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Folder Title:
Our Comments/Interagency 5-Labs [Climate Change Study]

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S	20	5	1	1

DOE Labs Study: Potential Reductions in Carbon Emissions in 2010

We estimated the emissions reductions under the high efficiency/low carbon with $50/ton permit scenario. The data are insufficient to calculate the emissions reductions for the $25/ton permit scenario, and in the efficiency scenario all reductions result from non-price policy influences.[1]

Buildings:

The study states that the penetration rate of cost-effective technologies under the high efficiency case is 65%: 60% results from unspecified programs and 5% from the permit price. We estimated the emissions reductions for each technology by multiplying the emissions reduction by 0.923 (60/65) to calculate the reductions from non-price policy responses. The remaining reductions were appropriated to the price response.

Note: Because of rounding in the numbers presented in appendix C-2, the technology reductions for commercial and residential buildings do not sum to the totals for this sector.

87% of the emissions reductions occur through non-price policy induced technology adoption.

Utilities:

All reductions occur because of the permit price.

Transportation:

Without documentation, it is impossible to discern the effects of specific technologies on the transportation sector. The report merely provides details on how these technology improvements can result in a percentage increase in fuel efficiency. In computing cost-effectiveness, the study assumed constant fuel prices at $1.20/gallon (p. 5.45). Since there is no assumed increase in fuel prices, we assume that all carbon reductions in this sector should be appropriated to the non-price policy response category.

Industry:

The analysis for this sector is not very revealing: the documentation from their model runs would be quite helpful. However, we can break it down by industry in several cases. The report does provide a set of examples of energy efficiency technologies, but does not indicate the extent of their adoption in this analysis.

62% of carbon emissions occur as a result of non-price policy influences on behavior.

---

[1] While we assume that the efficiency scenario causes technology adoption through non-price policy response, the report does occasionally state that fuel taxes could be one policy option in this scenario (e.g., p. 5.3).

Review of DOE Labs Study

Unspecified Policies:

- *No Program Descriptions:* The authors do not estimate the costs or even describe the programs necessary to stimulate the adoption of the new energy-efficient technology they find could reduce emissions of approximately 200 million metric tons of carbon equivalent (MMTCE) by 2010. These reductions correspond to about ½ of the reductions needed to attain 1990 levels by 2010. In the absence of cost estimates this information is of little use in the evaluation of alternative policy options.

- *Costs of Programs*: Given reasonable assumptions, government programs may cost many tens of billions of dollars per year above the costs of existing programs to reduce 200+ million tons of carbon. The marginal cost of emissions reductions, including the cost of the government program, is likely to greatly exceed the permit price. As a result these programs may be less cost-effective than a cap-and-trade emissions control program.

- *Luck*: The transportation sector requires "luck" in terms of technological innovation to achieve the projected emissions reductions. Without a permit price, this luck appears likely only through stringent standards, such as increasing CAFE.

Overestimates Reductions/Underestimates Costs:

- *Behavioral Changes Ignored:* The analysis appears to ignore the behavioral changes that offset the energy efficiencies promised by the new technologies. For example, more efficient windows lead to houses with more glass, and more efficient cars lead to more vehicle miles traveled. Thus these innovations offer real value to consumers, but smaller energy savings than engineers forecast.

- *Cost Effectiveness Calculated Using Average, Not Marginal Prices*: Many of the innovations in electrical use appear to be assumed to be cost effective based on an assumption of average, not marginal electricity prices. The marginal prices may be half as much as the average prices. ← incl. sunk costs'

- *Price Declines Resulting from Reductions in Energy Demand Are Not Taken into Account*: The study assumes a 12% decrease in energy use, but does not account for this effect on price when calculating cost effectiveness for energy efficient technologies.

- *Study Double Counts Emissions Reductions Occurring Under Business-As-Usual*: The labs study double counts 22 MMTCE in reductions in the efficiency case that will occur under the business-as-usual case.

- *Interactions Ignored, Double Counting "Likely" in Utilities Sector Analysis*: The double counting of dispatching and retooling coal plants to natural gas results in about 9 MMTCE of overestimated reductions.

- *Industry Sector Analysis Ignores the Costs of Accelerating Retirement.*

DOE Labs Study

Double Counting:

Reductions in BAU Double Counted 197 millions CE AEEI 0.1 %, About half

Reductions in Utilities Sector Double Counted e.g. Fuel switching dispatching with existing plant — Reconverting coal plants for natural gas

Cost Effectiveness Flaws

Ignores Implementation Costs

Ignores Behavioral Changes e.g. more glass more vehicle miles traveled

Ignores Capital Retirement Acceleration

Ignores Falling Energy Prices from new tech.

many admitted

Using Average Costs Over-Estimates Energy Savings

time horizon for alt view cost effectiveness calculations: 18 yrs in bldgs A-1.9

	Com	Res	
lighting	12	1	lifetimes
other	7	10	
	C-2.12	C-2.8	

Appendix C

Policies

How can we get there without a roadmap?

What will it cost us?

Focused on only 1 goal: 1990 in 2010

(OK ~~fine~~ for DOE to release.) A lot of hard work by knowledgeable people: [But shouldn't go to principals.]

Reason: it's not a suitable basis for policy-making.

Doesn't consistently & accurately link "technology" goals to policy levers available to the president.

Joe Roam said Told Labs not to look at policies. not their job.

Many of the limitns. are explicitly acknowledged. ("caveats"). Good.

It's not a questn. of "techn. optimism" vs "tech. pess."
(And still less "green" vs "brown.")
Rather it's: goals vs policy instruments to achieve them.
eng. vs. behavior

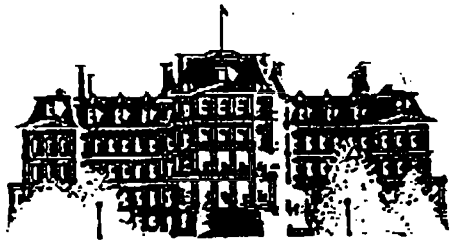
[Analogy with a scientist who studies heartbeat & rest of cardiovascular.]

~~Bu~~ some parts of the study do: utilities ... $50/ton

But others don't: Transp...
Presumably govt. R+D is policy instr. But ..
& diffusion

For every efficient pgm., there's a wasteful one. Ethanol very expensive driven more by politics than good env./ec. policy.

EXECUTIVE OFFICE OF THE PRESIDENT



THE OLD EXECUTIVE OFFICE BUILDING

COUNCIL OF ECONOMIC ADVISERS
17TH AND PENNSYLVANIA AVENUE, NW
WASHINGTON, DC 20502

****

TO: Jeff Frankel **OFFICE:**

FAX NUMBER: 965-6422 **TEL NUMBER:**

***

FROM: JOE ALDY

FAX NUMBER: (202) 395-6809 **TEL NUMBER: (202) 395-1455**

ROOM: 317B

NO. OF PAGES (inc cover) 4 **DATE:** 8/18/97

SUBJECT: Lab study chart

MESSAGE:

I'll send the 1-page after the 3.
Happy reading.

8/19/97

5-Labs mtg.

Marq Manlque Shar

Larry Petersen Joe R Levine Brown — Laitner

DOE LBL OakR

Art Rosenfeld
OBFSI..
Bldgs-

Attempt to marry micro technology
with broader mainstream perspective.
Get half way on D side.
Turns out can also get half (from price) on supply side.

President asked Labs to do a CC strategy
+ Ecast

Bill Huntington
Link
DeCanio LBL

DOE Labs Study

Double Counting

Reductions in BAU Double Counted 20 m tons or 0.1% AEI double counted

Reductions in Utilities Sector Double Counted e.g. fuel-switching with existing plant — Retooling for natural gas

Cost Effectiveness Flaws

Ignores Implementation Costs

Ignores Behavioral Changes

Ignores Capital Retirement Acceleration

Ignores Falling Energy Prices

Using Average Costs Over Estimates Energy Savings

Policies

How can we get there without a roadmap?

What will it cost us?

Focused on only 1 goal: 1990 in 2010

Definitely → This is the one number that will get all ~~the~~ attention

Jeff.

What would you feel about taking out the "net savings" figures (the $6 to $38 billion figures)?

Mark

Jon,

~~Are we asking~~
Should we ask them to do this

JF

Table 1.5 Estimated Costs and Benefits of the Efficiency and High-Efficiency/Low-Carbon Scenarios : Optimistic and Pessimistic View Estimates (billions of 1995$, annualized)

	Efficiency Case[a]			High-Efficiency/Low-Carbon Case[b]		
	Benefits[c] (billion 1995$)	Costs[d] (billion 1995$)	Carbon[c] Savings MtC	Benefits (billion 1995$)	Costs (billion 1995$)	Carbon Savings MtC
Energy Efficiency						
Buildings	14-17	7-14	20-25	26-33	14-26	49-62
Industry	6-7	3-5	18-22	12-15	8-13	66-82
Transportation	22-27	16-30	58-73	32-40	23-43	82-103
Electricity Dispatch	0	0	0	0	2	44-55
Electricity Repowering	0	0	0	0	2	32-40
Other Low-Carbon Techologies	0	0	0	0	2	33-41
Total	**42-51**	**26-49**	**96-120**	**70-88**	**51-88**	**306-383**

Compare w/ 8/1 draft

a Energy efficiency category includes ethanol in transportation.

b Benefits and carbon savings in the HE/LC case are relative to BAU case.

c Benefits are calculated as annual energy savings. The scenarios are meant to be point estimates. In the "pessimistic" case, we have assumed that only 80% of the carbon savings are achieved, even though the technology and implementation costs are unchanged. The range on carbon savings represents this assumption.

d Costs are calculated from differing viewpoints: the "optimistic" case uses discount rates that vary between 7% and 12.5% for the different sectors, as described in the text. For the "pessimistic" case, the discount rates used to annualize costs vary between 15% and 20%. Also in this case, the cost of implementing programs (30%) and an overall package of programs and policies (15%) is taken to be twice that of the "optimistic" case.

The range of estimates in Table 1.5 reflects our attempt to "bound" optimistic and pessimistic assessments. There are clearly other ways in which these bounds could be described, just as there are many scenarios that could have been analyzed. However, we believe that the assumption that 80% of the carbon reductions are achieved at the costs identified, valuation of costs and benefits at discount rates noticeably higher than the likely cost of capital, and doubling the cost of programs and policies from typical experience today is a strong reflection of pessimism in costs for our cases. It is worth noting that if the implementation costs were taken to be much higher than we believe to be reasonable – 50% of investments costs for programs and 25% overall – this would add about $10 billion per year to the costs of the high-efficiency/low-carbon in the pessimistic case.

In addition to these costs, one needs to calculate the impact of the cases on natural gas demand. In all of these cases, natural gas replaces very large quantities of coal. Higher natural gas demand would result in higher natural gas prices, which in turn would increase the cost of substituting natural gas for coal in power production, etc. As it turns out, our scenarios have somewhat reduced gas demand compared with the BAU case (or with AEO97 baseline for 2010, on which the price of natural gas in our work is based). Specifically, demand for natural gas in the HE/LC ($50/tonne) case declines in 2010 by 2 quads compared with the business-as-usual case. This is the result of declines of 0.5 quads for buildings, 1.0 quads for industry, and 0.5 quads for electricity. The latter occurs because of the balance among three factors:

- Increase in gas demand because of the large-scale substitution of natural gas for coal
- Decrease of gas demand because of the use of many low-carbon technologies that do not use natural gas (wind, nuclear power plant extensions, power plant efficiency upgrades, hydropower expansion, co-firing with biofuels), and

Joseph E. Aldy
09/04/97 09:26:24 PM

Record Type: Record

To: Jeffrey A. Frankel/CEA/EOP

cc:
Subject: Read before you talk to Mark Mazur: DOE 5 labs study

Jeff,

I thought about the 5 labs study during my jog, and I have changed my mind. I really don't think we should have them include energy savings in the report (the renaming of benefits I mentioned in my earlier email). I think their numbers are absolute trash, and we should make that very clear. I don't think we want to be fighting these numbers once they get out. Mark may ask you why we have such serious problems with their estimates -- although we highlight many failings in our August 22 memo. Here are some key points:

Benefits/Energy Savings

--> The energy savings calculations do not incorporate behavioral responses that would lead to an increase in energy use. If air conditioners use less energy per output, people run them more often. If cars are more fuel efficient, people will drive more.

--> The energy savings calculations do not incorporate the price decline associated with reduced demand for energy. Energy consumption in the high efficiency case declines 12% relative to BAU -- while Mark claimed to me that this is "just a second order effect", I think 12% appears substantial.

--> The energy savings calculations for buildings use average cost, not marginal cost, of electricity, and therefore overestimate energy savings.

--> The economics literature has found that actual energy savings do not compare to engineers' dreams of energy savings because real people live in real houses and work in real firms, not in ideal model houses and ideal model firms (Metcalf and Hassett 6/97 NBER paper).

Costs

--> The government cost estimates are "made up" according to Mark. Our estimate indicates that the cost to government could be tens of billions of dollars per year. Further, they do not assess the costs of standards (e.g., CAFE, national building codes, appliance standards) which account for half of all emission reductions.

--> The industry sector analysis ignores the costs of accelerating capital retirement.

--> Without any empirical or theoretical justification, the transportation sector analysis assumes that a whole set of technologies will come into play and will achieve 100% penetration in 20 years at NO NET COST. This is the "luck" that is required by the analysis.

Joseph E. Aldy
09/05/97 03:17:12 PM

Record Type: Record

To: Jeffrey A. Frankel/CEA/EOP

cc:
Subject: Gruber and 5 labs

Jeff,

I just spoke with Jon about the 5 labs study. He agrees that we should stand by our guns on this one. He asked me to call Mark Mazur and tell him that the bottom line is that we (CEA and Treasury) will not sign off on the report so long as that chart and references to the costs stay in. I just left a message for Mark with his secretary. Jon said he would also call TJ and relay this to him. What happens if we don't sign off and they release the report as is?

Joe

DEPARTMENT OF THE TREASURY
WASHINGTON, D.C. 20220

September 4, 1997

MEMORANDUM FOR T. J. GLAUTHIER

FROM: Robert Gillingham RG
Jonathan Gruber JG

SUBJECT: 5-Labs Revision

We think this revision is a substantial improvement. Most of our comments are editorial (see attached draft). The major exceptions revolve, not surprizingly, around the treatment of "cost" estimates. We continue to feel that the analysis presents scenarios that *could* be achieved, rather than scenarios that *should* be achieved—regardless of climate benefits—on the basis of cost savings. To address this concern, we recommend (1) eliminating the modifier "cost-effective" when referring to technologies, (2) deleting Table 1.5 and substantially modifying or eliminating the discussion of costs on pp. 15 through 18, and (3) weakening the claim of rough cost/benefit parity in the second overarching conclusion in the executive summary (*e.g.*, recognizing that energy savings are a substantial offset without arguing relative magnitude).

We continue to believe the scenarios are informative primarily in terms of what is technically feasible. We do not believe the paper demonstrates the validity of the criteria used for selecting "cost-effective" technologies. The reasons for this skepticism are outlined in our earlier comments - the underlying model of the costs of technology adoption is not economically rigorous, with limitations that include low discount rates, and in particular extremely low implementation costs.

We view these criteria as one way of selecting technologies that could be adopted; the paper then does a very good job of quantifying the impact of adopting these technologies on energy use and carbon emissions. A possible substitute for Table 1.5 might be a table of reductions in energy consumption valued at today's (or 2010's) prices to quantify the *energy-cost* saving, with the appropriate caveat that it would take a full-blown general-equilibrium analysis (beyond the scope of the paper) to determine what prices would actually obtain. Going further than that, in our opinion, is too ambitious and—for the purposes of this paper—is not critical.

Joseph E. Aldy
09/29/97 04:53:56 PM

Record Type: Record

To: Jeffrey A. Frankel/CEA/EOP

cc:
Subject: for your 5pm: technology and 5 labs

Jeff,

3 numbers to think about for your meeting:

1) 5 Labs predicts economic costs from private investment of $26-$49 billion/year for the efficiency case (the basis of today's technology discussion). This gets you ~120 MMTCE (or 155 in today's discussion). This cost number is in addition to government costs (estimated today at $500 million/year).

2) A back of the envelope estimate of how much it costs per ton to generate 120 MMTCE of carbon savings at a price tag of $50 billion would be more than $400/ton. (Simply dividing $50 b/120 MMTCE.)

3) To gain a sense of context about what $50 billion/year in private investment means, consider that net income to corporations in 1993 was about $500 billion.

Joseph E. Aldy
09/04/97 06:56:18 PM

Record Type: Record

To: Jeffrey A. Frankel/CEA/EOP

cc:
Subject: conversation with Mark Mazur

Jeff,

I just got off the phone with Mark. He called regarding our comments on the 5 labs study we faxed over today. The good news: our second point on the baseline will be addressed. The bad news: they want to keep their benefits and costs numbers in there. Regarding benefits, they would be willing to change the term to energy savings, but they don't want to change the costs. He suggested that they could include a statement that this is not a full social benefit-cost analysis. I expressed concern that the numbers in the charts, even with caveats in the text, could be misused. I told him I would talk to you about this. I stated that I could live with changing benefits to energy-savings, but I had serious reservations about keeping costs in there. Regarding our concern about cost-effectiveness, Mark said that they would go through and remove some, and be more careful about their use of the term, but that they would likely keep the term in there in some cases.

Mark also asked me what we are doing on T&T, following up from the meeting this afternoon. I said that we were thinking about the issue. He said that Gardiner is concerned about us using "his researchers" -- bascially, Battelle. Mark asked if we had asked Battelle to do runs for us, and I said we had asked for a couple. Mark then asked me if we were using any DOE staff, and I told him that we asked Phil Tseng to do 3-4 runs for us a couple of weeks ago. He then asked me if were using any other EPA folks (G-cubed or DRI), and I told him that we had talked to some EPA folks 3-4 weeks ago for some of the outputs from IAT runs, but we had not asked them to do any model runs for us. I hope I didn't say too much -- Mark said that while I wasn't a fountain of knowledge, I was less evasive than you.

Mark will call you in the morning to discuss both the 5 labs study and the T&T issue. Have fun.

Joe

MEMORANDUM

TO: Jay Shogren

FROM: Joe Aldy and Quindi Franco

DATE: August 11, 1997

RE: Review of DOE Labs Study, June 10 Draft

We provide an assessment of *U.S. Carbon Reductions by 2010 and Beyond: The Potential Impact of Energy-Efficient and Low-Carbon Technologies* (DOE Labs Study, June 10 draft). The report identifies carbon reductions and their associated costs in the buildings, industry, transportation, and electric power sectors under two hypothetical climate policy scenarios. The study finds that, with unspecified "very aggressive policies" and a $50/ton permit price, carbon emissions can be stabilized at 1990 levels by 2010. In reviewing the report, we believe it is beneficial to highlight several limitations of the study. First, the authors do not provide descriptions of the government programs necessary to stimulate the necessary technology adoption to reduce emissions of 180 million metric tons of carbon equivalent (MMTCE). Based on the actual history of CCAP, we estimate the costs of government programs to achieve these reductions could total $45 billion (1995$), depending on the form of the marginal cost curve. Really? We annuitized this figure and found that government programs could cost $1.1 billion annually into perpetuity. These are costs in addition to existing program costs to improve energy efficiency technology development and adoption. Second, the analyses across sectors are not integrated. Therefore, the penetration rate of energy efficient technologies may be overestimated because the separate sectoral analyses do not account for declines in fuel prices. Third, the industry sector analysis ignores the costs of accelerating capital retirement, resulting in either an overestimate of reductions or an underestimate of costs. Fourth, the transportation sector requires "luck" in terms of technological innovation to achieve the projected emissions reductions. Fifth, the utilities sector analysis resulted in double counting of emissions reductions. These examples of the qualifications can provide additional insight into the projections of emissions reductions and costs. Upon receiving the final version of the report and documentation of the analyses, we will update this review.

