EB) Heating and Curing	190	360	930
5 Electroplating	1,880	1,960	2,630
6 Flexible Manufacturing Systems (B)	4	50	300
7 Induction Heating	19,700	33,700	45,500
8 Infrared (IR) Drying and Curing	1,170	1,910	3,110
9 Laser Processing	28	50	135
10 Resistance Heating of Metals	8	32	110
11 Ultraviolet (UV) Curing of Metals	650	1,280	2,080
TOTAL METALS FABRICATION	23,932	39,757	55,645
1 Resistance Heating and Melting of Non-Metals	2,680	3,500	4,270
2 Electron Beam (EB) Curing	*	*	*
3 Flexible Manufacturing Systems	*	*	*
4 Infrared (IR) Drying and Curing of Non-Metals	590	960	1,560
5 Laser Processing	*	*	*
6 Microwave Heating and Drying	130	150	240
7 Radio-Frequency (RF) Heating and Drying	2,000	2,440	2,970
8 Ultraviolet (UV) Curing	*	*	*
TOTAL NON-METALS FABRICATION	5,400	7,050	9,040
GRAND TOTAL	189,884	359,067	581,955

NOTES: (A) This figure is not load growth, but electricity supplied to motors with adjustable-speed AC drives.
(B) This figure is not necessarily load growth, but a substitution of electricity used in flexible manufacturing and automation for electricity used in less-sophisticated manufacturing equipment.
* Electricity use by these manufacturing electrotechnologies is included in the metals fabrication electrotechnology projections, since it is difficult to accurately categorize use by industry sector.

SOURCE: *Industrial Electrotechnologies and Electrification, Volume 1: Electrotechnology Reference Guide*, EM 4527, developed by Resource Dynamics, Inc. for EPRI, April 1986.

These historical trends are not explained by the increased generation of nuclear energy, changes in the structure of the economy's output, or changes in prices. However, a major factor is undoubtedly improvements in the efficiency of fossil fuel use in direct applications. Nonetheless, it appears that increased electrification is an important factor causing decreased carbon dioxide emissions.

Electricity has been an effective tool contributing to past gains in energy efficiency, but it also can play a role in achieving additional gains in the future. A study by the Oak Ridge National Laboratory, "Energy Efficiency: How Far Can We Go?" projected that as the market share of electricity goes up, the nation will become more energy efficient. One of the conclusions in the study was that, to achieve a 26 percent increase in overall energy efficiency, electricity's market share must increase in relation to other fuels. As documented throughout this report, increased energy efficiency is a major factor in curbing carbon dioxide emissions.

11 RAILROAD TRANSPORTATION

INDUSTRY SECTOR OVERVIEW

Railroad transportation is an entire industry sector (SIC 40), including both freight railroads and the National Railroad Passenger Corporation (AMTRAK). In terms of energy consumption and economic activity, freight railroads are the dominant component. This chapter discusses energy performance and carbon dioxide emissions within the entire railroad transportation industry sector. Table 15 shows key data for this industry sector.

TABLE 15
RAILROAD TRANSPORTATION INDUSTRY SECTOR (SIC 40)
EMPLOYEES AND VALUE ADDED

SIC	Industry	1990 Value Added (\$ millions)	Total Employees	1992 Average Annual Employment	
				Production Workers	
				Employees	Average Weekly Earnings
40	Railroad transportation	\$ 25,413*	258,500	a	\$ 736.37

Sources: *Annual Survey of Manufactures; Employment and Earnings.*

* Revenues. Value added is not available.

According to data compiled by the Department of Energy from its most recent energy survey, in 1988 the industry sector consumed 0.59 percent of total U.S. energy consumption. Of this amount 99 percent was carbon-based fuels that produced 0.69 percent of total U.S. carbon dioxide emissions from fossil fuel burning and cement production.

HISTORICAL TRENDS

Figures 30 and 31 show production and energy and emissions intensity in the railroad transportation industry sector for freight operations, which are the largest component of the industry sector. Figures 32 and 33 show production and energy intensity for Amtrak operations; emissions intensity is not shown because of data limitations.

Freight Transportation

- *Output:* Revenue ton-miles freight increased by 17.1 percent from 1974 to 1988. Total output increased from 851.0 billion ton-miles to 996.2 billion ton-miles.
- *Energy Consumption:* Energy consumption for freight transportation decreased by 23.6 percent from 1974 to 1988, from 565.9 trillion Btus to 432.3 trillion Btus.
- *Energy Intensity:* Energy intensity, measured as energy consumption per unit of output, decreased 34.8 percent from 1974 to 1988.
- *Carbon Dioxide Emissions:* Total emissions of carbon dioxide declined by 27 million metric tons of carbon, or 23.6 percent, from 1974 to 1988. Total emissions were 11.3 million metric tons of carbon in 1974, declining to 8.63 million metric tons of carbon in 1988.