Overview of Report

The Labs Study estimated the carbon emissions reduction opportunities available through technology development and adoption and fuel switching. The Study employs the Energy Information Administration's 1997 baseline (AEO97) for the buildings and industry sectors. For the transportation sector, the authors changed the AEO97 assumption of increasing fuel efficiency in automobiles to constant fuel efficiency. Double counting. For the utility sector, the baseline was modified to reflect a fully competitive bulk-power market in the year 2010. Discharge, shutdown, repowering, and new construction decisions were optimized to select the amount of capacity that minimized the cost of the power-supply system plus the cost of unserved energy. Compared to AEO97, the final baseline has slightly lower energy prices, larger electricity sales, and a greater share of gas generation. The study provides emissions reductions from this baseline for two scenarios: 1) "efficiency" and 2)"high efficiency/low carbon", over the period 1998-2010. The study describes neither the policies necessary to achieve emissions reductions nor the costs of federal programs for these scenarios, only their outcomes: increased adoption rates and better technologies.

Efficiency Scenario

This case assumes that all technologies adopted are at zero or negative net cost to the user given more aggressive federal policies to stimulate development and diffusion of energy efficient technologies. The Study estimates that 120 MMTCE will be reduced at negative net cost in this scenario. None of these reductions occur in the utility sector as a function of fuel switching or technology adoption to increase combustion efficiency.

High Efficiency/Low Carbon Scenario

This case assumes a "greater commitment" to reduce emissions through federal policies, in concert with state and private activities and a $50/ton permit price that stimulates low carbon technologies (read: primarily fuel switching). The policy is announced in 2000 and the policy's restrictions are phased-in through 2010. There is an assumed announcement effect (although an AEEI is not specified), increased domestic and international R&D in low-carbon technologies, and a "change in psychology". The Study estimates reductions of 180 MMTCE from the baseline through energy efficient technology adoption at negative net cost (see high efficiency without low carbon technology in chart below). The carbon permits will yield an additional 150-200 MMTCE of reductions through low-carbon technology adoption. Given that these occur at a permit price of $50/ton, the Study estimates the upper limits of these costs to be $10 billion per year in 2010.

Carbon Emissions (MMTCE): 1990 - 2010

1990	2010 Baseline	2010 Efficiency	2010 High Efficiency (w/o Low Carbon Tech)	2010 High Efficiency/Low Carbon
1340	1720	1600	1540	1340 - 1390

Review

The Lab Study employs several important assumptions in the analyses. Learning about these qualifications can enhance one's understanding of the estimates regarding cost-effectiveness and emissions reductions in this study. We present several of the most significant assumptions and discussions of their impact below.

The Study Does Not Specify Policies to Achieve Carbon Reductions

> "Cost effectiveness is improved because R&D, in combination with increased deployment efforts, result in declining capital costs. We do not specify the policies, economic conditions, or exogenous events that could precipitate such changes" (p. 1.4).

The entire study is premised on two sets of undefined policies: an "aggressive" or "invigorated" public sector effort to stimulate energy efficient technology adoption (efficiency case) and a "very aggressive" public sector effort to stimulate technology development and adoption (high efficiency/low carbon case). The only specific policy instrument mentioned in the report is a $50/ton tradeable permit. The study makes vague references to policies and only provides details on what these unidentified policies would result in: 1) "better technology" (p. 1.5); 2) "higher penetration rates" (p. 1.6); 3) "changing the capital recovery factor [in industry sector] from 33% to 15%" (p. 4.8); and 4) "technological breakthroughs" (p. 5.3). These policy effects would result in reductions of 180 MMTCE for "free": firms and individuals receive energy cost-savings in excess of technology adoption and implementation costs.

The report specifically states that the efficiency case reduces, but does not eliminate, market barriers (p. x) and that implementation costs are ignored (p. xvi). First, we will discuss the implications of reducing market barriers, and then we will address the cost issue. Market barriers occur in well-functioning, but occasionally complex, private markets. Information is fully transmitted among all those in the market, although some information may seem incomplete to non-participants (read: policy or market analysts). A person addresses all real costs, but these costs can go undetected by analysts, hence the term "hidden costs". For market barriers, private costs match social costs, and resource allocation is efficient. Policy intervention to eliminate a market barrier cannot make society better off and usually makes society worse off, regardless of the implementation mechanism.[1]

The economics literature has identified several barriers that explain the slow rate of technology adoption: 1) qualitative attributes differ across technologies; 2) private attributes of information; 3) private discount rate diverges from social rate; and 4) heterogeneous usage levels.

Qualitative attributes of technologies can affect adoption. Consumers of technology prefer technologies because of a set of characteristics, not just energy efficiency. For example, some technology consumers may purchase a product with a lower efficiency than another product because the former is more reliable than the efficiency-superior product.

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[1] In contrast, policy intervention to eliminate a market failure (such as carbon emissions) may make society better off, depending on the costs of the intervention.

Private attributes of information include the tasks of learning how a new technology works with one's existing suite of technologies and identifying technology suppliers. Transaction costs exist with these tasks. If opportunities for economic gains in supplying this information exist, one would expect arbitrage to occur where middlemen consultants would assess the needs of potential adopters and match them with the appropriate suppliers.

The social discount rates to evaluate new technologies may not fully capture the uncertainty and risks faced by individuals and firms. These private actors may use a much higher discount rate reflecting the uncertainty of future energy prices, the reliability of the technology, the irreversibility of a technology investment, and the constraints on their ability to borrow capital.

Heterogeneous use of energy-intensive technology can affect who benefits from efficiency investments and who does not. If a technology is cost-effective on average, it may not be cost-effective for individuals who do not use much energy.

These four types of market barriers illustrate the economic behavior that explains the apparent under adoption of energy efficiency technology (the "efficiency gap"). These barriers clearly demonstrate the difference between the technological maximum adoption (which only assumes technology costs) and the economic maximum adoption (which assumes total costs). A set of climate change policies to stimulate technology adoption could increase efficiency, but only because they also decrease the effect of a market failure (carbon emissions). Social welfare is improved because the net benefits of indirectly fixing the market failure exceed the costs of removing the barriers. If carbon emissions are appropriately priced (assuming in this case that $50/ton is the correct carbon price), a policy to remove a barrier (e.g., lower the capital recovery factor from 33% to 15%), will generate negative net benefits. High adoption rates will be realized once prices rise enough for some technologies to clear the barriers.

From the literature on market barriers, we know that the costs of reducing barriers are greater than their benefits. In this case, the authors of the Labs Study do not provide an estimate of the costs to government to lower market barriers to achieve these substantial reductions (and they only provide benefits in terms of projected emissions reductions). We calculated estimates of the costs of emissions reductions programs based on the government's experience with the Climate Change Action Plan (CCAP). CCAP promotes carbon reductions through a broad array of voluntary programs that stimulate "cost-effective" technology adoption by private firms. Participation by a firm in a CCAP program implies that carbon is reduced and the firm gains financially.[2] CCAP received appropriations totaling $494 million (1995$) during the FY95 - FY97 period. During this period, the Department of Energy and the Environmental Protection Agency can account for reductions of 14 MMTCE (see attached table). Each ton of carbon reduced in CCAP cost the federal government, on average, $35.29 (1995$) over this three year period. Assuming a flat marginal cost curve (MC = AC of CCAP) to reduce 180 MMTCE beyond the baseline, the government costs of the unidentified policies in the Labs Study would

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[2] Note that CCAP efforts are incorporated in the AEO97 baseline.

exceed $6.3 billion. To account for the opportunity cost of capital through time, we annuitized this value and found that government costs would run about $150 million annually into perpetuity.[3] However, the marginal costs of technology adoption in the efficiency and high efficiency/low carbon scenarios are definitely higher than the average cost of 14 million metric tons reduced in the baseline scenario, especially as more and more efforts to reduce emissions are undertaken. Assuming that costs increase 10% for every 10 million metric tons of carbon reduced, then the government cost would total $16.1 billion (annuity of $375 million). This is a slowly increasing marginal cost curve given baseline assumptions of gains in energy efficiency. Assuming that costs increase 20% for every 10 million metric tons of carbon reduced, then the cost to government would exceed $45.2 billion (annuity of $1.1 billion) (see attached chart).

The Sectoral Analyses Are Not Integrated

> "The model runs for each of the three end-use sectors were not integrated and therefore may overstate the effects of technology penetration. In an integrated modeling effort, fuel prices might fall as consumption declines, resulting in less penetration of energy-conserving technologies" (p. 1.1).

The analyses of the various sectors assume that the reduction of 180 MMTCE occurs through energy efficient technology adoption without any price effect. This implies that, with government programs, private agents will adopt technologies because the benefits (energy cost-savings) exceed the costs of adoption. The authors claim that these reductions occur at zero or negative net costs. By failing to account for the effect of decreased energy demand due to energy efficiency technology adoption, some of those adoption decisions that occur on the margin would no longer generate positive net benefits for private consumers. The Labs Study indicates that energy consumption will decline from the baseline by 11.6% under the high efficiency/low carbon case (p. xi). This decrease in demand should result in a decrease in the price of energy, and cause some energy efficient technologies to become unattractive to private agents.

In addition, the absence of an integrated analysis precludes an assessment of the economy-wide effects of a tradeable permit system. As previous studies have indicated, the nature of the permit allocation (e.g., grandfathering, auction, or a hybrid) and the characteristics of the revenue recycling (e.g., various adjustments to existing taxes) can affect economy-wide investment. Understanding the effects on investment is instrumental in assessing the likelihood of success of these scenarios, given that they rely on substantial R&D and technology adoption.

The Industry Sector Analysis Ignores the Costs of Accelerated Retirement

> "When the economic losses of accelerated retirement are accounted for this means that, at the margin, all investments are not likely to be cost effective at our assumed 15% CRF [capital recovery factor]. Since we do not have a model to

---

[3] We employed a 7% discount rate to calculate the annuities in this paper.

> account for this potential early retirement and the economic losses, we must caveat our estimates of investment and net costs. ...the investment cost may be understated by the amount of loss due to any early retirement that may occur" (p. 4.15).

This assumption implies that one of three results should be accounted for in the analysis. First, the projected emissions reduction should be revised downward, because the assessment of the industry sector overestimates technology adoption by ignoring these costs. Second, the cost of reducing emissions, if the reduced carbon from this sector remains constant, should increase, with some technology adoption decisions occurring at positive net costs. Third, if the authors maintain the same costs and emissions estimates, then the costs of government programs to somehow force down the CRF from 33% to 15% would increase.

The Transportation Sector Requires "Luck" to Achieve Carbon Reductions

> "[B]ecause the [transportation sector] outcomes postulated in the high efficiency/low carbon scenario require technological breakthroughs, they require a certain degree of luck to be achieved by 2010. There are no credible methods to accurately gauge the probability of such breakthroughs -- we believe they stand a decent chance of occurring with an intensification of research efforts, but we stop short of claiming they are a likely outcome of such an intensification" (p. 5.3).

Note that this statement includes two qualifications: luck on top of intensified research efforts. To achieve just the efficiency level of emissions reductions for this sector (73 MMTCE), these intensified research efforts may require two to ten times existing funding on transportation (p. 5.3). To gain a sense of the magnitude of what such an increase in funding might be, consider that the Partnership for a New Generation of Vehicles (PNGV) alone is funded at the federal level at $263 million. Private sector costs of participating in the PNGV are in addition to this large sum. Further, the estimates of costless (on net) carbon reductions relies on a series of tenuous assumptions: commercial development of the fuel cell for passenger cars, commercial availability of cellulosic ethanol (and the elimination of the ethanol excise tax exemption), and an apparently arbitrary 30% reduction in costs for "certain key technologies" (p. 5.24). These technologies are not identified, and the report does not provide documentation for the NEMS model runs conducted for the transportation sector.

Interactions Ignored, Double Counting "Likely" in Utilities Sector Analysis

> "Chapter 7 considers other electricity supply technology options, including: converting coal-based power plants to natural gas; cofiring coal with biomass; efficiency improvements in generation and transmission and distribution systems; extending the life of existing nuclear plants; increasing generation and capacity of existing hydropower plants; and constructing new powerplants using advanced coal technologies. Each of these options is assessed independently. Thus,

interactions between the options are not taken into account, and the possibility of double counting is therefore likely" (p. 7.1).

The emissions reductions in the electricity sector come from two sources. First, utilities undertake fuel switching at the $50/ton permit price through carbon-ordered dispatching. Second, utilities modify their capital stock through several technology options such as those listed in the above quotation. As electricity production moves away from coal in the first analysis, fewer and fewer plants (and therefore potential emissions reductions) will be available for conversion to natural gas or cofiring with biomass. The second set of analyses were "static" and did not optimize unit/plant production cost, dispatch, or system load. Conversations with one of the co-authors (Stanley Hadley of Oak Ridge National Laboratory) indicate that 10 GW of coal-to-gas conversions (approximately 9 million tons of carbon reductions) were double-counted.[4]

Furthermore, the analysis of specific options did not examine the effect of increasing fuel prices (from gas demand due to coal-to-gas repowering). Given the range of assumptions considered in the study, the authors actually estimated that repowering coal plants for natural gas could result in carbon reductions between 5 million and 269 million tons (p. 7.2), depending on the gas/coal price differential, the cost of carbon, and the costs of sulfur dioxide and nitrous oxide emissions. This is quite a substantial range. The Labs Study estimates that natural gas consumption will increase 14% to 191% above 2010 baseline consumption. However, the DRI 1.25 run in the IAT report indicates a 16% decline in natural gas consumption, while the SGM run resulted in only a negligible decline and Markal-Macro generated a 6% increase in natural gas consumption. These three models indicate that a non-integrated analysis that does not account for the price change in natural gas may overestimate natural gas substitution for coal and emissions reductions from fuel switching.

[4] Hadley noted that a subsequent draft of the report should address at least some of the double counting, but he did not provide details.

Summary of Greenhouse Gas Emissions-Reduction Actions

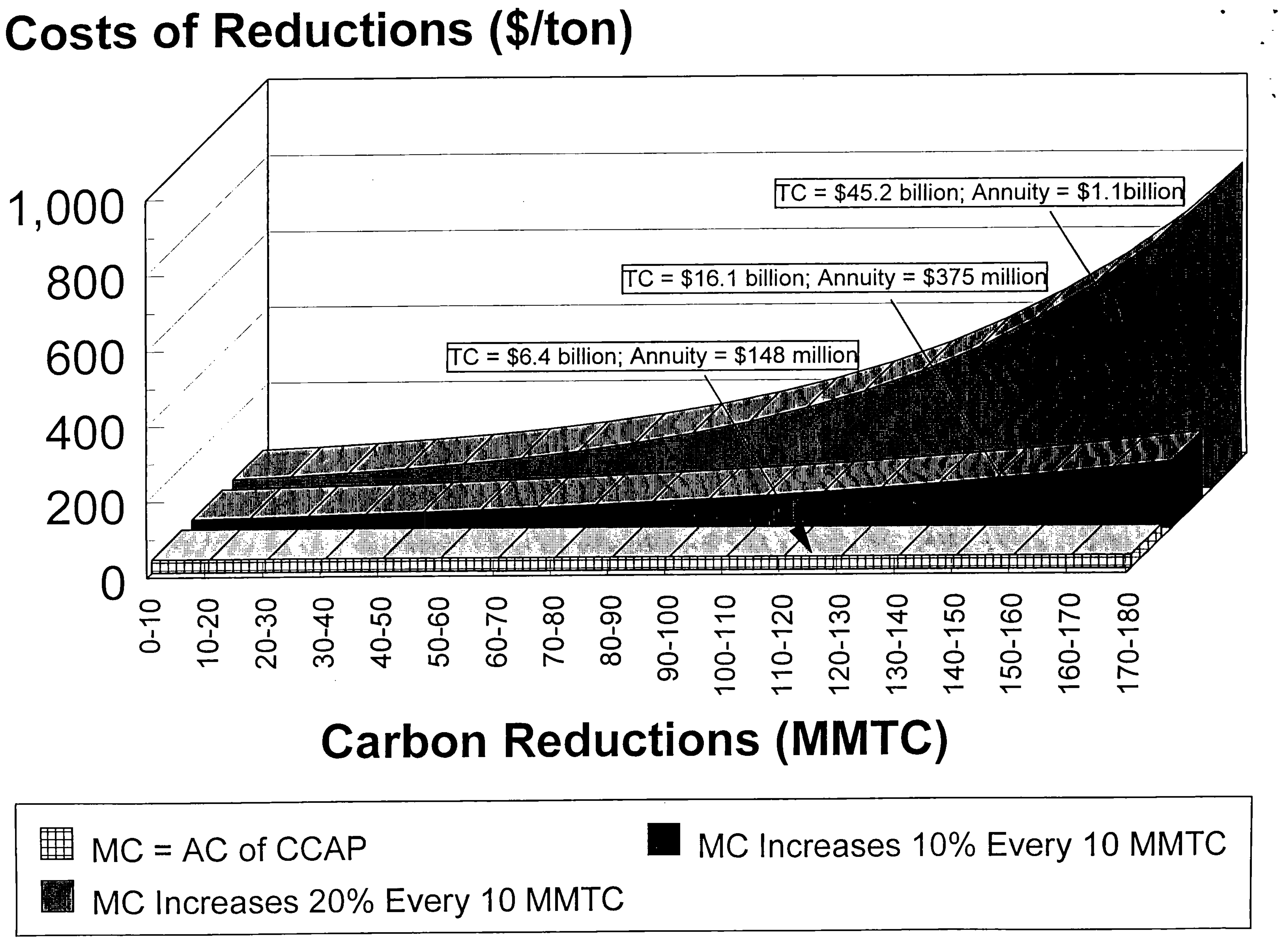
Million Metric Tons of Carbon Equivalent

Source: U.S. Climate Action Report—1997

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
Residential & Commercial Sector Actions		**26.9**	**10.3**	--
New	Rebuild America	2.0	1.6	--
1 and 2	Expanded Green Lights and Energy Star Buildings	3.6	3.3	--
3	State Revolving Fund for Public Buildings	1.1	Terminated	
4 5	Cost-Shared Demonstrations of Emerging Technologies Operation and Maintenance Training for Commercial Building Facility Managers and Operators	3.8	0.0	--
6	Energy Star Products	5.0	4.3	--
7	Residential Appliance Standards	6.8	0.2	--
8 and 11 9 10	Energy Partnerships for Affordable Housing Cool Communities Update State Building Codes	4.4	0.4	--
New	Construction of Energy-Efficient Commercial and Industrial Buildings		0.1	--
New	Superwindow Collaborative		0.0	--
New	Expand Markets for Next-Generation Lighting Products		0.2	--
New	Fuel Cells Initiative		0.0	--
Industrial Sector Actions		**19.0**	**4.8**	--
12	Motor Challenge	8.8	1.8	--
13 14	Industrial Golden Carrot Programs Accelerate the Adoption of Energy-Efficient Process Technologies	2.9	Merged into Action 12 Terminated	
15	Industrial Assessment Centers	0.5	CCAP Component Terminated	
16	Waste Minimization	4.2	2.1	--
17 18	Improve Efficiency of Fertilizer Nitrogen Use Reduce the Use of Pesticides	2.7	0.8 Terminated	--
Transportation Sector Actions		**8.1**	**5.3**	--
19 20 21	Cash Value of Parking Innovative Transportation Strategies Telecommuting Program	6.6	4.6	--
22	Fuel Economy Labels for Tires	1.5	0.7	--
Energy Supply Actions		**10.8**	**1.3**	--
23	Increase Natural Gas Share of Energy Use Though Federal Regulatory Reform	2.2	Terminated	

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
24	Promote Seasonal Gas Use for Control of Nitrogen Oxides	2.8	0.5	--
25	High-Efficiency Gas Technologies	0.6	Terminated	
26	Renewable-Energy Commercialization	0.8	0.3	--
27	Expand Utility Integrated Resource Planning	1.4	Terminated	
28	Profitable Hydroelectric Efficiency Upgrades	2.0	0.0	--
29 30	Energy-Efficient Distribution Transformer Standards Energy Star Distribution Transformers	0.8	0.5	--
31	Transmission Pricing Reform	0.8	Terminated	
New	Green Power Network	Not included	0.0	--
Land-Use Change & Forestry Actions		**10.0**	**2.4**	--
43	Private Depletion of Nonindustrial Private Forests	4.0	Terminated	
44	Accelerate Tree Planting in Nonindustrial Private Forests	0.5	0.4	--
16	Waste Minimization	4.2	2.0	--
9	Expand Cool Communities	0.5	To be determined	
Methane Actions		**16.3**	**15.5**	--
32	Expand Natural Gas STAR	3.0	3.4	--
33	Increase Stringency of Landfill Rule	4.2	6.3	--
34	Landfill Methane Outreach Program	1.1	1.9	--
35	Coalbed Methane Outreach Program	2.2	2.6	--
36	RD&D for Coal Mine Methane	1.5	Terminated	
37	RD&D for Landfill Methane	1.0	Terminated	
38	AgSTAR Program	1.5	0.3	--
39	Ruminant Livestock Efficiency Program	1.8	1.0	--
Actions to Address Other Greenhouse Gases		**16.3**	**25.4**	--
17	Improved Fertilizer Management	4.5	5.3	--
40	Significant New Alternatives Program	5.0	6.4	--
41	HFC-23 Partnerships	5.0	5.0	--
42	Voluntary Aluminum Partnership	1.8	2.2	--
New	Environmental Stewardship Initiative	Not included	6.5	--
Foundation Actions			**11.3**	--
	Climate Wise	Not estimated	1.8	--
	Climate Challenge	Not estimated	7.6	--
	State and Local Outreach Programs	Not estimated	1.9	--
Total GHG Emission Reductions From CCAP		108.6	76.0	14.0

Data is not readily available for cumulative emissions reductions for many CCAP programs. Emissions reductions of about 5 MMTCE can be attributed to DOE's CCAP programs. EPA's Office of Air and Radiation is responsible for emissions reductions of about 9 MMTCE through their CCAP programs.


Costs of Reductions ($/ton)
1,000
800
600
400
200
0
TC = $45.2 billion; Annuity = $1.1billion
TC = $16.1 billion; Annuity = $375 million
TC = $6.4 billion; Annuity = $148 million
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100-110
110-120
120-130
130-140
140-150
150-160
160-170
170-180
Carbon Reductions (MMTC)
MC = AC of CCAP
MC Increases 10% Every 10 MMTC
MC Increases 20% Every 10 MMTC

Department of Energy
Washington, DC 20585

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Director, Office of Public Affairs
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Comments: Call Dan Reicher
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MEDIA CONTACTS:
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FOR IMMEDIATE RELEASE
September xx, 1997

Clean Technology Can Achieve Significant Greenhouse Gas Reductions

Peer-Reviewed Energy Study: What's Good for Environment is Good for Economy

National investment in energy-efficiency and clean energy technologies can reduce U.S. emissions of global warming gases and produce energy savings that roughly equal or exceed the costs to implement them, Energy Department experts predict. A study conducted by five Department of Energy laboratories and peer-reviewed by industry and academic experts demonstrates that the United States could hold down the costs of meeting climate change goals through technological solutions such as advanced natural gas turbines, biomass and biofuels, and energy-saving appliances. Many consumers and businesses could actually save money through reduced energy use and lower overall energy bills.

MGT 9001

"This analysis provides strong evidence that progress on climate change can be achieved without increasing the nation's energy bill. What's good for the environment also can be good for the economy," said Energy Secretary Federico Peña. "President Clinton's plan to make technology a cornerstone for reducing greenhouse gas emissions can achieve these results. From the Partnership for a New Generation of Vehicles that's creating the super-efficient car of the future to expanded use of renewable energy sources, the technology solution is already creating environmental benefits and savings in energy costs."

Current projections suggest that a carbon emissions reduction of 390 million metric tons (MMT) would be required to reduce U.S. emissions in 2010 to 1990 levels. The study models a scenario that combines a vigorous national technology program with a domestic system of carbon trading to achieve the reduction. The study concludes that such an approach could reduce emissions by up to 390 MMT. A new generation of technologies and international carbon emission trading could result in further reductions over the next quarter century.

This study estimated the potential costs of the reductions at $50 to $90 billion per year. Costs in the study include incremental investments to deploy clean energy or energy efficient technologies by consumers and industry as well as those associated with hypothetical increases in energy prices. In addition, Energy Department experts reviewed energy cost savings resulting from the use of these technologies; these estimated savings through 2010 total $70 to $90 billion per year. This indicates that the clean energy investments could produce energy cost savings roughly equal to or greater than the costs of implementation, on a life-cycle basis.

The "bottoms-up" approach in the study examines 200 specific technologies in four major sectors of the economy -- buildings, industry, transportation and electric utilities -- and analyzes the possible advances in each sector. For the buildings, industry and transportation sectors, the study analyzes the impacts of end-use energy-efficiency improvements and low-carbon technologies on carbon emissions. The utility sector analysis estimates the impacts of clean energy activities, such as increased use of natural gas and renewable energy. While no one measure can address the entire problem, technologies already in development could contribute substantially to the reductions. For example:

- **Transportation:** The Partnership for a New Generation of Vehicles is developing advanced automobiles that will be three times more fuel-efficient than today's vehicles but still safe and affordable. In the biofuels area, cellulosic ethanol, a promising biofuel made from agricultural and forestry wastes, produces no net carbon emissions; the Energy Department projects cutting the cost of ethanol to under 70 cents/gallon by 2010.

- **Buildings:** The study projects promising carbon reductions from energy-efficient appliances supported by the Energy Department, including a 1 kilowatt-hour/day refrigerator and advanced lighting. Advanced fuel cells powered by natural gas will produce electricity and provide heating at 80-percent efficiency, while lowering the current cost of power.

- **Utilities:** Wind turbines are expected to produce power at less than 3 cents/kilowatt-hour by 2010. Biomass co-firing with coal at some plants could produce significant emissions reductions.

- **Industry:** Advanced turbines are expected to achieve 80 percent system efficiency, producing electricity and steam in industrial plants at less than today's costs. Advanced motor systems and clean industrial technologies can cut emissions and costs while increasing productivity.

The Department of Energy's Oak Ridge and Lawrence Berkeley National Laboratories led the comprehensive one-year analysis, with contributions by the National Renewable Energy Laboratory and Pacific Northwest and Argonne National Laboratories. The findings, which were reviewed extensively by representatives from industry and academia, are consistent with those of two previous studies. Those studies, released by the National Academy of Sciences and Office of Technology Assessment in 1991, also concluded that technology could play a prominent role in reducing U.S. greenhouse gas emissions.

To request a summary or full copy of the study, titled ***Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficiency and Low-Carbon Technologies by 2010 and Beyond***, media can call the Department of Energy Press Office at 202/586-5806; others can call Public Inquiries at 202/586-5575.

- DOE -

END FAX

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Joe Romm
Acting Assistant Secretary for Energy Efficiency and Renewable Energy

FROM: Randy Lutter and Joe Aldy

DATE: September 4, 1997

RE: Comments on revised executive summary and chapter one of *Scenarios of U.S. Carbon Reductions*

We appreciate the opportunity to review the August 29 draft of the executive summary and chapter one of *Scenarios of U.S. Carbon Reductions*. In this draft, we note that the authors addressed many of our comments made at the August 19 meeting. Since this is a Department of Energy labs report, and not an interagency or CEA report, we do not intend to hold up the report simply because the views presented do not conform in all respects to our own. However, two modifications to chapter one should be made prior to the release of the report.

- First, all references to the "cost-effectiveness" of technologies should be removed and the estimates of costs and benefits in table 1.5 should be deleted. As we noted in our August 22 comments, the report does not appropriately account for all of the costs associated with technology adoption decisions. Without an assessment of the behavioral responses to policies aimed at stimulating technology adoption, the private cost of achieving these emission reductions is unknown. Further, the report insufficiently details the costs of government programs, and does not ascribe any costs to society of standards. Thus, claims of "cost-effectiveness" are premature at best.

  The benefits resulting from energy cost savings do not reflect appropriate energy prices and should not be provided in this table. Since the analyses are not integrated, the energy prices do not reflect declines in demand, resulting decreases in prices, and the behavioral responses of consumers. However, qualitative statements could be included in the text, such as: "The adoption of energy efficient technologies would result in substantial energy cost savings to consumers."

- Second, chapter one should clarify the divergence between the report's BAU case and the Annual Energy Outlook 1997 reference case. We understand that transportation emissions under the BAU reflect a modified assumption about fuel efficiency improvements in the AEO reference case. However, we do not understand the discrepancy in emissions for the buildings and industry sectors between the two reports (see comment 8 in August 22 memorandum). A discussion of the assumptions that resulted in this divergence, or a modification of the projected emissions would be appropriate.

We look forward to receiving your responses to our August 22 memorandum in the near future.

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

FAX

CC: JA

Date:	August 29, 1997	**Total Pages:**	
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From:	Mark Levine & Marilyn Brown	**Phone:**	(510) 486-5238
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Joe Romm	(202) 586-9260
Eric Petersen (DOE)	(202) 586-2176
Marilyn Brown (ORNL)	(423) 576-7572

MEMORANDUM

August 29, 1997

TO: T.J. Glauthier (OMB), Jeff Frankel (CEA), Robert Gillingham and Jon Gruber (Treasury), Peter Orszag (NEC)

FROM: Mark D. Levine and Marilyn Brown

RE: Executive Summary and Chapter 1 of thc Report "Scenarios of U.S. Carbon Reductions"

CC: Joe Romm, Eric Petersen, Mark Mazur

We are faxing to you a modified version of the Executive Summary and Chapter 1 of the referenced report. In this version, we have attempted to respond to the concerns expressed in the meeting on August 19 while still expressing the major findings of the report.

We have received two sets of comments from you and expect to give you substantive responses to these comments in the near future.

EXECUTIVE SUMMARY

This report presents the results of a study conducted by five U.S. Department of Energy national laboratories that quantifies the potential for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States.[1] The study documents in detail how four key sectors of the economy – buildings, transportation, industry, and electric utilities – could respond to directed programs and policies to expand adoption of energy-efficiency and low-carbon technologies, an increase in the relative price of carbon-based fuels by $25 or $50/tonne (e.g., as a result of a cap on domestic carbon emissions and a market for carbon "permits"), and an aggressive program of targeted research and development. Current projections suggest that a carbon emissions reduction of 380 million metric tons per year (MtC/year) is required to stabilize U.S. emissions in 2010 at 1990 levels.

The study, which has been peer-reviewed by industry and academic experts, uses a technology-by-technology assessment as well as an engineering-economic modeling approach. It draws upon a wide variety of technology cost and performance information to assess potential impacts. Analysis of the buildings, industry, and transportation sectors quantifies the impacts of end-use energy-efficiency improvements on carbon emissions. The utility sector analysis estimates the impacts of those improvements on utility carbon emissions, and quantifies additional emissions reductions through conversion of a number of coal power plants to natural gas, dispatching of the utility grid with $25 and $50/tonne carbon permit prices, the accelerated use of biomass cofiring and wind energy, and other low-carbon electricity supply options. Finally, a number of other promising low-carbon technologies are examined to determine their potential for reducing emissions in the end-use sectors, including advanced gas turbines in industry, transportation biofuels, and fuel cells in buildings.

Three overarching conclusions emerge from the analysis of alternative carbon scenarios. First, a vigorous national commitment to develop and deploy cost-effective energy-efficient and low-carbon technologies has the potential to restrain the growth in U.S. energy consumption and carbon emissions such that levels in 2010 are close to those in 1997 (for energy) and 1990 (for carbon). We analyze a case in which energy efficiency can reduce carbon emissions by 120 MtC/year by 2010. We analyze a second case, with policies that promote adoption of energy-efficient and low carbon technologies and a $25/tonne carbon permit price, with emission reductions of 230 MtC/year in 2010. Under a $50/tonne carbon permit price and aggresive policies, 2010 emissions could be cut by about 380 MtC/year. The analysis also suggests that substantial additional savings are available if permit prices were to begin to rise above the $50/tonne level.

The second conclusion is that, if feasible ways are found to implement the carbon reductions as described above, all the cases (with reductions varying between 120 and 380 MtC/year by 2010) can produce direct benefits that are roughly equal to or exceed costs.[2] The analysis includes only technologies estimated to be cost-effective under 2010 energy prices (with a $25/tonne and $50/tonne carbon permit price for the respective cases); it has not, however, analyzed specific policies to achieve the cases, identified the political feasibility of policies, or described a pathway to achieve the cases.

The third conclusion is that a next generation of energy-efficient and low-carbon technologies promises to enable the continuation of an aggressive pace of carbon reductions over the next quarter century. This report documents a wide array of advanced technology options that could be cost-competitive by the year 2020, assuming a vigorous and sustained program of energy R&D beginning now and extending beyond 2010.

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[1] The five national laboratories participating in the study were: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). LBNL and ORNL were the co-leaders of the effort.

[2] Here we count as benefits only the energy savings to the nation. We have not credited reduced CO_2 emissions or other external benefits. Costs include the increased technology cost plus an approximate estimate of the costs of program and policy implementation.

Chapter 1
ANALYSIS RESULTS

This report presents the results of a study conducted by five U.S. Department of Energy national laboratories that quantifies the potential for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States.[1] The stimulus for this study derives from a growing recognition that any national effort to reduce the growth of greenhouse gas emissions must consider ways of increasing the productivity of energy use. To add greater definition to this view, we quantify the reductions in carbon emissions that can be attained through the improved performance and increased penetration of efficient and low-carbon technologies by the year 2010. We also take a longer-term perspective by characterizing the potential for future research and development to produce further carbon reductions over the next quarter century. As such, this report underscores the value of energy technology research, development, demonstration, and diffusion as a public response to global climate change.

Three overarching conclusions emerge from our analysis of alternative carbon reduction scenarios. First, a vigorous national commitment to develop and deploy cost-effective energy-efficient and low-carbon technologies could reverse the trend toward increasing carbon emissions. Along with utility sector investments, such a commitment could helt the growth in U.S. energy consumption and carbon emissions so that levels in 2010 are close to those in 1997 (for energy) and in 1990 (for carbon). It must be noted that such a vigorous national commitment would have to go far beyond current efforts. Second, if feasible ways are found to implement the carbon reductions, the cases analyzed in the study are judged to yield direct benefits that are roughly equal to or greater than costs. Third, a next generation of energy-efficient and low-carbon technologies promises to enable the continuation of an aggressive pace of carbon reductions over the next quarter century.

1.1 OBJECTIVES OF THE REPORT

The purposes of this study are threefold:

1. To provide a quantitative assessment of the reduction in energy consumption and carbon emissions that could result by the year 2010 from a vigorous national commitment to accelerate the development and deployment of cost-effective energy-efficient and low-carbon technologies;
2. To document the costs and performance of the technologies that underpin a year 2010 scenario in which substantial energy savings and carbon emissions reductions are achieved;
3. To illustrate the potential for energy-efficiency and renewable energy R&D to produce further reductions in energy use and carbon emissions by the year 2020.

1.2 METHODOLOGY

To achieve these objectives, we started with the *Annual Energy Outlook 1997* (AEO97) reference case forecasts for the year 2010 (Energy Information Administration, 1996). After thoroughly reviewing these forecasts on a sector-by-sector basis, and working with EIA staff, we chose to accept the EIA "business-as-usual" (BAU) scenario as is for buildings and industry. We modified some of the assumptions and data to produce a new BAU case – not greatly different from the EIA case – for the transportation and the electric utility sectors.

We then assembled existing information on the performance and costs of technologies to increase energy efficiency or, for selected end-uses, to switch from one fuel to another (e.g., from electricity to natural gas for residential end-uses or from gasoline to biofuels for transportation). For the buildings sector, the technology performance and cost data base are extensive. For transportation, the data base – although less fully developed than for buildings – is sufficient for our purposes. For industry, only partial information on technologies and costs is presently available. As a result, the analysis for industry relies primarily on historical relations between energy use and economic activity and much less on explicit technological opportunities. The industrial analysis also includes some examples of industrial low-carbon technologies. The analysis of low-carbon supply technologies in the electricity sector is based on a review of the literature including detailed technology characterizations prepared by DOE in conjunction with its national laboratories and industry.

Next we created scenarios of increased energy efficiency and lower carbon emissions using the technology data (or, in the industrial sector, historical relations) as key inputs. We chose to run three scenarios other than the BAU case. We have termed the first the "efficiency" (EFF) case. It assumes that the United States increases its emphasis on energy efficiency through enhanced public- and private-sector efforts. The general philosophy of the efficiency case is that it reduces, but does not eliminate, various market barriers and lags to the adoption of cost-effective energy efficiency technology.[2]

The other two cases, dubbed the $25 permit and the $50 permit "high-efficiency/low-carbon" (HE/LC) cases, describe a world in which, as a result of commitments made on a climate treaty or other factors, the nation has embarked on a path to reduce carbon emissions. Both of these cases assume a major effort to reduce carbon emissions through federal policies and programs (including environmental regulatory reform), strengthened state programs, and very active private sector involvement. Both also include a focused national R&D effort to develop and transform markets for low-carbon energy options (e.g., fuel cells for microcogeneration in buildings and advanced turbine systems for combined heat and power in industry). The difference between the two HE/LC cases is in the assumption of a carbon permit price resulting from a domestic trading scheme for carbon emissions with a cap on U.S. emissions (or from equivalent policy measures that increase the price of carbon-based fuels relative to those with less carbon). We assume a domestic permit price of $25 and $50 per tonne of carbon for the two cases. Both of these HE/LC cases include a program of research, development, demonstration and diffusion that is more vigorous than in the efficiency case. In the buildings and industry sectors, the carbon price signal, combined with policies promoting energy efficiency, is believed to trigger most of the additional carbon reductions. In the transportation sector, it is the R&D-driven technology breakthroughs that generate the bulk of the carbon reductions beyond the efficiency case. For the electricity sector, higher prices for carbon-based fuels cause larger shifts from coal to natural gas; for this sector, these same higher relative prices combined with federal and private research, development, and demonstration can bring advanced low-carbon technologies to market.

Although most of the analysis focuses on 2010, we also look beyond this date. Here we describe new technologies, materials, processes, manufacturing methods, and other R&D advances that promise to offer significant energy benefits by the year 2020; for this time period, we make no effort to forecast specific levels of market penetration, energy savings, or carbon reductions. Thus, instead of creating scenarios we describe the technological innovations that could enable the continuation of an aggressive pace of decarbonization well into the next quarter century, if appropriate investments in R&D were made.