Passenger Transportation

- *Output:* Revenue passenger-miles for Amtrak increased by 33.5 percent from 1974 to 1988. Total output increased from 4,259 million passenger-miles to 5,686 million passenger-miles.
- *Energy Consumption:* Energy consumption for Amtrak increased by 1.4 percent from 1974 to 1988, or from 13.8 trillion Btus to 14.0 trillion Btus.
- *Energy Intensity:* Energy intensity, per unit of output, decreased 24.0 percent from 1974 to 1988.
- *Carbon Dioxide Emissions:* carbon emissions decreased by 0.013 million metric tons, or 3.0 percent, from 1974 to 1988. Total emissions in 1974 were 0.434 million metric tons, decreasing to 0.421 million metric tons carbon in 1988. Carbon emissions intensity, the amount of carbon dioxide per unit of output in 1988 was 27.3 percent lower than in 1974.

Figure 30

Railroad Transportation Sector--Freight Production, Energy, and Emissions

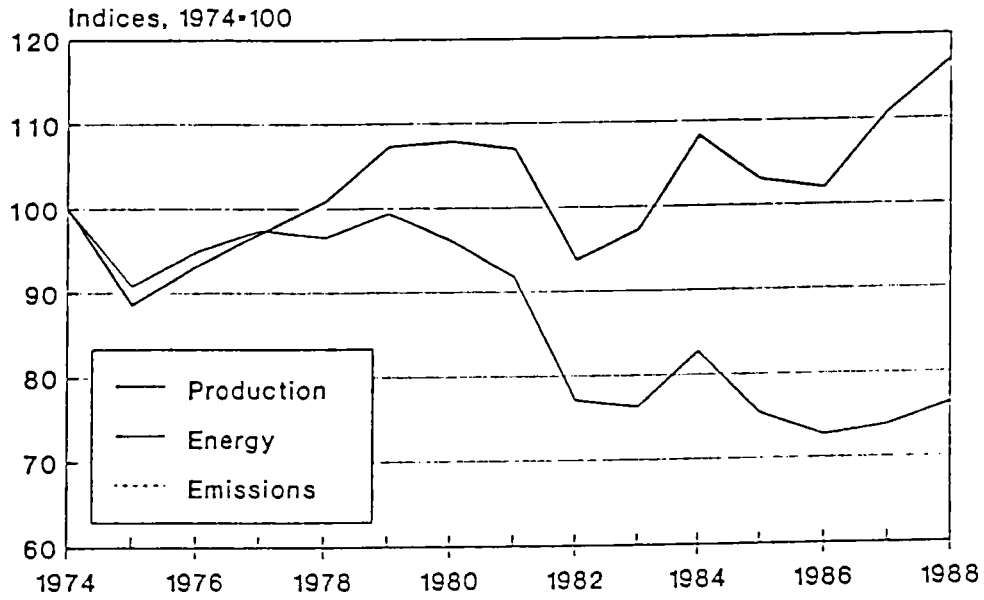


Figure 31

Railroad Transportation Sector--Freight Energy and Emissions Intensity

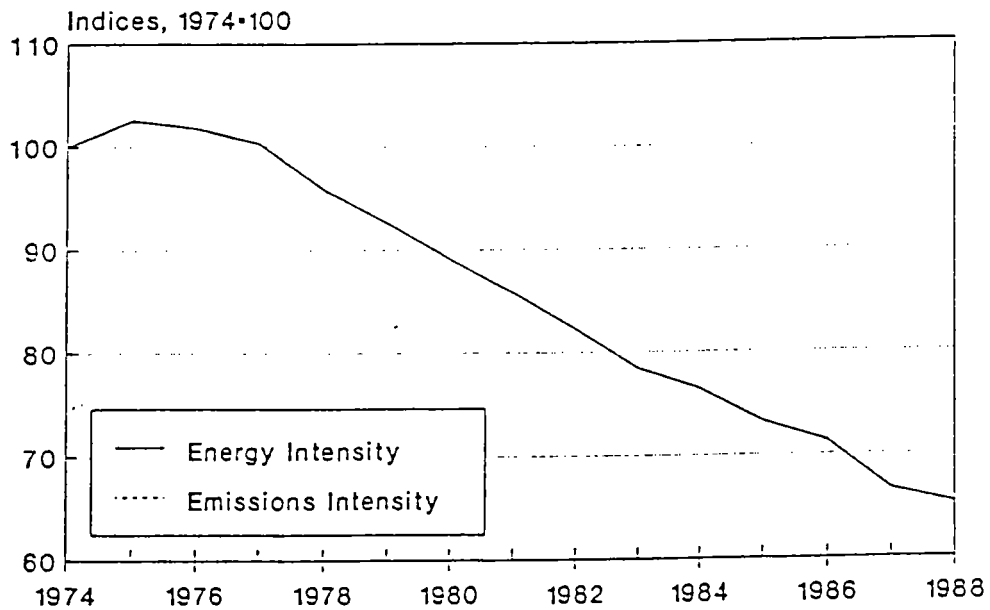


Figure 32
 Railroad Transportation Sector--AMTRAK
 Production and Energy

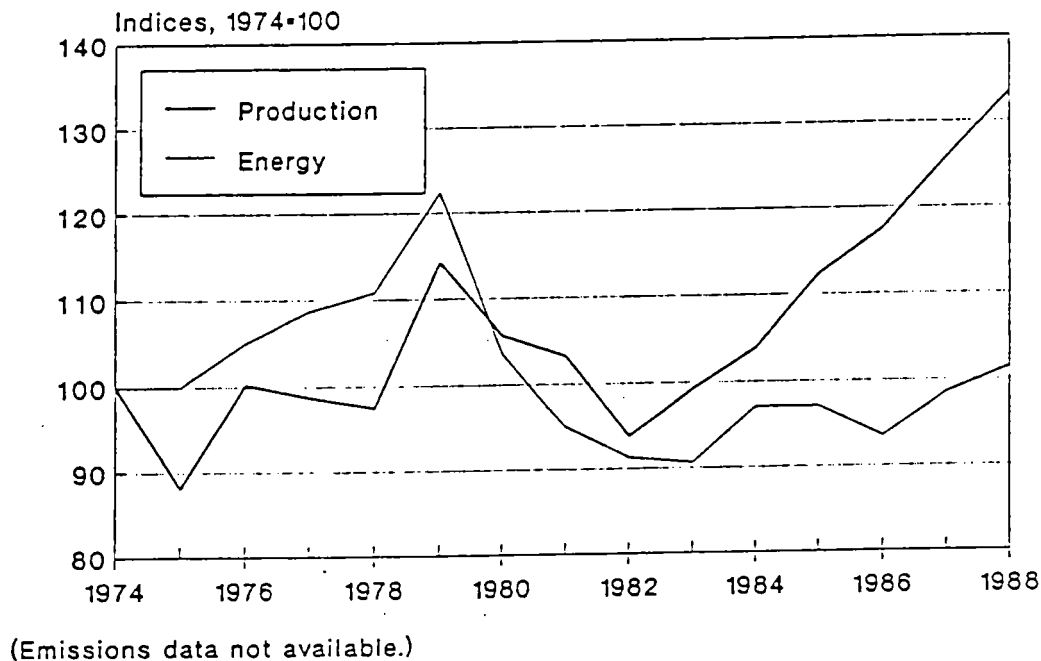
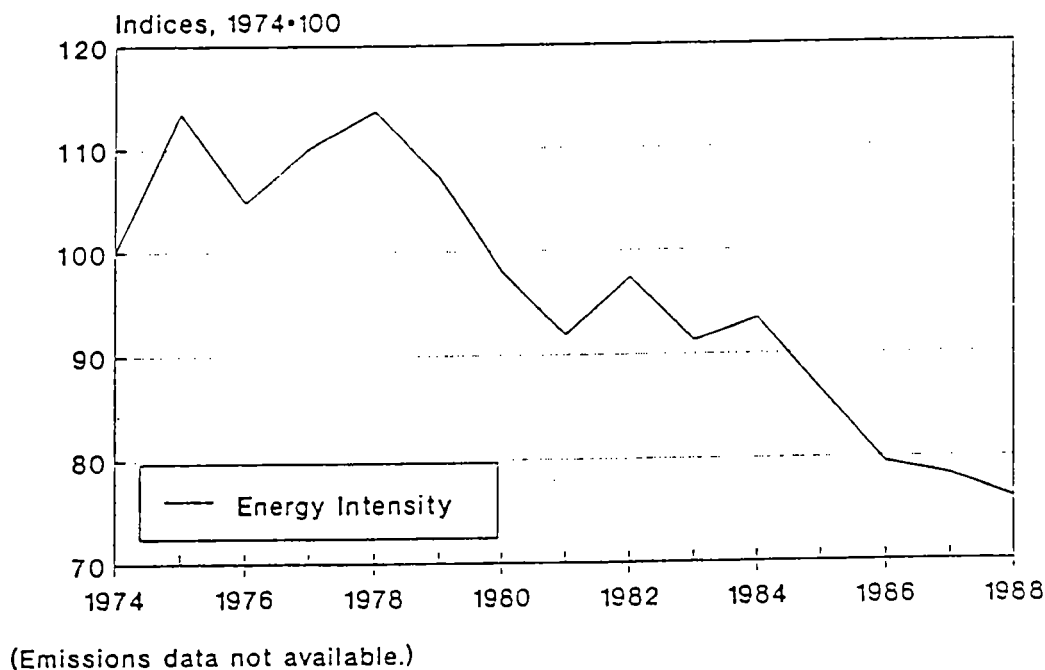