1.3 BACKGROUND

The decade of gains in energy productivity achieved by the U.S. following the 1973-74 Arab oil embargo represents a period of economic growth that was decoupled from increases in energy consumption, resulting in substantial economic benefits. Between 1973 and 1986, the nation's consumption of primary energy froze at about 74 quads – while the GNP grew by 35%. Starting in 1986, energy prices began a descent in real terms that has continued to the present. As a result, energy demand grew from 74 quads in 1986 to 91 quads in 1995, and carbon emissions have been increasing at a similar pace.

Despite the growth in energy consumption since 1986, the U.S. economy today remains more energy productive than it was 25 years ago. In 1970, 19.6 thousand Btu of energy were consumed for each (1992) dollar of GDP. By 1995, the energy intensity of the economy had dropped to 13.4 thousand Btu of energy per (1992) dollar of GDP. The U.S. Department of Energy (DOE) estimates that the country is saving $150 to $200 billion annually as a result of these improvements.

Nevertheless, many cost-effective energy-efficient technologies remain underutilized, as discussed in Chapter 2. A host of market barriers account for these lost opportunities. And declining energy R&D expenditures may cause promising technology options to be foregone.

The rationale for government support of energy-efficiency R&D is strong. Much energy-efficiency research is both long-term and high-risk and therefore is not adequately funded by the private sector – despite the possibility of sizable gains in the long run. Furthermore, advances in energy efficiency offer substantial public benefits (such as carbon reductions and improved national security through greater oil independence) that cannot be fully captured in the private marketplace.

The benefits of past public investments in energy-efficiency R&D have been well documented. Between 1978 and 1996, DOE spent approximately $8 billion on energy-efficiency research, development and demonstration (RD&D). Just five of the technologies that were developed or demonstrated with a fraction of this DOE support have resulted in net benefits of $28 billion through 1996. Many other R&D successes have produced technologies yielding substantial energy and cost savings in the market. The DOE RD&D portfolio has also led to significant environmental, health, productivity, and economic competitiveness benefits.

1.4 RESULTS

1.4.1 Prospects for Improved Efficiencies by the Year 2010

Table 1.1 and Figure 1.1 compare the nation's primary energy use in quads for the years 1990 and 1997 (projected) with the results of three scenarios for 2010. (We have included only the high-efficiency/low-carbon case at $50/tonne in the table and figure for simplicity.) The $50/tonne HE/LC case shown below does not reflect the energy impacts of the selected low-carbon technologies described later in this summary (e.g., stationary fuel cells for buildings, advanced turbine systems and biomass gasification in industry) or the supply-side options shown in Table 1.4.

Table 1.1 Primary Energy Use in Quads: 1990-2010

	1990	1997	2010: Business-as-Usual Case	2010: Efficiency Case	2010: High-Efficiency/Low-Carbon Case ($50/tonne C)
Buildings	29.4	33.7	36.0	34.1	32.0
Industry	32.1	32.6	37.4	35.4	33.6
Transportation	22.6	25.5	32.3	29.2	27.8
Total	84.2	91.8	105.7	98.7	93.4

Source: Energy use estimates for 1990 come from EIA (1996a, Table 2.1, p. 39).
Energy use estimates for 1997 come from forecasts conducted for EIA (1996b).
Numbers may not add to the totals due to rounding.

The major observations are as follows:

- In the business-as-usual case, energy use increases by 22 quads (26%) between 1990 and 2010; 8 quads of this increase have occurred during the first seven years of this 20-year period. The fastest growing sector during these initial seven years has been buildings (4.3 quads) followed by transportation (2.9 quads) and industry (0.5 quads). In the BAU case, the fastest growing sector during the remaining 13 years is transportation (6.8 quads). This is followed by industry (4.8 quads) and then buildings (2.3 quads). The rapid projected growth in the energy consumed for transportation is driven by estimates of increased per capita travel and minimal fuel efficiency gains.

- The efficiency scenario cuts the overall growth between 1990 and 2010 from 22 to 15 quads. This is a 17% increase over the level of energy consumption in 1990, down from a 26% increase in the BAU case. Relative to the BAU case, the efficiency scenario for transportation delivers slightly more energy savings (3.1 quads) than do the same scenarios for the industrial (2.0) or buildings (1.9) sectors. Compared with 1997 levels, the smallest increase in energy growth for this case is in buildings (0.4 quads), followed by industry (2.8 quads), and transportation (3.7 quads).

- The high-efficiency/low-carbon scenario with $50/tonne carbon charge further decreases the overall growth between 1990 and 2010, reducing it from 22 to 9 quads. This is an 11% increase over the level of energy consumption in 1990. Relative to the BAU case, the high-efficiency/low-carbon scenario for buildings, industry, and transportation delivers energy savings ranging from 3.8 to 4.5 quads for each sector. Compared with 1997 levels, the buildings sector is down about 2 quads and industry and transportation are up 1 and 2 quads, respectively.

Figure 1.1 Primary Energy Use in Quads: 1990-2010

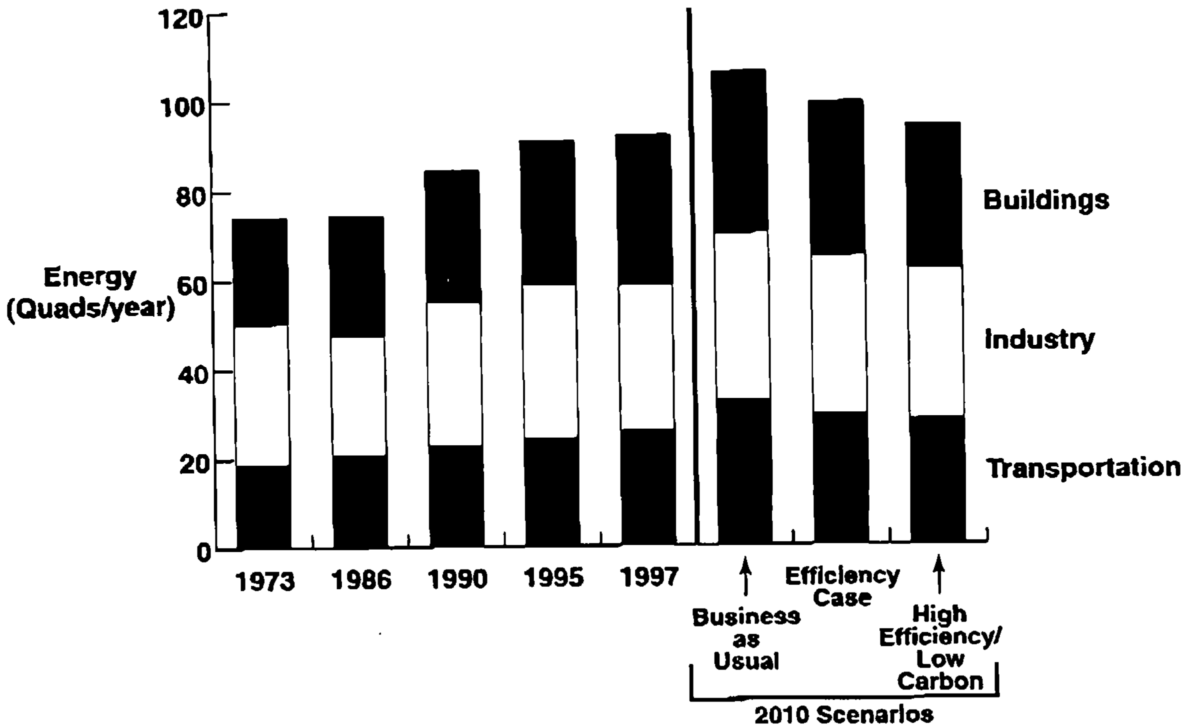


Table 1.2 documents the impact of these projected energy savings in 2010 on carbon emissions in that same year. It also presents the results of the HE/LC scenarios with both $25 and $50 per tonne carbon charges. These scenarios show significant carbon reductions from the combination of greater efficiency improvements and increased use of advanced low-carbon technologies.[3] In these cases, a number of low-carbon technologies have high rates of adoption (e.g., advanced turbine systems and biomass gasification in industry), the utility grid is dispatched to reduce carbon emissions (by using many coal plants for intermediate power and by running more natural gas plants as base load), a set of coal-based power plants are repowered, nuclear plant lifetimes are extended, and key renewable energy technologies are deployed. In all cases, these technologies and measures are estimated to be cost-effective with a differential carbon fee of $50/tonne.

Table 1.2 Carbon Emissions (MtC): 1990-2010

	1990	1997	2010 Business-as-Usual (BAU) Case	2010 Efficiency Case	2010 High-Efficiency/ Low-Carbon[a] $25/tonne	2010 High-Efficiency/ Low-Carbon[a] $50/tonne
Buildings	460	511	571	546	527	509
Industry	452	482	534	512	488	452
Transportation	432	486	616	543	528	513
Utilities[b]	-	-	–	–	-48	–136
Total (rounded)	1340	1480	1720	1600	1490	1340
Change from 1990		140	380	260	150	0
Change from BAU	–	–	–	-120	-230	-380

[a]This scenario includes the carbon emission reductions resulting from a carbon permit price of $25 or $50/tonne: (1) dispatch of power plants in which natural gas is favored relative to coal, (2) repowering and partial repowering of coal-based power plants to convert to natural gas, and (3) introduction of selected low-carbon technologies to replace conventional ones, primarily in the industrial and utility sectors.

[b]The entries in the last two columns are negative as they correspond to reductions in carbon emissions resulting from the increased use of natural gas and low-carbon technology for electricity generation as a result of the $50/tonne carbon permit price in this scenario.

Table 1.2 presents results for the business as usual and three efficiency and/or low carbon cases in 2010 as point estimates, because they are meant to be scenarios. When we use these scenarios for analysis, in section 1.5, we describe sources of uncertainty and the effects of uncertainty on our understanding of the implications of these cases. For now, we only describe the different cases.

Figures 1.2 and 1.3 complement the above table by illustrating the carbon emissions reductions from each scenario. The major observations are:

- In the BAU case, carbon emissions are forecast to increase by approximately 380 million tonnes.

- The energy-efficiency gains incorporated in the efficiency case cut overall growth between 1990 and 2010 by one-third (from 380 to 260 million tonnes). This represents a carbon increase of 19% above 1990 emissions.

- The HE/LC scenario with $25/tonne carbon charge has the potential to reduce carbon emissions by 230 million tonnes from the BAU case in 2010. The largest part of these carbon reductions are from increased efficiency, but major changes in electricity supply (carbon-based dispatching and repowering) contribute nearly 35 million tonnes, and other low-carbon technology, particularly renewables and advanced turbine systems, produce approximately another 25 million tonnes.

- The HE/LC scenario with $50/tonne carbon charge has the potential to reduce carbon emissions by approximately 380 million tonnes, thereby achieving 1990 carbon emission levels in 2010. Of this 380 million tonne carbon reduction, about 190 million tonnes are from increased energy efficiency, 140 million tonnes results from increases in the use of low-carbon fuels and technologies in the utility sector, and 50 million tonnes results from the use of low-carbon technology in industry and transportation.

Figure 1.2 Reductions in Carbon Emissions from Each Scenario

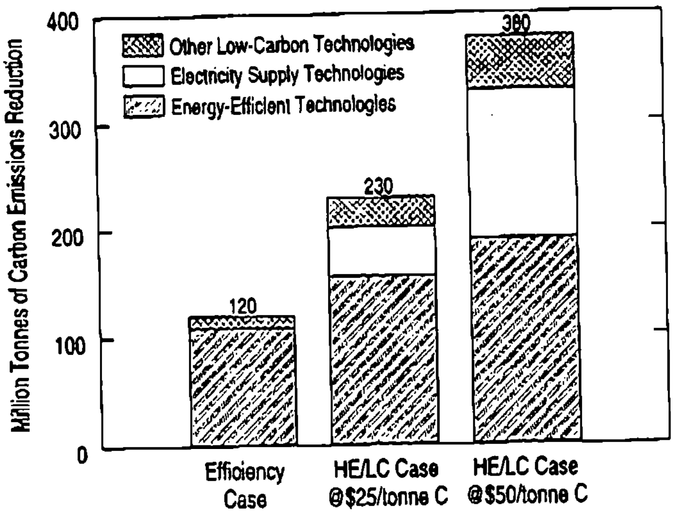
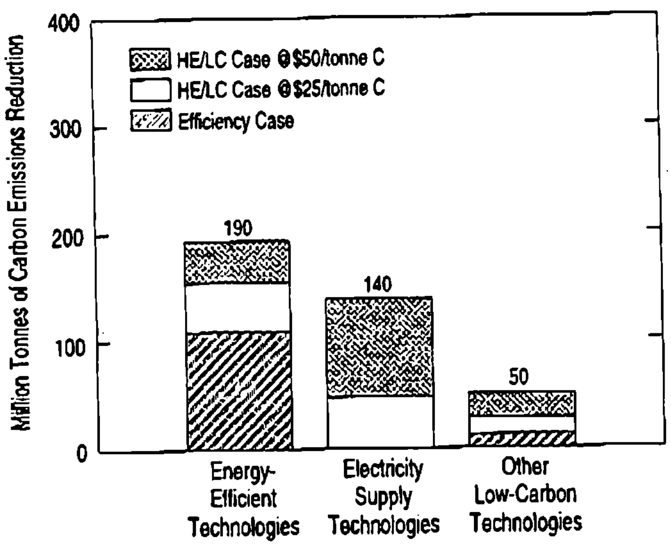


Figure 1.3 Reductions in Carbon Emissions from Each Type of Technology



100 million of the 140 million tonnes of carbon reductions in the utility sector comes from redispatching the utility system (favoring the use of low-carbon fuels) and from repowering coal plants with natural gas. Both are cost-effective with a $50/tonne carbon charge. The remaining 40 million tonnes are from renewables (wind, co-firing coal-based power plants with biofuels, expansion of hydropower capacity), nuclear power plant life extensions, and power plant efficiency improvements.

The remaining 50 million tonnes of carbon reductions in industry and transportation are about equally divided among three sets of fuels/technologies: (1) advanced combustion turbine cogenerators in industry, (2) biomass and black liquor gasification and low-carbon industrial processes, and (3) cellulosic ethanol/gasoline blends for automobiles.

- Approximately 140 MtC of the increase in carbon emissions between 1990 and 2010 will have occurred by the end of 1997; thus, it is useful to look at the 13-year forecast starting with 1997.

The carbon reductions incorporated in the efficiency case cut the overall *growth* in carbon emissions between 1997 and 2010 from 240 million tonnes (as forecast in the BAU case) to 120. The HE/LC scenario with $50/tonne carbon charge *reduces* carbon emissions in 2010 by about 130 million tonnes (compared with the 1997 level).

Table 1.3 provides a comparison of the growth rate in energy and in carbon emissions for the four cases, from 1990 to 2010. For the BAU and efficiency cases, the growth in carbon emissions is slightly more rapid than the increase in energy demand. For the HE/LC cases, carbon emissions decline while energy consumption rises. The carbon reduction reflects the increased deployment of low-carbon fuels and technologies as a consequence of the relative increase in price of carbon-based fuels precipitated by the $50/tonne incentive.

Table 1.3 Average Annual Energy and Carbon Growth Rates, 1997 to 2010, for Four Cases

	Business-As-Usual (BAU)	Efficiency Case	High Efficiency/ Low Carbon Case ($25/tonne)	High Efficiency/ Low Carbon Case ($50/tonne)
Gross Domestic Product (GDP)[a]	1.88%	1.88%	1.88%	1.88%
Energy Demand	1.09%	0.56%	0.34%	0.13%
Carbon Emissions	1.16%	0.60%	0.05%	-0.76%
Energy Consumption Per GDP (E/GDP)	-0.77%	-1.30%	-1.51%	-1.71%
Carbon Emissions Per GDP (C/GDP)[b]	-0.70%	-1.25%	-1.79%	-2.59%

[a] The Gross Domestic Product (GDP) in 1995 was $7251 billion in 1995 dollars. The 1.88% annual growth was assumed to apply to the entire period, 1995-2010 to derive the results above.

[b] The carbon decrease per unit GDP growth for 1990 to 2010 is 0.7%, 1.1%, 1.4% and 1.9% per year for the reference, efficiency, $25/tonne HE/LC, and $50/tonne HE/LC cases, respectively.

It is useful to compare the scenarios in this study to those of other studies. The 1991 report by the Office of Technology Assessment (OTA) titled *Changing by Degrees* (U.S. Congress, 1991) analyzed the potential for energy efficiency to reduce carbon emissions by the year 2015, starting with the base year of 1987. Its "moderate" scenario results in a 15% rise in carbon emissions, from 1300 MtC/year of carbon in 1987 to 1500 MtC/year of carbon in 2015 (compared to a BAU forecast of 1900 MtC/year). Its "tough" scenario results in a 20% to 35% emissions reduction relative to 1987 levels, or emissions levels of 850 to 1000 MtC/year of carbon in 2015. Our efficiency and HE/LC cases ranging from 1.3 to 1.6 billion tonnes of carbon emissions in 2010 are comparable to OTA's "moderate" case and show considerably higher emissions than OTA's "tough" case.

Another benchmark is provided by the 1992 National Academy of Sciences (NAS) report on *Policy Implications of Greenhouse Warming* (National Academy of Sciences, 1992). This study identified a set of energy conservation technologies that had either a positive economic return or that had a cost of less than $2.50 per tonne of carbon. Altogether, NAS concluded that these technologies offer the potential to reduce carbon emissions by 463 million tonnes, with more than half of these reductions arising from cost-effective investments in building energy efficiency. Our efficiency and HE/LC cases suggest the potential for reducing carbon emissions by between 120 and 380 million tonnes by the year 2010. One reason that the NAS estimate is higher is because it is not limited to the 2010 time frame, but rather characterizes the full potential for carbon reductions. Thus, it did not take into account the replacement rates for equipment and processes, and other factors that prevent the instantaneous, full market penetration of cost-effective energy-efficient and low-carbon technologies.

1.4.2 R&D's Potential for Further Benefits by 2020

If carbon reductions in 2010 and beyond are to be sustained at reasonable cost, vigorous R&D efforts are needed to fill the pipeline of next-generation energy technologies. It is difficult to estimate the carbon savings that will accrue from these technologies; however, our effort to characterize their features suggests that an aggressive pace of carbon reductions over the next quarter century can be sustained, with a sufficient investment in R&D. Our analysis of R&D potential for the year 2020 focuses on opportunities for improved energy-efficiency and renewable energy technologies. The potential long-term contributions of carbon sequestration, advanced coal technologies, and nuclear power may also be significant. However, the treatment of vigorous R&D initiatives to improve these supply options beyond 2010 is beyond the scope of this report.

Renewable energy technologies will likely play a crucial role in limiting carbon emissions over the long term. Low-carbon energy supply options are needed to fuel domestic and international economic development without stimulating further global warming. Although renewable resources account for only 7% of the nation's total energy consumption at present, many believe that they are at the beginning of a long-term growth trajectory. With continuing technological development and cost reductions, renewables could become preferred energy resources some time within the next several decades. Early evidence of this transition is seen in the continuing adoption of renewable power systems, including especially wind farms and biomass power systems, even in the face of low gas-fired power generation costs and considerable uncertainty in today's electric energy sector.

With a vigorous and sustained program of research, development and deployment, biomass, wind, photovoltaics, geothermal, and solar thermal technologies could deliver significant quantities of electricity in 2020, thereby substantially displacing carbon emissions. For example, the use of forestry and agricultural residues in biomass power systems continues to be an attractive power option where those residues exist. The successful development of higher-efficiency biomass gasification systems would make this technology competitive in a wider range of applications, including for power systems using dedicated feed stock supply systems. At the same time, biological and agricultural research on biomass production will lead both to higher biomass yields and better species for energy conversion purposes in the future.

A second area in which a vigorous and sustained R&D effort could spawn a range of key improvements is in wind power systems. Potential improvements include

- Advanced blade shapes that increase wind power capture while reducing stress loads
- Elimination of gearboxes through development of direct-drive generators
- Variable speed turbines, and
- Better resource prediction that will increase the value of wind power to power systems operators.

A third area of renewables development that is at the beginning of a long-term growth path is the use of renewables in buildings. Solar daylighting, passive solar designs, solar water heating, and geothermal heat pumps already are cost-competitive in many applications, but are not yet widely used. R&D advances could substantially accelerate their market penetration. In addition, building-integrated photovoltaic products will benefit directly from advances in materials research. The ultimate vision is that many buildings will become "net energy generators" through a combination of renewable energy and energy-efficiency technologies.

In the next quarter century, improved energy-efficiency technologies will result from a combination of incremental advances and fundamental breakthroughs. Incremental improvements in all sectors can be achieved by the greater reliance on more precise and reliable sensors and controls or on lower-cost sensors and controls, often integrated into industrial processes, transportation systems, and buildings. Advanced manufacturing technologies, including rapid prototyping and ultraprecision fabrication, also offer broad opportunities for continuous incremental improvements in energy efficiency and renewable energy. Breakthroughs in bioprocessing, separations, superconductivity, catalysts, and materials can have wide-ranging impacts on energy efficiency and carbon emissions by the year 2020. Examples of specific technology opportunities are described in this report, by sector.

Five R&D areas offer great promise to reduce significantly the energy requirements of our nation's buildings in 2020:

- Advanced construction methods and materials
- Adaptive building envelopes
- Multi-functional equipment
- Integrated, advanced lighting systems, controls and communications and
- Self-powered buildings.

In addition to the broad application of better process modeling, sensors, and controls in industry, many process/industry-specific opportunities for efficiency gains exist. These are described for each of DOE's targeted industries of the future: pulp and paper, chemicals, petroleum refining, glass, aluminum, iron and steel, and metal casting.

Many of the advanced technologies that have the potential to significantly improve the energy efficiency of transportation need considerable R&D investment before they can become commercially available in the year 2020. For example, to achieve fuel economies in the 60-80 miles per gallon (MPG) range and remain affordable and safe, light-duty vehicles will need

- Breakthroughs in manufacturing processes for composite materials
- Large reduction in fuel cell costs and/or cost reductions and performance gains in batteries
- Ultra-low rolling resistance tires
- High-efficiency accessories and
- Highly aerodynamic designs.

Opportunities for R&D to lead to improvements in the energy efficiency of other transportation modes are also described in this report.

In all, the continued adoption of energy efficient and renewable energy technologies and a steady flow of technology improvements from collaborative R&D programs with industry could make such environmentally friendly technology an attractive option for domestic and global energy economies in the future. With strong public-private partnerships to support the necessary R&D and market transformation activities, ample cost-effective energy products and practices will be available in 2020.

1.5 ASSESSMENT OF COSTS AND SOURCES OF CARBON REDUCTIONS

The business-as-usual scenario projects an increase of 380 MtC/year between 1990 and 2010. In our efficiency scenario, in which the nation actively pursues policies and programs to promote market acceptance of energy efficiency while expanding commitments to research and development, energy-efficient technologies reduce this growth in carbon emissions by 120 MtC/year. Under a carbon cap and trading system, in which permits for carbon sell for either $25 or $50/tonne C, very substantial carbon reductions appear possible. Detailed results for these cases, showing the sources of the carbon reductions, are contained in Table 1.4. (Summaries of these results were presented in Figures 1.2 and 1.3.) Results indicate that, for the $50/tonne HE/LC case, there is a potential to roughly return to 1990 levels of carbon emissions in 2010. About two-thirds of the increase in carbon emissions is eliminated in the case with a $25/tonne carbon charge (Table 1.4).

The estimates in Table 1.4 include ranges for most of the electricity supply options and the other low-carbon technologies. There are no ranges for the efficiency technologies because the models used to estimate their penetration are nonstochastic. When selecting a single estimate for the $50/tonne case, numbers from the low end of the ranges were generally selected in order to be cautious. Because we did not conduct an integrating analysis in which supply options compete against one another, we felt it important to minimize potential overlap by entering the supply options in conservative quantities. Also note that several renewable resources that could play a greater role by 2010 are omitted from Table 1.4; these resources include include photovoltaics, geothermal, solar thermal, and landfill gas.

One should not ascribe too much significance to specific entries in Table 1.4 There are many different technologies, both on the supply and demand side of the energy system, that will compete to achieve carbon reductions in an environment in which policies and economic signals favor such reductions. Thus, for example, Table 4.1 shows advanced turbine systems in industry cutting carbon emissions by 17 MtC/year in 2010, co-firing coal with biomass reducing emissions by the same amount, and other low-carbon supply technologies (wind, nuclear plant extensions, hydropower expansion, and power plant efficiency) contributing 24 MtC/year. The actual choice of technology depends on how the economics of the different systems evolve over time, how the industry to supply technology develops, the nature and speed of deregulation within the utility industry, and numerous other factors that cannot be known today. As such, we do not intend the results in Table 1.4 to be taken as a prediction of one technology over another to achieve carbon reductions. In this instance, we have posited one of many possible mixes of supply technologies. These same comments apply to the demand-side sectors and technologies.

We summarize below the expected technology costs in 2010, as well as the cost of implementing a carbon permit system. While these costs are necessarily uncertain, they are our best estimates and, in our view, as likely to be high as to be low. We note, however, that we have focused our analysis on technology costs, and have not assessed the viability of specific policies or programs to achieve market acceptance. As described below, we do account for program and policy costs in an approximate manner.

Table 1.4 Potential Annual Reductions in Carbon Emissions in 2010, Compared to the Business-As-Usual Forecast for 2010 (MtC)

	Efficiency Case	High-Efficiency/Low-Carbon Case	
		$25/tonne	$50/tonne*
Buildings			
Energy efficiency	25	42	59
Fuel cells		2	3
	25	44	62
Industry			
Energy efficiency	22	36	51
Advanced turbine systems		5	17 (15-26)
Biomass and black liquor gasification, cement clinker replacement, and aluminum technologies		5	14 (13-16)
	22	46	82
Transportation			
Energy efficiency	61	74	87
Ethanol	12	14	16
	73	88	103
Utility Supply Options			
Carbon-ordered dispatching		25	55
Converting coal-based power plants to natural gas		9	40 (25-66)
Co-firing coal with biomass		5	17 (16-24)
Wind		2	7 (6-20)
Extending the life of existing nuclear plants		3	5 (4-7)
Hydropower expansions		2	4 (3-5)
Power plant efficiency		2	8 (7-13)
		48	136
Total (rounded)	**120**	**226**	**383**

*Numbers in parenthesis are ranges, as documented in the text of the report. See Appendix A-1 for a description of the derivation of the results in this table.

Appendix A-2 describes the full set of calculations used to derive the direct costs and benefits of the cases. The costs considered include the incremental technology investment by consumers and businesses, fuel price increases, and the estimated cost of federal, state, and local programs required to achieve the carbon emissions reductions. These constitute the direct costs of the scenarios. The highest of these by far is the incremental investment costs. However, the generally higher first cost of these technologies is counterbalanced by substantially lower operating costs. The benefits considered are limited to the savings in operating (energy) costs from the technology investments.

Using these factors as the direct costs and benefits of the scenarios, we have analyzed the economics of carbon emissions reductions from two different perspectives in order to establish a credible range of costs. In the first, which we label "optimistic," we evaluate all costs and benefits with a real discount rate that approximates the cost of capital *for efficiency investments* for the different end-use sectors:

- 7% for buildings
- 10% for transportation
- 12.5% for industry.

The lowest discount rate, for buildings, is based on the fact that the money for residential buildings is derived from home mortgages or home improvement loans. The higher rate for industry reflects the fact that energy-efficiency investments have to compete with investments for other projects. These discount rates are not those that describe current market behavior, but rather are reflective of costs of capital if the market did invest in the energy-efficiency measures. For the "optimistic" case, we assume costs for efficiency measures brought about by utility, federal programs, and state programs (e.g., demand-side management programs by utilities, federal market transformation programs) to be 15% of technology costs. We also assume that at least half of the efficiency occurs as a result of federal policies (e.g., standards or carbon permit charges) which add very low direct program costs. Thus, the overall costs of implementation are taken to be about 7% in the "optimistic" case. The electric supply-side technologies are assumed to add an incremental cost of $30/tonne carbon in 2010, based on an average estimate of the incremental costs of the technologies from the appropriate sections of this report.

These programs and policies are not specified in this study, but the broad nature of the actions could include technology R&D partnerships such as the current Partnership for a Next Generation of Vehicles and Industries of the Future; energy efficiency codes and standards; expanded partnerships, technical assistance, and information programs to accelerate the adoption of energy-efficient technologies; incentives through the tax system directed at investments in energy-efficient technology in industry; and a variety of non-federal programs to accelerate market diffusion of energy-efficient and low-carbon technologies.

The second perspective, which we label "pessimistic," assumes that there are hidden costs associated with achieving widespread market acceptance of many of the efficiency and low-carbon technologies, even after the imposition of a carbon charge and the implementation of major policies and programs to promote a low-carbon future. In this perspective, we evaluate costs and benefits at a real discount rate of 15% for buildings and 20% for transportation and industry. Program costs are increased to 30% of the cost of efficiency measures, an estimate that is a high bound compared with federal, state, and utility experience. Overall implementation costs (programs and directed policies) are taken to be 15% of technology investments in this case. Other data and assumptions in this case are the same as for the "optimistic" case.

The results of the economic analysis are presented in Table 1.5. Estimated direct costs are $26-$49 billion per year for the efficiency scenario and $51 to $88 billion per year for the high-efficiency/low-carbon scenario. Estimated savings per year in 2010 are $42 to $51 billion per year in the efficiency case and $70-$88 billion per year for the high-efficiency/low-carbon case. The costs, which are a small portion of annual gross private domestic investment of about $1.4 trillion in 2020, are likely to be more than balanced by savings in energy bills. Thus, net costs to the U.S. economy are near or below zero in this time frame.

Table 1.5 Estimated Costs and Benefits of the Efficiency and High-Efficiency/Low-Carbon Scenarios : Optimistic and Pessimistic View Estimates (billions of 1995$, annualized)

	Efficiency Case[a]			High-Efficiency/Low-Carbon Case[b]		
	Benefits[c] (billion 1995$)	Costs[d] (billion 1995$)	Carbon[c] Savings MtC	Benefits (billion 1995$)	Costs (billion 1995$)	Carbon Savings MtC
Energy Efficiency						
Buildings	14-17	7-14	20-25	26-33	14-26	49-62
Industry	6-7	3-5	18-22	12-15	8-13	66-82
Transportation	22-27	16-30	58-73	32-40	23-43	82-103
Electricity Dispatch	0	0	0	0	2	44-55
Electricity Repowering	0	0	0	0	2	32-40
Other Low-Carbon Techologies	0	0	0	0	2	33-41
Total	**42-51**	**26-49**	**96-120**	**70-88**	**51-88**	**306-383**

a Energy efficiency category includes ethanol in transportation.

b Benefits and carbon savings in the HE/LC case are relative to BAU case.

c Benefits are calculated as annual energy savings. The scenarios are meant to be point estimates. In the "pessimistic" case, we have assumed that only 80% of the carbon savings are achieved, even though the technology and implementation costs are unchanged. The range on carbon savings represents this assumption.

d Costs are calculated from differing viewpoints: the "optimistic" case uses discount rates that vary between 7% and 12.5% for the different sectors, as described in the text. For the "pessimistic" case, the discount rates used to annualize costs vary between 15% and 20%. Also in this case, the cost of implementing programs (30%) and an overall package of programs and policies (15%) is taken to be twice that of the "optimistic" case.

The range of estimates in Table 1.5 reflects our attempt to "bound" optimistic and pessimistic assessments. There are clearly other ways in which these bounds could be described, just as there are many scenarios that could have been analyzed. However, we believe that the assumption that 80% of the carbon reductions are achieved at the costs identified, valuation of costs and benefits at discount rates noticeably higher than the likely cost of capital, and doubling the cost of programs and policies from typical experience today is a strong reflection of pessimism in costs for our cases. It is worth noting that if the implementation costs were taken to be much higher than we believe to be reasonable – 50% of investments costs for programs and 25% overall – this would add about $10 billion per year to the costs of the high-efficiency/low-carbon in the pessimistic case.

In addition to these costs, one needs to calculate the impact of the cases on natural gas demand. In all of these cases, natural gas replaces very large quantities of coal. Higher natural gas demand would result in higher natural gas prices, which in turn would increase the cost of substituting natural gas for coal in power production, etc. As it turns out, our scenarios have somewhat reduced gas demand compared with the BAU case (or with AEO97 baseline for 2010, on which the price of natural gas in our work is based). Specifically, demand for natural gas in the HE/LC ($50/tonne) case declines in 2010 by 2 quads compared with the business-as-usual case. This is the result of declines of 0.5 quads for buildings, 1.0 quads for industry, and 0.5 quads for electricity. The latter occurs because of the balance among three factors:

- Increase in gas demand because of the large-scale substitution of natural gas for coal
- Decrease of gas demand because of the use of many low-carbon technologies that do not use natural gas (wind, nuclear power plant extensions, power plant efficiency upgrades, hydropower expansion, co-firing with biofuels), and

- The large increase in cogeneration, which reduces demand for natural gas for heating applications.

The sum of the second and third effects are somewhat greater than the first, and thus total natural gas demand associated with electricity generation declines. This will reduce the cost of natural gas, a benefit that we have not included in

The $50/tonne carbon charge, while not constituting a direct cost, does represent a potentially large transfer payment. The magnitude of the transfer payment, as well as the losers and winners from the transfers, depends on the nature of policy and its implementation as a cap and trade system or some alternative. The amount of money that could be in play is very large: $50/tonne times 1.3 billion tonnes per year equals $65 billion per year.

In short, while there will surely be winners and losers for these energy-efficiency and low-carbon scenarios, our analysis shows that their net economic costs – under a range of assumptions and alternative methods of cost analysis – are favorable.

The achievability of the cases depends on many factors. In all cases, carbon reductions require the nation to embark on an aggressive set of policies and programs. Such efforts could occur in response to an international agreement on climate change or to other events that result in a national determination to reduce the growth of carbon emissions. In the high-efficiency/low-carbon cases, we assume a vigorous national program of research, development, demonstration, and diffusion, and a trading regime for carbon with a domestic permit price of either $25/tonne or $50/tonne carbon. Without some scheme that provides strong incentives for switching from coal to natural gas, and for deploying other low-carbon technologies, much of the potential for carbon reductions will not be realized.

Government policies and programs that encourage and/or require the adoption of energy-efficiency and low-carbon technologies will be needed, along with incentives for industry to invest more in these technologies. Additional private and public investments are necessary, not only to accelerate the introduction of new technologies into the market before 2010 but also to ensure the availability of technologies for the period after 2010. The transportation and utility sectors are especially dependent on early technological advances to achieve the scenario results in 2010.

There is no assurance that these and other driving forces will cause the scenarios we have described to take place. Our major conclusion is that cost-effective technology can be deployed to achieve major reductions in carbon emissions by 2010. Cost-effective energy efficiency alone can take the nation 30 to 50% of the way to 1990 levels. Two additional utility sector measures can reduce carbon emissions by another 30% at an estimated cost of $50/tonne carbon: carbon-based dispatch and conversion of existing power plants from coal to natural gas.[4] Finally, we identify several additional technologies that can contribute up to 20% of the several carbon reductions, also for less than $50/tonne. A next generation of advanced energy-efficiency and renewable energy technologies promises to enable the continuation of an aggressive pace of energy and carbon reductions over the next quarter century.

1.6 REFERENCES

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ENDNOTES

[1] The five national laboratories participating in the study were: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). LBNL and ORNL were the co-leaders of the effort.

[2] See Section 2.2.3 for a definition of cost-effective energy efficiency technology.

[3] $50 per tonne of carbon corresponds to 12.5 cents per gallon of gasoline or 0.5 cents per kilowatt-hour for electricity produced from natural gas at 53% efficiency (or 1.3 cents per kilowatt-hour for coal at 34% efficiency). $25 per tonne would cut these gasoline and electricity price increments in half.

[4] The cost curve for repowering is relatively flat; as such, considerable additional reductions are possible at a cost not too different from $50/tonne. The results are highly sensitive to the price differential between coal and natural gas; at a lower (higher) price differential, a higher (lower) permit price of carbon is needed.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Joe Romm
Acting Assistant Secretary for Energy Efficiency and Renewable Energy
U.S. Department of the Energy

FROM: Jason Shogren and Joe Aldy JS JA

DATE: August 22, 1997

RE: Review of 5-Labs Report: *Scenarios of U.S. Carbon Reductions*

Enclosed you will find our comments on the report *Scenarios of U.S. Carbon Reductions*. We appreciate the opportunity to review the report and we trust you will incorporate our comments.

Comments on "Scenarios of U.S. Carbon Reductions" (5 Labs Study)

General comment

The report, *Scenarios of U.S. Carbon Reductions*, presents a useful cataloging of the technological options that could play a key role in reducing greenhouse gas emissions. The report does not present the specific policies or the behavioral responses that will trigger the adoption or diffusion of these technologies. As such, the report cannot serve as the basis of decision-making by top policy-makers (as opposed to background detail that others may find useful). The report as written, however, leaves the impression that these technologies are policy, which they are not. The U.S. government does not have directly under its control the decisions of private firms and consumers whether to adopt these technologies. The report must be either redone to reflect how likely these technologies will be used given the behavioral responses to likely policies, or reframed to reflect what it is--a catalog of technologies that might be used to address global climate change. The latter path is more straightforward and could readily be accomplished. *Among other changes, it is essential that DOE remove references to "net savings" from the report because this does not reflect the actual costs of implementing these policies.*

Our specific comments follow.

Executive Summary

1) paragraph 3: The point regarding the opportunity to reduce emissions through "a vigorous national commitment" should be explicit that this commitment is implemented through federal policies. To state that 120 MMTCE can be reduced by "energy efficiency alone" seems to imply that these reductions are free. These reductions through energy efficiency are induced by aggressive policies, and the statement should reflect that. The subsequent discussion of reductions with carbon permits should also reflect that the level of reductions can occur only through a carbon pricing policy in addition to any non-price policies (e.g., standards).

2) Paragraph 4: Estimates of energy cost savings should not be provided unless and until an adequate estimation approach is used to calculate cost savings.

3) Paragraph 5: This paragraph should really concentrate on the point that this study identifies a vast array of technologies that may reduce carbon emissions through climate policy. This is the true strength of the study, and it should be emphasized more.

Chapter 1

4) The entire study is premised on two sets of undefined policies: an "aggressive" or "invigorated" public sector effort to stimulate energy efficient technology adoption (efficiency case) and a "very aggressive" public sector effort to stimulate technology development and adoption (high efficiency/low carbon case). The only specific policy instrument mentioned in the report is a tradeable permit at prices of $25/ton and $50/ton. The study merely asserts that these unidentified policies would result in: 1) "better technology" (p. 2.5); 2) "higher penetration rates" (p. 2.5); 3) "changing the capital recovery factor [in industry sector] from 33% to 15%" (p. 4.6); and 4) "technological breakthroughs" (p. 5.3). These policy effects would result in reductions of about 200 MMTCE for "free": firms and individuals receive energy cost-savings greater than or equal to technology adoption costs.