Figure 33
 Railroad Transportation Sector--AMTRAK
 Energy Intensity



Factors Affecting Historical Trends

During the early 1980s the industry carried out an extensive research program to investigate the various aspects of train resistance and to develop technologies and practices to reduce resistance and fuel consumption. A wide range of new management practices were adopted as a result of this research, including:

- More effective training programs for engineers in the most efficient ways to operate trains safely.
- Slower acceleration and deceleration.
- Use of locomotive dynamic brakes.
- Reduced idling time in terminals.
- Reducing empty car miles through better fleet management.
- Matching locomotives to their trains to optimize energy use.
- Storing less efficient locomotives.
- Closing doors on empty cars to reduce wind resistance, and making other operating improvements.
- Improving track quality to reduce train resistance and allow more efficient speeds.
- Consolidating parallel rail lines to optimize train dispatching.
- Running "through trains" and unit trains over several connecting railroads to improve equipment utilization and service.

In addition, a number of new or improved technologies also have been developed and deployed to increase efficiency and reduce energy use, including:

- Improved communications and signaling to gain more efficient operations.
- Higher horsepower, more efficient locomotives.
- Lighter weight and higher capacity freight cars.
- Use of double stack trains to carry freight containers.

- Use of friction-reducing engine lubricating oils, wheel flange lubricators to reduce train resistance, lower resistance freight car trucks; and improved rebuild standards for locomotive traction motors and engines.

Current Issues and Outlook

Future gains in energy efficiency can be expected from wider implementation within the industry of many of the current state-of-the-art practices and technologies described earlier. In addition, converting from direct current (D.C.) to alternating current (A.C.) traction motors, as some railroads are beginning to do, will require fewer locomotives, save fuel, and reduce emissions.

The railroad industry also is supporting R&D on additional new technologies to improve energy efficiency. For example:

- Railroads are examining natural gas and other alternative fuels to assess their feasibility.
- Fuel cells and advanced energy storage systems such as high speed flywheels are being examined as potential technologies that could become available after the turn of the century.
- An integral intermodal train concept now under development would distribute motive power through the train to reduce train forces and allow lighter weight cars. Containers and highway trailers would also be better spaced to minimize aerodynamic drag and reduce fuel consumption.

Finally, the industry has urged maximum use of Intermodal Surface Transportation Efficiency Act (ISTEA) funds for intermodal connectors. Greater use of intermodal transportation would conserve fuel and reduce emissions, including carbon dioxide.

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GLOBAL CLIMATE COALITION

GLOBAL CLIMATE COALITION MEMBERSHIP

Board Membership

Aluminum Association, Inc.
American Automobile Manufacturers Association
American Electric Power Service Corporation
American Forest & Paper Institute
American Mining Congress
American Iron & Steel Institute
American Petroleum Institute
American Portland Cement Alliance
Association of American Railroads
Atlantic Richfield Company
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ELCON
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National Lime Association
National Coal Association
National Rural Electric Cooperatives Association
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Texaco, Inc.
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U.S. Chamber of Commerce
Union Electric Company

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Amoco Corporation
Arizona Public Service Company
Armco, Inc.
Association of International Automobile Manufacturers
BP America, Inc.
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CONRAIL
Consumers Power
Du Pont Company
Eastman Kodak
LTV Steel Company, Inc.
Midland Enterprises
Nestle
Norfolk Southern
Northern Indiana Public Service Co.
Ohio Edison
Pennsylvania Power & Light Company
Railway Progress Institute
Shell Oil Company
Union Carbide Corporation
Union Pacific Railroad



BACKGROUND

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The Global Climate Coalition An Overview

What It Is:

The Global Climate Coalition (GCC) is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on the global climate change issue.