The report specifically states that the efficiency case reduces, but does not eliminate, market barriers and that implementation costs are ignored. Policy intervention to eliminate a market barrier cannot make society better off and generally makes society worse off to the extent that it imposes costs. In particular, a set of climate change policies to stimulate technology adoption could increase efficiency, but only because they also decrease the effect of a market failure (carbon emissions). Social welfare is improved because the net benefits of indirectly fixing the market failure exceed the costs of removing the barriers. If carbon emissions are appropriately priced (assuming in this case that $50/ton is the correct carbon price), a policy to remove a barrier will generate negative net benefits. High adoption rates will be realized once prices rise enough for some technologies to clear the barriers.[1]

The economics literature has identified several barriers that help explain the slow rate of technology adoption.[2]

- Qualitative attributes of technologies can affect adoption. Consumers of technology prefer technologies because of a set of characteristics, not just energy efficiency. For example, some consumers may purchase a product with a lower efficiency because the former is more reliable than the efficiency-superior product.

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[1] In contrast, policy intervention to address a market failure (such as unpriced carbon emissions) may well make society better off, depending on the stringency of the intervention.

[2] For a review of these issues, see Gilbert Metcalf and Kevin Hassett, "Measuring the Energy Savings from Home Improvement Investments: Evidence from Monthly Billing Data," National Bureau of Economic Research Working Paper 6074, June 1997; Jeffrey A. Dubin and Daniel L. McFadden, "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption," *Econometrica*, vol. 52, no. 2, 1984; Adam B. Jaffe and Robert N. Stavins, "Energy-Efficiency Investments and Public Policy", *Energy Journal*, vol. 15, no. 2, 1994; Albert L. Nichols, "Demand-Side Management: Overcoming Market Barriers or Obscuring Real Costs?" *Energy Policy,* vol. 22, no. 10, 1994; Jerry Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *Bell Journal of Economics,* vol. 10, 1979.

- New technologies may be costly to integrate with existing ones. Until all components of a complex system are fully depreciated it may make sense to replace energy inefficient components with another like-wise inefficient component.

- Uncertainty of future energy prices, or constraints on the ability to borrow capital may make households act as if they have implausibly high implicit discount rates.

- Just because a technology is cost-effective on average does not mean that it is cost-effective for all individuals. Those who may use the device less intensively may find it optimal to purchase a less efficient model.

These barriers clearly demonstrate that investments to minimize energy costs are different from investments to minimize the total costs of production.

The study provides a crude estimate of the costs to government of lowering market barriers to achieve the estimated emissions reductions. A sense of the likely costs can be derived by evaluating the experience of the Climate Change Action Plan (CCAP). CCAP promotes carbon reductions through a broad array of voluntary programs that stimulate "cost-effective" technology adoption by private firms. Participation by a firm in a CCAP program is supposed to reduce carbon emissions and to offer financial returns.[3] We do not address an important threshold question of why cost-minimizing firms would ever need any need help from government programs to take actions that would lower their costs.

CCAP received appropriations totaling $494 million (1995$) during the FY95 - FY97 period. We assume that these costs are distributed uniformly over the three years. During this period, the Department of Energy and the Environmental Protection Agency can account for reductions of 14 MMTCE (see attached table). Evaluating the cost effectiveness of these programs requires an assumption about emissions reductions in the outyears. Since the programs are persuading firms to adopt innovations that offer financial returns, we believe that the firms would soon have adopted them in the absence of the programs. Thus the emissions reductions might last for several years. To develop illustrative cost estimates we assume between 2 and 7 years of emissions reductions. We describe our estimates given the assumption of 2 years; the method for the assumption of 7 years is identical.[4] Assuming constant effectiveness of program expenditures, the emissions reductions attributable to past expenditures would grow from 2.8 million tons in the first year to 5.6 million in the second year and third years, and then decline to 2.8 million tons in the 4th year, before falling to 0 in the 5th and subsequent years. The ratio of

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[3] Note that CCAP efforts are incorporated in the AEO97 baseline.

[4] This analysis was conducted based on the June 10 draft that stated 180 MMTCE of reductions associated with government programs could be expected under a "very aggressive" set of policies. Since the August 1 draft notes that more non-price policy induced reductions would be expected, the cost estimates provided in this discussion underestimate the program costs associated with this greater number of reductions.

the present value of these costs and of these tons is \$33/ton using a 7 percent discount rate. Thus taking into account the lag between program expenditures and emissions reductions, the average cost effectiveness is \$33/ton (with a 7 year assumption the cost effectiveness is \$13/ton). Assuming constant program effectiveness would imply Federal costs of \$5.9 billion per year (with the 7 year assumption the total cost estimate would be half as much.)

We believe that there are several good reasons to think that the cost of reducing emissions will rise, however, as these or similar programs are expanded. For example, if the potential adopters differed in terms of their cost savings (or willingness to adopt innovations) then the government program would encounter diminishing returns as it tried to reach the less receptive users of technology. Suppose that the (marginal) program cost effectiveness deteriorated by 10 percent every time the annual reductions in emissions grew by as much as the annual reductions implied by the current program. In this instance the marginal cost of achieving 180 million tons of emissions reductions would be about 21 times greater than the marginal cost of the existing program, and far in excess of reasonable values for a ton of carbon emissions averted. In this case the total cost of the program would be \$45 billion per year. Similar assumptions for the 7 year case would lead to total costs of nearly \$7 billion per year, and marginal costs of \$80/ton. Thus we believe that the cost of a government program to ensure energy reductions of 180 million metric tons of carbon could easily run into many tens of billions of dollars per year. In addition, the marginal cost-effectiveness of these programs could substantially exceed reasonable estimates of the value of carbon emissions reductions.

Of course the government might choose to achieve these reductions using command and control type regulations, such as national building codes, or increasingly stringent CAFE standards. These would substitute private sector costs for government administrative costs.

5) 1.1, paragraph 1: Sentence 3 should note that "the improved performance and increased penetration of efficient and low-carbon technologies" are program- and price-induced.

6) 1.1, section 1.1, purpose 1: The statement about a "vigorous national commitment" should be explicit that this means a commitment through government programs.

7) 1.4, Table 1.1: The study notes that it employs EIA's Annual Energy Outlook 1997 projections for the business-as-usual case in 2010 with a modification to the transportation sector. However, the numbers in this chart do not match up with the numbers in the AEO97 reference case. In fact, they are much closer to the AEO97 low economic growth case (for industry and buildings). We assume that the labs study is using the reference case from AEO97 since it uses the reference case carbon emissions for 2010. If this is the case, then the following should be the sectoral breakdown of energy consumption (AEO97, pp. 97-99, and pp. 125-127):

Buildings:	36.81 quads
Residential:	20.83 quads
Commercial:	15.98 quads
Industrial:	39.69 quads
Transportation:	31.39+ quads[5]
Total:	107.89+ quads

If the labs study employs the low economic growth case, then it should state so explicitly in the report and explain why this case, as opposed to the reference or other cases, was selected. Otherwise, the AEO97 numbers should be used.

8) 1.6, Table 1.2: The 2010 BAU carbon emissions for buildings and industry seem not to match the AEO97 reference case emissions for these sectors. AEO97 projects carbon emissions to be 576.1 MMTCE for buildings (residential: 321.4; commercial: 254.7) and industry to be 548.5 MMTCE in 2010. This implies that, with the adjusted transportation emissions, BAU should total 1740 MMTCE, not 1720.

9) 1.8, Table 1.3: The study states that it employs the Annual Energy Outlook business-as-usual (BAU) forecast for the buildings and industry sectors, with modifications that are "not greatly different from the EIA case" (p. 1.2) for the transportation sector.[6] The one modification stated in the study affects the fuel efficiency of the light duty vehicle fleet. While AEO97 assumes that fuel efficiency will increase in the future, the labs study assumes that fuel efficiency will remain constant. This change should result in a slower rate of energy efficiency improvement in the economy under business as usual conditions.

The AEO97 BAU forecast assumes an improvement of energy efficiency of 0.9% per year through 2015 (annual E/GDP = -0.9%) (AEO97, p. 4). The study assumes energy efficiency improvement under BAU occurs at a rate of 0.77%. This difference appears to be somewhat significant. Inferring from the transportation chapter (table 5.1), this report states that energy use would increase 0.9 quads over the AEO97 reference case. CEA contacted Art Andersen at the Energy Information Administration to determine how much of an effect holding fuel efficiency constant would have on the E/GDP ratio.[7] According to Andersen, constant fuel efficiency would "disappear in the rounding" in the E/GDP ratio. He stated that this assumption would

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[5] The 1997 AEO projects transportation energy consumption to be 31.39 quads in 2010. With the labs study assumption regarding constant fuel efficiency, the projected energy consumed in this sector should increase. Although the text never explicitly states the extent of this increase, we inferred that it is 0.9 quads. However, since Andersen informed us that the increase would be 0.6 quads, we assessed both in a subsequent comment.

[6] The labs study also modified the electricity sector forecast, but that modification is not relevant to our discussion of the energy efficiency of the economy.

[7] Art Andersen is the Director of the Energy Demand and Integration Division, EIA.

result in energy use increasing by 0.6 quads in 2010 over the reference case. CEA recalculated the E/GDP ratio used in the AEO97 BAU to account for this extra energy use (assuming GDP remains the same across these cases), and found that annual E/GDP would decrease 0.86% under the constant fuel efficiency assumption (0.6 quads case). With the inference from the transportation chapter, the annual E/GDP rate would be -0.85% (0.9 quads case). The labs study BAU assumes fewer energy efficiency improvements than should be expected under these adjusted BAU scenarios.

Two related implications arise from this. First, since the study employs a modified version of the AEO97 energy use forecast, it should modify the AEO97 carbon emissions forecast. With a slower improvement in energy efficiency under the lab study assumptions, the 2010 BAU carbon emissions should be greater than the 1722.4 MMTCE in AEO97 (AEO97, p. 120). As we note in the previous comment, by incorporating the AEO97 reference case carbon emissions for buildings and industry, the BAU should be about 1740 MMTCE. This obviously implies that more reductions will be necessary to stabilize emissions at the 1990 level in 2010.

Second, the carbon reductions calculated for the various scenarios in this study are based on this -0.77% E/GDP BAU. This implies that some of the carbon reductions claimed under the efficiency and high efficiency cases actually occur in the -0.86% BAU. This double-counting could be significant. The CEA-generated BAU (0.6 quads case) accounts for 17% of the E/GDP gains assumed in the efficiency case (see attached chart).[8] The alternative CEA-generated BAU (0.9 quads case) accounts for 15% of the E/GDP gains assumed in the efficiency case. Assuming that E/GDP and carbon reductions are perfectly correlated (given that the efficiency case involves no fuel switching, this is reasonable), then the efficiency case overestimates emissions reductions by 18 to 20 MMTCE.

The text should explain why the lab study E/GDP ratio differs from the AEO97 ratio since it does not seem to result exclusively from keeping fuel efficiency constant. Further, the 2010 BAU emissions reductions should reflect the E/GDP ratio (whether it is -0.77%, -0.85%, -0.86%, or some other rate) used in the study.

10) 1.11, Table 1.4: It would be valuable to understand the effect of non-price policies and permit prices on the carbon reductions. Could you break down the high efficiency cases into two categories: non-price policy induced and permit induced technology adoption?

11) 1.12, paragraph 1: The discussion on government programs costing 15% of investment costs should include references to the literature that have estimated this percentage. Does the literature describe the marginal costs for government programs, or does it just provide this average cost value? Consistent with the literature on technology adoption, the marginal costs should not be

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[8] The AEO97 BAU would capture 25% of the efficiency gains in the efficiency scenario.

assumed to be the same for all units of adoption. In fact, it is likely that the marginal costs increase for higher rates of adoption.

12) 1.12, paragraph 1: The text in this paragraph notes that government costs in the best estimate case are 15% of total investment costs, while figure A-1.1 on p. A-1.2 indicates that the costs are 7% of investment costs for the end-use sectors and 1% for the electricity sector. Which costs are correct?

13) 1.12, paragraph 1: The text notes that "one could argue that... a social discount rate" of 3% or 7% should be used. Alternatively, one could argue that since these analyses assess private decisions on technology adoption, that private marginal rates of time preference should be used that reflect "current market behavior". This analysis is not attempting to conduct a social benefit-cost analysis. Rather, it is attempting to model the private individual or firm's benefits and costs associated with a technology adoption decision. Since this report projects technology adoption assuming a set of aggressive policies, the rates of time preference actually used by individuals and firms should be used in assessing the extent of adoption.

Further, the report should not rely on government fiat to lower discount rates. It is very difficult to lower people's time preferences through policy. Government programs do not increase adoption rates by lowering time preferences, but by lowering the costs of adoption or increasing the benefits of adoption. For example, government programs cost-share the adoption of environmentally-benign agricultural production techniques through the Environmental Quality Incentives Program. Farmers still employ the same discount rate, but their stream of costs are lower because of the government subsidy, and so adoption increases. The report should not assume that government policies can lower private time preference rates, but rather that government policies can affect the stream of costs and benefits of an adoption decision.

14) 1.12, paragraph 5: Again, until the complete costs of investment and accurate cost-savings can be estimated, the text on net benefits should be deleted.

15) 1.13, Table 1.5: The estimates of carbon reductions under the alternative view do not appear to match with the carbon reductions in table A-1.2 on p. A-1.5. It seems implausible that discount rates could double and have no effects on any technology adoption decision in this report. Are the numbers in the appendix the right set? Is it true that every single energy efficient technology adoption decision is cost-effective under the "best estimate" discount rate and the "alternative view" discount rate? If these technologies are such big winners, then why aren't people and firms already adopting them?

16) 1.14: Unless and until the costs and cost-savings issues are adequately addressed, estimates of net savings should be omitted.

17) 1.15, paragraph 3: As stated in the executive summary comments, the text should not state "energy efficiency alone can take the nation 30 to 50% of the way to 1990 levels." If energy

efficiency could achieve these reductions "alone", there would be no need for an invigorated federal policy effort. It should be explicitly stated that policy instruments to achieve this goal are omitted from the analysis.

Chapter 2

18) 2.6, transportation sector bullet: The text states that the transportation sector analysis uses a 5 year time horizon. However, the description of the best estimate and alternative view cost effectiveness calculations on p. A-1.10 indicate that a time horizon of 14 years was used. Further, the transportation chapter indicates that the cost effectiveness analyses were conducted using a 6% discount rate in combination with a decline in usage and depreciation to calculate fuel savings (p. 5.45). The footnote to table 5.9 implies that the analyses used a 14 year time horizon as well. The report should clarify these inconsistencies.

Chapters 3-7

19) There does not appear to be any discussion of the $25/ton permit scenario in these chapters. Further, the appendices do not explicitly detail this case. The results from this scenario need to be documented in the text and in the appendices. For example, it is impossible to identify the penetration rate for this scenario in the buildings chapter (see p. 3.3). The industry chapter discusses three scenarios: BAU, efficiency, and high efficiency (p. 4.2). The descriptions of the high efficiency case in transportation on p. 5.3 and p. 5.31 do not even mention a permit price. The electricity sector appears to only consider a $50/ton permit (p. 6.9).

20) The results from the alternative view cost analysis should be incorporated in these chapters.

Chapter 3

21) 3.3: In the context of fully incorporating the effects of climate policy on energy prices, the analyses on buildings technologies should be modified. Under the efficiency case, energy consumption declines. This scenario should be changed to reflect the downward effect on prices resulting from this decreased energy consumption. The result would be to reduce the net improvement in energy use resulting from technological advances. The high efficiency scenario should reflect two counteracting effects on prices: the decline in energy consumption and the $50/ton permit fee. The study ignores the former effect and insufficiently incorporates the latter effect. For example, in the buildings chapter, the penetration rate is assumed to be 65% instead of 60% of the maximum cost-effective technical potential in this scenario because of the $50/ton permit price. However, the energy-cost savings calculations for buildings technologies assume the same energy price as in the business as usual scenario. Since the study assumes that exogenous, undefined policy influences drive the penetration rates, the penetration rate should be set at 60% and the energy cost-savings should be recalculated with the appropriate energy price. In addition, the assumed energy use for these technologies should be based on consumers' responses to the lower operating costs. For example, if running an air conditioner becomes less

expensive with a new energy efficient technology, people will run the air conditioner more. This latter effect decreases the carbon reductions associated with each adoption decision.

22) 3.9 and Appendix C-1: The study uses the average cost of electricity to calculate the energy cost savings of these technologies. Many of the electricity-dependent technologies are only cost effective based on the assumption of average, not marginal electricity prices. Since marginal prices may be much lower than average prices, especially in cases where households use less electricity, this may overestimate the extent of cost effective technologies. The analysis should be modified using marginal electricity prices.

23) 3.23, box: The text in the box is not clear on the inclusion of fuel cell technology in the high efficiency scenarios. The first paragraph states that fuel cells were not included in the main building sector scenarios. However, emissions reductions of 3 MMTCE from fuel cells are listed under buildings in Table 1.4 on p. 1.11. Further, the discussion on fuel cells in the text outside of this box implies that fuel cell technology will not be available until 2020 (since it falls in the section "Potential for Advanced Technologies in 2020"). If the study relies on ADL's analysis of fuel cell adoption, then the assumptions of ADL's assessment should be provided in an appendix. Two issues should be addressed here. First, if fuel cells are projected to be adopted under the high efficiency scenarios, then this discussion should be placed in the appropriate section of this chapter (not the 2020 section), and the inconsistencies in the text should be remedied. Second, if fuel cells are adopted, then a discussion of the carbon emissions accounting should be provided to ensure that the study does not double count emissions reductions from energy efficient technology adoption and from switching energy sources to fuel cells.

24) 3.29, summary bullet two: This states that the high efficiency scenario yields 91 MMTCE of carbon reductions from the BAU emissions level. However, Table 1.4 indicates that only 44 MMTCE of reductions occur under the $25/ton permit price and only 62 MMTCE of reductions occur under the $50/ton permit price. Which carbon reduction estimate is correct?

Chapter 4

25) 4.6, paragraph 4: The analysis assumes that the capital recovery factor falls by more than half. This appears to be an arbitrary reduction. Did industry behave as if it operated under a lower CRF during the 1970s oil shocks? There is no discussion of the economic behavior necessary to result in this outcome.

26) 4.6, paragraph 4: The high efficiency penetration rate is assumed to be double the rate used in the efficiency scenario, which is the undefined "normal" rate. It is impossible to determine how much of this doubling of penetration results from undefined, aggressive policy efforts and how much results from the permit price. It would be valuable to understand the relative impacts of both.

27) 4.13, paragraph 4: The text states that the high efficiency case causes an acceleration of capital retirement, but does not estimate these costs. Could you estimate the costs of early retirement? If not, can you provide some information on the extent of early retirement (e.g., percentage of capital retired early under this scenario)?

Chapter 5

28) Does this sectoral analysis consider the impact of a permit price? Neither the $25/ton permit nor the $50/ton permit are mentioned in the entire chapter. Do all improvements in fuel efficiency and cellulosic ethanol result from non-price policy responses? As the report states, a degree of "luck" is required to achieve the necessary technological breakthroughs to result in the projected carbon reductions. However, without a price incentive, the probability of the nation becoming "lucky" appears more unlikely. If this analysis does not incorporate the permit prices, then this should be made explicit in the discussion of the high efficiency case.

29) The methodology for this sector is insufficiently transparent to grasp easily the impact of technology development and adoption on carbon reductions. Further, the appendices for transportation do not provide the details to remedy the shortcomings in the chapter. It is difficult to compute carbon reductions from increases in fuel efficiency. The text should take the reader through the process of piecing together all of these energy efficient technologies, illustrating the final effect on fuel economy, and then translating this into carbon reductions.

30) 5.4, Table 5.1: Why do the energy consumption numbers for this sector in 1997 vary across scenarios? We understand that the start year for the scenario analyses is 1998 (e.g., refer to Table 4.8 on p. 4.12 that implies 1998 as the start year for assessing cumulative incremental investment).

31) 5.21, paragraph 2: Does the assumption about reducing technology costs reflect any empirical analysis on transportation technologies? For example, the 1970s oil shocks and fuel efficient imports spurred domestic fuel efficiency R&D. Does this analysis incorporate information about accelerating technology development and lowering technology costs that may be available from this earlier period?

32) 5.23, paragraph 3: As we have noted before, it is difficult to modify consumers' preferences. Assuming that the demand for horsepower will decrease because consumers will become "more green" over the next decade appears tenuous. This statement is repeated on p. 5.32. Is there any evidence that concern about global warming has affected consumers' purchase decisions to date?

33) 5.25, paragraph 1: If the turbocompound diesel engine and the advanced LE-55 heat engine are not available in the reference case (which implies that the earliest these are available is 2016), then how are they made available by 2003? Is there any precedent for accelerating transportation technology from a time horizon of at least 18 years to a horizon of only 5 years? How do these

engines conform to present emissions standards for particulates and NO_x and how will future standards under the new ozone and particulate matter rules affect them?

34) 5.25, paragraph 1: The efficiency case assumes that advanced drag reduction in heavy trucks has become available this year, but this is excluded from the reference case. First, has this actually occurred? Second, if it has already occurred, then why is it excluded from BAU?

35) 5.25, paragraph 4: Again, the assumption of reducing a technology price appears arbitrary. What is the basis for assuming that the trigger price for heavy truck technologies will fall?

36) 5.25, paragraph 5: The efficiency analysis assumes penetration rates of 100% for several of the heavy truck technologies over a 20 year period. This seems incongruous with the assumptions in the other sector analyses that imply much lower penetration rates. 100% penetration of a technology within 20 years, that is not expected to be available 18 years from now in the BAU, appears to be an extreme and unsubstantiated assumption.

37) 5.32, paragraph 1: The analysis assumes that fuel cells, because their costs are unknown, will be cost effective. This is an entirely arbitrary assumption, especially for a technology that is not even projected to become available in the BAU scenario. There is absolutely no economic basis for this assumption. This assumption is all the more extraordinary given that this analysis does not (apparently) incorporate the impacts of a carbon permit on fuel prices.

38) 5.36, Table 5.7: If the scenarios overestimate fuel economy, as stated in the footnote, then the numbers should be revised to remedy this error.

39) 5.38, paragraph 2: The modification of assumed improvement of fuel efficiency by multiplying the expected improvement by 0.7 to reflect offsetting performance effects, appears arbitrary. Why wouldn't the fraction be much smaller? The introduction to this chapter indicates that almost all improvements in fuel efficiency are offset by performance effects. Why would only 30% of fuel efficiency improvements in the future be offset?

40) 5.45: The chapter is not explicit about its accounting of fuel efficiency improvements in light duty vehicles and the change in the fuel mix reflecting an increase in cellulosic ethanol and the use of fuel cell technology. We cannot determine if carbon reductions are double counted. The study does not discuss how cellulosic ethanol and fuel cells are accounted for in the energy cost savings description on pp. 5.43-5.45. If the reductions from fuel efficiency and the reductions from cellulosic ethanol and fuel cells do not overlap, then this should be stated explicitly. Again, a more transparent presentation of the methodology would address the readers' uncertainty about this issue.

41) 5.45, Table 5.9: The cost effectiveness estimates assume a constant price of $1.20 per gallon through the life of the vehicles. The gasoline price should be adjusted down to reflect the impact of decreased gasoline consumption due to fuel efficiency. Further, vehicle miles traveled should

increase through time as cars become more fuel efficient, consistent with the trend to date, instead of held constant.

Chapter 7

42) 7.1, paragraph 2: If the report has eliminated the double counting in this sector evident in the June 10 draft, then the sentence that states that double counting is "a likely possibility" should be deleted. A reference to appendix G-2 should be inserted.

43) 7.2, paragraph 3: Again, if the double counting has been remedied by integrating the dispatching and repowering analyses, then the following sentence should be modified: "The analytical approach was static in that the cost of repowering was computed for each candidate power plant but the analysis did not optimize unit/plant production cost, dispatch, or system load."

44) 7.6, paragraph 5: The reference to appendix G-2 appears to be wrong. This reference implies that appendix G-2 provides a methodology for SO_2 and NO_X benefits. Nothing in the text of chapter 7 reads as if the double counting issue from the June 10 draft has been resolved.

Appendices

45) A-1.9: The alternative view cost-effective estimates for buildings assumes an 18 year time horizon. However, the methodology discussion on p. 2.5 states that a "technology is defined as 'cost-effective' if it delivers a good or service at equal or lower life-cycle costs relative to the current practice". If cost-effectiveness is measured in terms of a technology's life cycle, then shouldn't the time horizon for calculating the stream of benefits be constrained by the life of the product? It is not possible for a technology to generate cost savings beyond its lifetime. In the buildings case, the end uses with the largest potential carbon reductions in the high efficiency case are other uses (10 MMTCE commercial, 6 MMTCE residential) and lighting (7 MMTCE commercial, 6 MMTCE residential). These account for 29 of the 62 MMTCE of reductions for this sector. However, the lifetimes for these end uses are much shorter than 18 years. For other uses, the lifetime ranges from 7 (commercial) to 10 years (residential). For lighting, the lifetime ranges from 1 (residential) to 12 years (commercial). The cost effectiveness estimates should be recalculated using specific end use lifetimes.

Summary of Greenhouse Gas Emissions-Reduction Actions

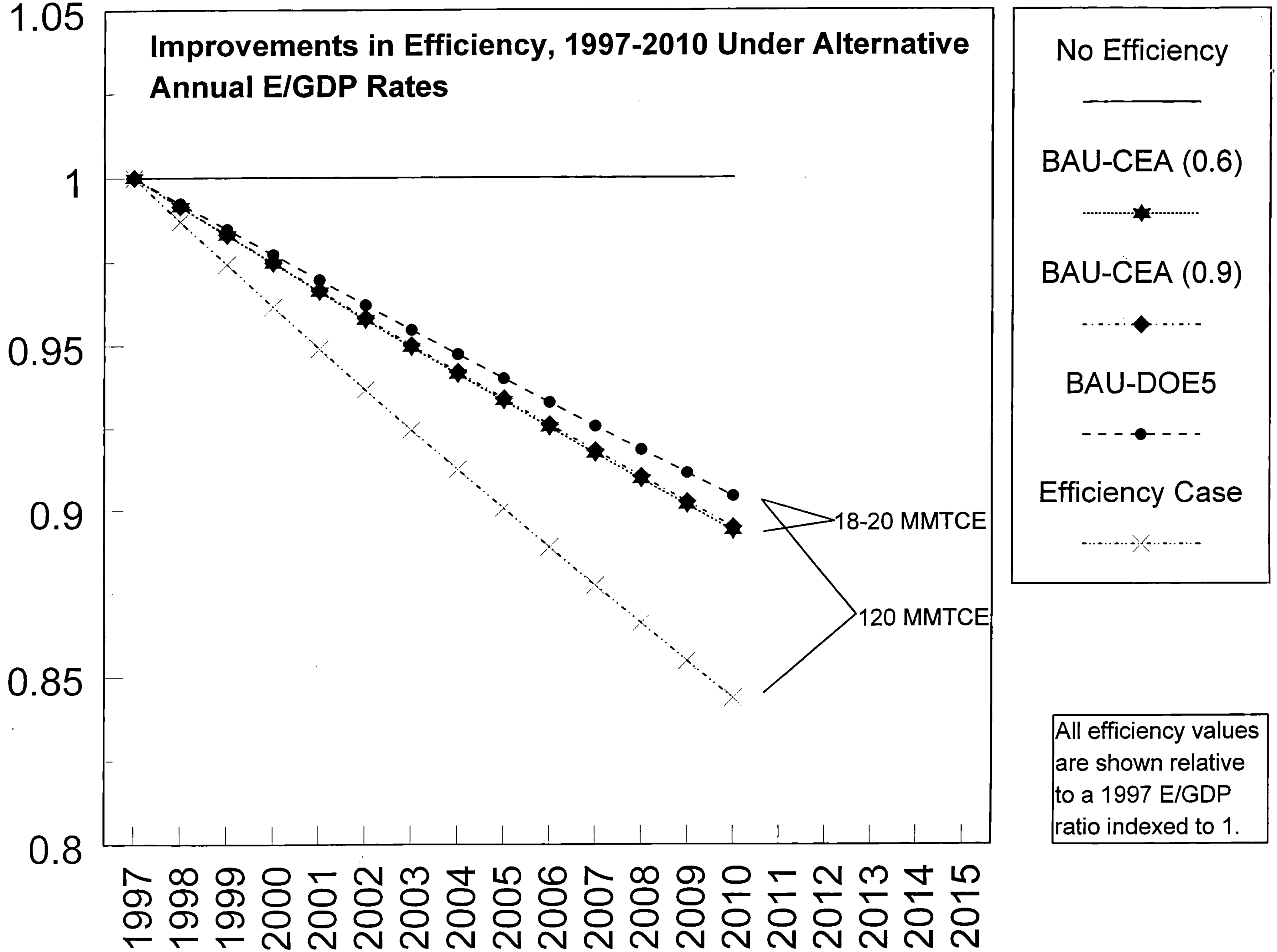
Million Metric Tons of Carbon Equivalent

Source: U.S. Climate Action Report—1997

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
Residential & Commercial Sector Actions		26.9	10.3	--
New	Rebuild America	2.0	1.6	--
1 and 2	Expanded Green Lights and Energy Star Buildings	3.6	3.3	--
3	State Revolving Fund for Public Buildings	1.1	Terminated	
4 5	Cost-Shared Demonstrations of Emerging Technologies Operation and Maintenance Training for Commercial Building Facility Managers and Operators	3.8	0.0	--
6	Energy Star Products	5.0	4.3	--
7	Residential Appliance Standards	6.8	0.2	--
8 and 11 9 10	Energy Partnerships for Affordable Housing Cool Communities Update State Building Codes	4.4	0.4	--
New	Construction of Energy-Efficient Commercial and Industrial Buildings		0.1	--
New	Superwindow Collaborative		0.0	--
New	Expand Markets for Next-Generation Lighting Products		0.2	--
New	Fuel Cells Initiative		0.0	--
Industrial Sector Actions		19.0	4.8	--
12	Motor Challenge	8.8	1.8	--
13 14	Industrial Golden Carrot Programs Accelerate the Adoption of Energy-Efficient Process Technologies	2.9	Merged into Action 12 Terminated	
15	Industrial Assessment Centers	0.5	CCAP Component Terminated	
16	Waste Minimization	4.2	2.1	--
17 18	Improve Efficiency of Fertilizer Nitrogen Use Reduce the Use of Pesticides	2.7	0.8 Terminated	--
Transportation Sector Actions		8.1	5.3	--
19 20 21	Cash Value of Parking Innovative Transportation Strategies Telecommuting Program	6.6	4.6	--
22	Fuel Economy Labels for Tires	1.5	0.7	--
Energy Supply Actions		10.8	1.3	--
23	Increase Natural Gas Share of Energy Use Though Federal Regulatory Reform	2.2	Terminated	

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
24	Promote Seasonal Gas Use for Control of Nitrogen Oxides	2.8	0.5	--
25	High-Efficiency Gas Technologies	0.6	Terminated	
26	Renewable-Energy Commercialization	0.8	0.3	--
27	Expand Utility Integrated Resource Planning	1.4	Terminated	
28	Profitable Hydroelectric Efficiency Upgrades	2.0	0.0	--
29 30	Energy-Efficient Distribution Transformer Standards Energy Star Distribution Transformers	0.8	0.5	--
31	Transmission Pricing Reform	0.8	Terminated	
New	Green Power Network	Not included	0.0	--
Land-Use Change & Forestry Actions		**10.0**	**2.4**	--
43	Private Depletion of Nonindustrial Private Forests	4.0	Terminated	
44	Accelerate Tree Planting in Nonindustrial Private Forests	0.5	0.4	--
16	Waste Minimization	4.2	2.0	--
9	Expand Cool Communities	0.5	To be determined	
Methane Actions		**16.3**	**15.5**	--
32	Expand Natural Gas STAR	3.0	3.4	--
33	Increase Stringency of Landfill Rule	4.2	6.3	--
34	Landfill Methane Outreach Program	1.1	1.9	--
35	Coalbed Methane Outreach Program	2.2	2.6	--
36	RD&D for Coal Mine Methane	1.5	Terminated	
37	RD&D for Landfill Methane	1.0	Terminated	
38	AgSTAR Program	1.5	0.3	--
39	Ruminant Livestock Efficiency Program	1.8	1.0	--
Actions to Address Other Greenhouse Gases		16.3	**25.4**	--
17	Improved Fertilizer Management	4.5	5.3	--
40	Significant New Alternatives Program	5.0	6.4	--
41	HFC-23 Partnerships	5.0	5.0	--
42	Voluntary Aluminum Partnership	1.8	2.2	--
New	Environmental Stewardship Initiative	Not included	6.5	--
Foundation Actions			**11.3**	--
	Climate Wise	Not estimated	1.8	--
	Climate Challenge	Not estimated	7.6	--
	State and Local Outreach Programs	Not estimated	1.9	--
Total GHG Emission Reductions From CCAP		108.6	76.0	14.0

Data is not readily available for cumulative emissions reductions for many CCAP programs. Emissions reductions of about 5 MMTCE can be attributed to DOE's CCAP programs. EPA's Office of Air and Radiation is responsible for emissions reductions of about 9 MMTCE through their CCAP programs.


Improvements in Efficiency, 1997-2010 Under Alternative Annual E/GDP Rates
1.05
1
0.95
0.9
0.85
0.8
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
18-20 MMTCE
120 MMTCE
No Efficiency
BAU-CEA (0.6)
BAU-CEA (0.9)
BAU-DOE5
Efficiency Case
All efficiency values are shown relative to a 1997 E/GDP ratio indexed to 1.

DEPARTMENT OF THE TREASURY
WASHINGTON, D.C. 20220
August 21, 1997

MEMORANDUM FOR T. J. GLAUTHIER
JOE ROMM

FROM: Robert Gillingham
Jonathan Gruber

SUBJECT: Comments on the "5-labs" Study

The 5-labs study does a very nice job of cataloging the current state and likely future path of technological developments. What it does not do, however, is shed much light on what government can or should do to enhance the role technology will play in mitigating the growth of carbon emissions. In particular, the contribution of the report is to document energy savings and emissions reductions that would accrue if U.S. consumers and businesses move closer to the current (and, in some cases, reasonably anticipated) technology frontier. Despite its efforts to justify these moves as "cost-effective," the report does not address the policies that would be needed to actually get consumers and businesses to adopt the technologies described in the report, nor does it present a rigorous assessment the societal costs that would accrue if they did. We believe that the results of the report should be presented as an accounting of what can, and might, be done, but not as a description of what should be done or how to do it. For instance, the analysis of refrigerators is best interpreted as a description of the energy and emissions that would be saved if 35 or 65 percent bought particular, energy-efficient models, rather than a policy goal or prescription. It is premature, furthermore, to argue that other choices would be against the best interests of the consumers actually making purchase decisions. The accounting of energy and emissions in the study is much more rigorous than the accounting of costs and welfare.

We appreciated the opportunity to read and comment on the report. We have attached more detailed comments that we hope you find useful.

COMMENTS ON *SCENARIOS OF* U.S. CARBON REDUCTIONS

Scenarios of U.S. Carbon Reductions, commonly known as the "5-labs study," examines the "potential for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States." This study does a very nice job of cataloging the current state and likely future path of technological developments. What it does not do, however, is shed much light on what role technology is likely to play in mitigating the growth of carbon emissions, or on what government can or should do to enhance this role.

As a tool for developing and implementing a technology policy, the report is hampered by the fact that it does not address any of the processes that determine the rate at which technology is developed and implemented. Rather, it catalogs technologies that currently exist, are likely to exist or could possibly exist by 2010, determines whether they are "cost-effective," and then makes somewhat arbitrary assumptions about the rate at which they are implemented. Although the analysis is couched in terms of the adoption of cost-effective technologies, cost-effectiveness is not rigorously defined; no evidence is presented on whether decision-makers are or are not acting in their best interest. It is important to recognize that the paper *does not demonstrate an irrational unwillingness to invest in energy efficiency*. The paper suggests that the adoption of standards and codes is necessary to ensure appropriate consumer behavior; again, *no such demonstration is made*. In other words, the study does not and cannot present evidence on the costs to either society or individual consumers and businesses of alternative technology paths.

The study reaches three overarching conclusions:

- A vigorous national commitment to develop and deploy cost-effective energy-efficient and low-carbon technologies has the potential to substantially reduce energy consumption and carbon emissions.
  - We would not argue with this conclusion. Rather we question (1) the level of government involvement—government R&D, tax incentives, efficiency standards, etc.—that would be necessary in the absence of energy-price increases and (2) whether the substantial increases in relative energy prices that would likely accompany constraints on carbon emissions would not be the most important component of any national commitment to reduce emissions.
- Carbon emissions can be reduced in ways that reduce energy costs more than they increase other societal costs.
  - We question this assertion. The study makes only rudimentary cost-benefit calculations that ignore important considerations that reasonably effect decisions to invest in energy efficiency. It also substantially understates the costs of government policies to promote technology.
- The next generation of energy-efficient and low-carbon technologies promises to

enable the continuation of an aggressive pace of cost-effective carbon reductions over the next quarter century.

- Again, absent a careful cost-benefit analysis, this conclusion is overly speculative. For instance, with respect to the transportation sector, the report concedes that future technological breakthroughs will be necessary to develop and implement the high-efficiency, low-carbon technologies. It is a stretch to *assume* that these breakthroughs will be forthcoming and that they will pass rigorous cost-benefit tests, especially in the absence of strong price signals.

The methodology used in the report is to analyze sequentially the three major end-users of energy—the residential and commercial building, industry and transportation sectors—and separately analyze the electric utility sector. For each sector, the study develops three scenarios—business-as-usual, efficiency, and high-efficiency/low carbon. They are conceptually defined as follows:

- *Business-as-usual (BAU).* Best estimate of future energy use given current trends in service demand, stock turnover and natural progress in the efficiency of new equipment. Assumes no change in federal policies.[1]
- *Efficiency (EFF).* Likely market penetration of "cost-effective," energy-efficient technologies given "an invigorated effort to promote energy efficiency through enhanced public and private-sector R&D and market transformation activities."
- *High-efficiency/low-carbon (HE/LC).* Optimistic but feasible market penetration for energy efficient and low-carbon technologies given a "greater commitment to reduce carbon emissions resulting from actions that might include the creation of a market value for carbon of $25 and $50 per tonne."

With the exception of the range of carbon emission charges, which seems out of place and is largely ignored in the study, these conceptual definitions are very vague. The operational definitions vary by sector and will be discussed in turn below.