GCC is dedicated to: 1) promoting scientific research on global climate change, 2) analyzing economic and societal impacts of policy options, 3) creating an understanding of the global dimensions of the issue to ensure that solutions are addressed equitably by all nations, 4) encouraging transfer of technology to developing nations, and 5) promoting a voluntary commitment of members to "Guiding Principles for Business" that benefit the environment, are consistent with good business practices and are technically and economically feasible.

What it Does:

GCC is the leading voice for industry on the global climate change issue, and represents its members before government agencies, Congress, the media and the general public. The group works cooperatively with governmental agencies and others on an international basis. The coalition contributes to a balanced debate on global climate change by sponsoring independent studies that examine the potential impacts of proposed global climate change policies on the economy. Through educational materials and programs, GCC supports an informed press and public, and an open scientific dialogue.

Where does GCC Stand?

GCC agrees with the scientific presumption that there is a natural "greenhouse effect" that protects Planet Earth from the freezing rigors of space. In addition, GCC agrees that the amount of so-called greenhouse gases in the Earth's atmosphere is increasing. It is an open question however, whether manmade contributions of greenhouse gases have contributed, or ever will contribute to an "enhanced greenhouse effect," which could result in a potentially harmful increase in global surface air temperatures.

There is considerable uncertainty within the scientific community about fundamental questions relating to this issue. Predictions about anthropogenic global warming are based on computer models designed to simulate atmospheric chemistry. GCC agrees with a growing number of



scientists who point out that these climate models (which have been used to frame the debate) can neither confirm that global warming is occurring now or predict future climate changes. While some minor climate changes have been suggested, it has yet to be determined whether these are the result of natural forces (like solar flares), human activity, natural long-term climate cycles or a combination of all of these factors.

GCC supports a coordinated international research program, the continuation of U.S. climate research efforts (\$1.4 billion requested for FY 1993), in addition to independent and industry sponsored research. GCC also supports activities to reduce greenhouse gas emissions that make sense in their own right, thus continuing sound business practices that will lead to more efficient use of energy.

GCC believes there are trade-offs associated with many of the regulatory schemes to control greenhouse gas emissions. Some of these proposals would impose a direct tax on businesses and consumers through energy or environmental fees while other proposals would impose a hidden tax through other indirect, control measures. These trade-offs would include higher energy and product costs to American consumers, higher operating costs for industry and a potential negative impact on employment. Importantly, many of these proposals would create a competitive advantage for our international trading partners at the expense of U.S. jobs and economic growth.

Who are GCC Members?

The current membership of GCC is a broad cross-section of U.S. business organizations and companies representing a range of industrial sectors, including: oil, coal, paper, automobile manufacturing, railroads, chemical manufacturing and utilities.

How is GCC Structured?

The GCC Board of Directors serves as the organization's governing body. The Operating Committee oversees the functional implementation of GCC activities, and John Shlaes, Executive Director, has oversight of day-to-day operations. To address specific aspects of the global climate change issue and to evaluate policy options, GCC utilizes twelve committees, including Science and Technology, Technology Cooperation, Economic Analysis, Industry Initiatives, and International, to name a few.

For More Information:

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MEMORANDUM

TO: Working Group III Lead Authors

FROM: Erik Haites

RE: Country Studies

DATE: February 14, 1994

The United Nations environment Programme (UNEP) has completed or underway a series of country studies related to climate change.

Inventories of Sources and Sinks

China, Costa Rica, Gambia, Mexico, Morocco, Nigeria, Poland, Senegal, Tanzania, Uganda, and Venezuela.

Costs of Greenhouse Gas Abatement Studies

First Phase: Denmark, Netherlands, India and Zimbabwe.

Additional studies by the Asian Energy Institute: Bangladesh, Brazil, China, Sudan, Iran, Japan, South Korea and Thailand.

Second Phase: Brazil, Denmark, Egypt, France, Indonesia, Netherlands, Senegal, Thailand, Venezuela, and Zimbabwe.

Reports on all of these costs studies are available from RISO in Denmark.

Country Studies
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Socio-economic Impacts of Climate Change

Southeast Asia (Indonesia, Malaysia, and Thailand), Brazil and Viet Nam. Reports on Namibia and parts of the Russian Federation are currently in preparation.

These reports are available from UNEP in Nairobi:

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