BUILDINGS

For buildings, the business-as-usual scenario is the Annual Energy Outlook (AEO) reference case. The efficiency scenario assumes that 35 percent of the "cost-effective energy savings potential" relative to the BAU is achieved. The high-efficiency/low-carbon scenario assumes that 65 percent of these savings are achieved. We have a number of problems with this analysis.

The cost-effective energy saving potential is badly defined. The study makes two critical assumptions in defining cost effectiveness. First, the analysis takes as given

[1] The report provides relatively little analysis of past trends and their determinants. The past has certainly informed our view of the future, and a more detailed analysis of the price and quantity paths, both past and in the BAU scenario, would be very useful.

that engineering estimates of energy use for alternative technologies are known with certainty and independent of the age of the capital good in which the technology is embodied. There is evidence that adopting these estimates is likely to overestimate savings (*e.g.*, attic insulation may not be perfectly installed; consumers may increase usage rates for energy-efficient appliances or consumers may add more windows when their energy costs are reduced).[2] Second, the analysis ignores the trends and uncertainty around these trends in the future prices of both capital goods and energy as well as the potential irreversibility of investment decisions (proper treatment of these issues goes a long way toward explaining high measured internal rates of return, which are often confused with high discount rates).[3] As a result of these two assumptions, the study almost certainly exaggerates the "cost-effectiveness" of investments in energy efficiency.

The assumed take-up rates of 35 percent and 65 percent are arbitrary. The study makes no attempt to model behavior; rather it makes arbitrary assumptions about the rate at which energy-saving investments are made. With no idea what determines the rate at which new technologies are adopted, we have no basis for informed policy-making. The HE/LC case includes substantial price increases in energy, yet the study simply raises the take-up rate for technologies deemed cost-effective *under a different—and much lower—scenario of energy prices.* The assumed take-up rate under the EFF case is bad enough, but the failure to explain how a carbon price would change the decision-making calculus in the HE/LC case is even worse.

A number of the examples are based on 1997 technologies. For instance, the refrigerator example assumes adoption of an energy-efficient 1995 model. This ignores the fact that refrigerator efficiency has been improving at a rapid rate for over 20 years (6.2 percent per year from 1972 to 1991). What does the AEO assume for the 1995 to 2010 period? Is it reasonable to assume that the type of saving assumed in the EFF case should be incorporated in the BAU case? Or is the BAU unnecessarily pessimistic?

The bulk of the savings in buildings are largely unexplained, coming from "miscellaneous electricity uses." The study admits that because of the importance of these uses, "it is crucial that more research be carried out, both to characterize how energy in used in the miscellaneous category and to identify technologies for improving the efficiency of sub-categories." With no clear understanding of these fundamental aspects of electricity use, how can we be confident to assume that this

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[2] See, *e.g.*, Gilbert Metcalf and Kevin Hassett, "Measuring the Energy Savings from Home Improvement Investments: Evidence from Monthly Billing Data," National Bureau of Economic Research Working Paper 6074, June 1997.

[3] See Robert Pindyck, "Irreversibility, Uncertainty, and Investment," *Journal of Economic Literature* 29, 1991, for a review of some of these issues. Also, see Gilbert Metcalf and Donald Rosenthal, "The 'New' View of Investment Decisions and Public Policy Analysis: An Application to Green Lights and Refrigerators," *Journal of Policy Analysis and Management*, Vol. 14, No. 4, 1995, for an application.

category accounts for most of the presumed savings?

INDUSTRY

For the industrial sector, the study relies on the Long-Term Industrial Energy Forecasting (LIEF) model, an econometric forecasting model, to explain investment in conservation technology; it uses the industrial module of the National Energy Modeling System (NEMS), which does not model investment, to assess the effect of that investment on energy use. The business-as-usual scenario is the Annual Energy Outlook (AEO) reference case. The efficiency scenario assumes that the "capital recovery factor" (CRF) for energy-efficient investment in the LIEF is reduced from 33 percent to 15 percent.[4] The high-efficiency/low-carbon scenario assumes, in addition, that the penetration rates for energy-efficient technology are doubled relative to the BAU scenario. This analysis suffers from problems similar to those in the analysis of the buildings sector.

The study models investment in the EFF and HE/LC scenarios by arbitrarily assuming that the return criterion for energy-efficient investment is reduced by more than 50 percent. No rationale is provided for this approach, nor are any policies posited that would lead to this result. Rather, it is simply a device to increase investment. As noted above, arbitrary assumptions about hurdle rates beg critical questions about the effect of uncertainty, changing relative prices and irreversibility on investment behavior. The approach used provides no insights into investment behavior; it implicitly *assumes* that behavior.

The HE/LC scenario depends on an arbitrary assumption about penetration rates and ignores price effects. The LIEF model "provides a mechanism for evaluating general investment in conservation technology as a function of energy prices, capital recovery rates, and other prices." Yet in evaluating the HE/LC scenario, the study ignores the postulated $25 and $50 carbon prices that are part of this scenario. Instead it *assumes* a doubling of penetration rates for new technology and retirement rates for old capital. The study makes no attempt to demonstrate that an increase in penetration/retirement rates is economically motivated.

Although no policies are modeled or advocated, the study lists a number of potentially costly and/or intrusive policies that could promote energy efficiency. These include accelerated depreciation, rebates or tax credits, regulation and efficiency standards, pricing and fiscal policies, and "other economic incentive programs."

TRANSPORTATION

For the transportation sector, the business-as-usual scenario is the Annual

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[4] A $50 carbon fee would certainly increase investment in energy efficiency, as does the drop in the CRF. The latter approach is not the right way to model expected relative price increases, however. Again, uncertainty and irreversibility should be explicitly modeled, making it clear that a high *apparent* hurdle rate is not the same as a high discount rate.

Energy Outlook (AEO) reference case, adjusted to reduce the assumed improvement in light-duty vehicle fuel economy. The efficiency scenario assumes earlier introduction of advanced fuel economy technology and adds certain key technologies that are not in the BAU. The high-efficiency/low-carbon scenario postulates future "breakthroughs" in technology. As with the other sectors, this analysis provides few insights for technology policy.

The efficiency scenario assumes accelerated adoption of existing technologies, but provides no reason why this might occur. Unlike the analysis of the other sectors, the analysis of the transportation sector does not even include any economic assumptions that might imply its conclusions. As a result, it promises no medium or longer-term gains.

The HE/LC scenario is even more ephemeral; it requires technological breakthroughs, primarily in fuel-cell technology. As the report notes, the EFF and HE/LC scenarios "differ from each other less in effort than in outcome. . . . In contrast, because the outcomes postulated in the high-efficiency/low-carbon scenario require technological breakthroughs, they require a certain degree of luck to be achieved by 2010." In other words, we do not need to try any harder to achieve the HE/LC scenario; we just have to be lucky.

The analysis raises the AEO energy baseline, but not the emissions baseline. Since it raises the AEO energy baseline, the study should also adjust the emissions baseline. As a result, the savings postulated relative to the AEO baseline would be reduced.

ELECTRICITY

The analysis of the electricity sector describes how the electricity demands inherent in the BAU, EFF and HE/LC scenarios can be met with lower carbon emissions. The BAU scenario is a fully competitive bulk-power market in the year 2010. The demands on this system are then adjusted to reflect the effects on electricity demand and supply of the EFF and HE/LC scenarios. These results are used in the sector analyses to evaluate carbon savings attributable to reductions in electricity consumption. They are also used to evaluate the opportunities for reducing carbon emissions in electricity generation in response to $25 and $50 carbon prices.

The EFF and HE/LC scenarios predict substantial reductions in electricity demand from baseline. The two scenarios predict reductions of 9 and 16 percent, respectively, in end-use electricity demand relative to BAU. In fact, they assume essentially *zero* growth in electricity demand between 1997 and 2010. To put this into perspective, electricity sales increased at an annual rate of 2.0 percent annual rate so far in the 90s and at more than a 3 percent rate over the past 25 years.

IMPLICATIONS OF THE STUDY

As the above discussion demonstrates, the study is primarily a catalog of potential improvements in energy efficiency. Neither the determinants of these improvements, nor their implications for energy demand behavior are examined. Rather, the study provides an *accounting* of two very stylized scenarios. Without developing and detailing the relationship between the study's scenarios and the policy mixes that would have to accompany them, it would be inappropriate to draw any conclusions from the study about the role of technology, much less the role of technology policy, in addressing global warming. Although the study provides no policy recommendations, it does hint at possibilities. Listing them provides some insight into the potential difficulties in making the scenarios "come true."

- *Aggressive R&D, both public and private.* The study continually refers to the need for aggressive R&D, but provides no suggestions as to how it could be fostered and at what cost.[5] The EFF scenario is basically an extrapolation of the Climate Change Action Plan; the likely success of this effort is at best problematic. Some have suggested a more vigorous effort, similar to the Apollo project. Although this sounds good, we should remember that the Apollo project required rechanneling 0.4 percent of the entire GDP of the 1960s into this one government project. Many of the climate change modeling efforts predict that reducing emissions levels to 1990 levels in 2010 would not cost much more than that in the absence of a technology program.
- *Tax incentives.* Investment tax credits, accelerated depreciation, and other tax incentives are available to spur the development and adoption of energy-saving technology. This approach has two problems. First, energy-efficiency investments should not be singled out unless they impose special costs. If they do, *disincentives* for using energy are more efficient than *incentives* for saving energy. Second, any substantial incentives would have to be "paid for" with other tax increases and spending cuts. As recent history has demonstrated, reaching consensus is not easy.
- *Regulations and standards.* Implicit in this study is the idea that regulations and standards could go a long way toward achieving the EFF and HE/LC scenarios. The types of standards that would be needed, however, would be very pervasive and potentially very intrusive. For instance, standards would have to be applied to building components (windows, insulation, etc.) and constructions techniques, consumer and commercial appliances, utility and industrial equipment, etc. If standard setting is a major policy instrument, achieving the standards could be very costly. Standards work best if they impose little cost, as the report alleges they often would. Basing policy on this assumption moves us quickly to the idea that better results depend less on effort than on luck.

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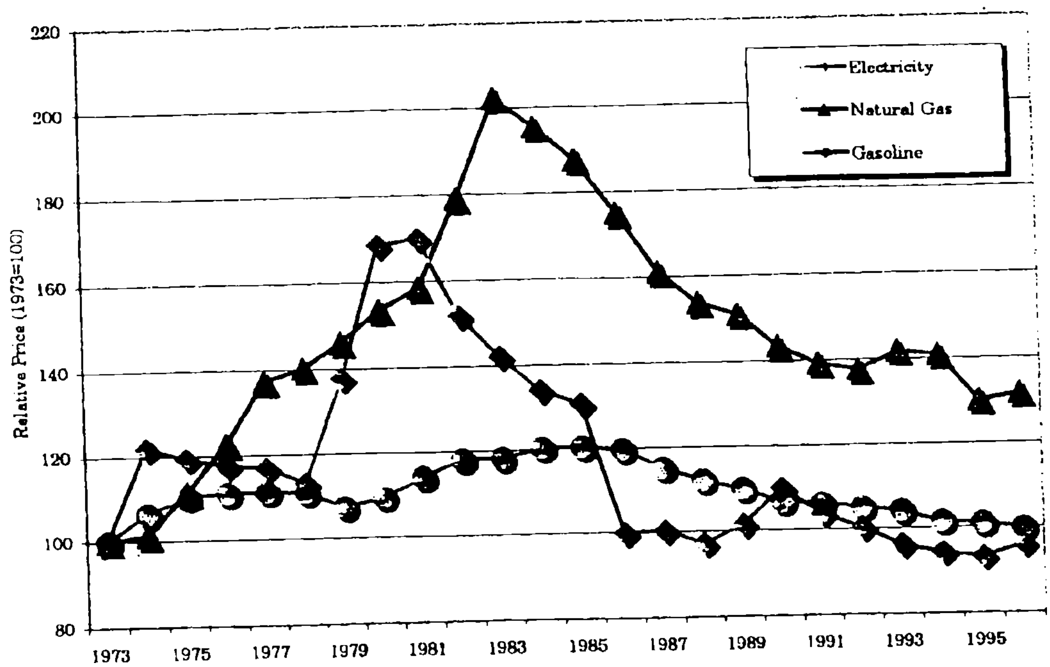
[5] The study (arbitrarily) assumes that government costs to promote energy conservation are equal to 7 percent of *energy savings*. This is very optimistic. For instance, a 10 percent tax credit would cost 10 percent of the total cost of all qualifying investment, even that which would have taken place in the absence of the credit. The load factor for explicit government subsidies would be roughly 10 times as large.

➢ *Higher prices.* The most obvious policy to spur energy conservation is to increase energy prices. The study presumes a substantial increase in prices in its HE/LC scenario, but never draws out the implications of higher prices for the development and adoption of advanced technology. The study points out how rapidly energy efficiency improves prior to the late 80s and 90s. This is not surprising, given price trends. As the chart below demonstrates, consumer energy prices, relative to other prices, grew very rapidly during the 70s and into the 80s. A commitment to reduce emissions and internal climate costs would presumably result in substantial increase in relative prices and accompanying increases in efficiency.

RELATIVE PRICES OF CONSUMER ENERGY



Under almost any feasible scenario that reduces carbon emissions, the pace of technological advance in energy conservation will increase. The importance and role of technology are not in question. What is in question is the value of looking at technology in a vacuum. The 5-labs study provides a plethora of useful information. It does not present this information in a form that is useful for policymaking, however. To be useful, it needs to be merged with careful analysis of the determinants of both consumer and business investment in energy-saving technology.

8/21/97 Draft

Joe Romm
Acting Assistant Secretary for Energy Efficiency
and Renewable Energy
U.S. Department of Energy

Dear Joe:

Enclosed you will find our comments on the report *Scenarios of U.S. Carbon Reductions*. We appreciate the opportunity to review the report and we trust you will incorporate our comments.

Sincerely,

Gillingham looked over the general comment on the 1st page and he is satisfied with it. He will try to review the specific comments and get back to me by the early morning. Do you have any comments/suggestions? Should the letter be under your name, or Jay's + mine?

Joe

Comments on "Scenarios of U.S. Carbon Reductions" (5 Labs Study)

General comment

The report, *Scenarios of U.S. Carbon Reductions*, presents a useful cataloging of the technological options that could play a key role in reducing greenhouse gas emissions. The report does not present the specific policies or the behavioral responses that will trigger the adoption or diffusion of these technologies. As such, the report does not present information in a form useful to policy making. The report as written, however, leaves the impression that these technologies are policy, which they are not. The report must be either redone to reflect how likely these technologies will be used given the behavioral responses to likely policies, or reframed to reflect what it is--a catalog of technologies to address global climate change. The latter path is more straightforward and could readily be accomplished. Among other changes, it is essential that DOE remove references to "net savings" from the report because this does not reflect the actual costs of implementing these policies.

Our specific comments follow.

Executive Summary

1) paragraph 3: The point regarding the opportunity to reduce emissions through "a vigorous national commitment" should be explicit that this commitment is implemented through federal policies. To state that 120 MMTCE can be reduced by "energy efficiency alone" implies that they are free. These reductions through energy efficiency are induced by aggressive policies, and the statement should reflect that. The subsequent discussion of reductions with carbon permits should also reflect that the level of reductions can occur only with both non-price policies (e.g., standards) and a carbon pricing policy (e.g., replace "assumptions" with "federal policies" in sentence 4).

2) Paragraph 4: Estimates of energy cost savings should not be provided until an adequate estimation approach is used to calculate cost savings.

3) Paragraph 5: This paragraph should really concentrate on the point that this study identifies a vast array of technologies that may reduce carbon emissions through climate policy. This is the true strength of the study, and it should be emphasized more.

Chapter 1

4) 1.1, paragraph 1: Sentence 3 should note that "the improved performance and increased penetration of efficient and low-carbon technologies" are program- and price-induced.

5) 1.1, section 1.1, purpose 1: The statement about a "vigorous national commitment" should be explicit that this means a commitment through government programs.

6) 1.4, Table 1.1: The study notes that it employs EIA's Annual Energy Outlook 1997 projections for the business-as-usual case in 2010 with a modification to the transportation sector. However, the numbers in this chart do not match up with the numbers in the AEO97 reference case. In fact, they are much closer to the AEO97 low economic growth case (for industry and buildings). We assume that the labs study is using the reference case from AEO97 since it uses the reference case carbon emissions for 2010. If this is the case, then the following should be the sectoral breakdown of energy consumption (AEO97, pp. 97-99, and pp. 125-127):

Buildings:	36.81 quads
Residential:	20.83 quads
Commercial:	15.98 quads
Industrial:	39.69 quads
Transportation:	31.39+ quads[1]
Total:	107.89+ quads

If the labs study employs the low economic growth case, then it should state so explicitly in the report and explain why this case, as opposed to the reference or other cases, was selected. Otherwise, the AEO97 numbers should be used.

7) 1.6, Table 1.2: The 2010 BAU carbon emissions for buildings and industry do not match the AEO97 reference case emissions for these sectors. AEO97 projects carbon emissions to be 576.1 MMTCE for buildings (residential: 321.4; commercial: 254.7) and industry to be 548.5 MMTCE in 2010. This implies that, with the adjusted transportation emissions, BAU should total 1740 MMTCE, not 1720.

8) 1.8, Table 1.3: The study states that it employs the Annual Energy Outlook business-as-usual (BAU) forecast for the buildings and industry sectors, with modifications that are "not greatly different from the EIA case" (p. 1.2) for the transportation sector.[2] The one modification stated in the study affects the fuel efficiency of the light duty vehicle fleet. While AEO97 assumes that fuel efficiency will increase in the future, the labs study assumes that fuel efficiency will remain

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[1] The 1997 AEO projects transportation energy consumption to be 31.39 quads in 2010. With the labs study assumption regarding constant fuel efficiency, the projected energy consumed in this sector should increase. Although the text never explicitly states the extent of this increase, we inferred that it is 0.9 quads. However, since Andersen informed us that the increase would be 0.6 quads, we assessed both in a subsequent comment.

[2] The labs study also modified the electricity sector forecast, but that modification is not relevant to our discussion of the energy efficiency of the economy.

constant. This change should result in a slower rate of energy efficiency improvement in the economy under business as usual conditions.

The AEO97 BAU forecast assumes an improvement of energy efficiency of 0.9% per year through 2015 (annual E/GDP = -0.9%) (AEO97, p. 4). The study assumes energy efficiency improvement under BAU occurs at a rate of 0.77%. This difference appears to be somewhat significant. Inferring from the transportation chapter (table 5.1), this report states that energy use would increase 0.9 quads over the AEO97 reference case. CEA contacted Art Andersen at the Energy Information Administration to determine how much of an effect holding fuel efficiency constant would have on the E/GDP ratio.[3] According to Andersen, constant fuel efficiency would "disappear in the rounding" in the E/GDP ratio. He stated that this assumption would result in energy use increasing by 0.6 quads in 2010 over the reference case. CEA recalculated the E/GDP ratio used in the AEO97 BAU to account for this extra energy use (assuming GDP remains the same across these cases), and found that annual E/GDP would decrease 0.86% under the constant fuel efficiency assumption (0.6 quads case). With the inference from the transportation chapter, the annual E/GDP rate would be -0.85% (0.9 quads case). The labs study BAU assumes fewer energy efficiency improvements than should be expected under these adjusted BAU scenarios.

Two related implications arise from this. First, since the study employs a modified version of the AEO97 energy use forecast, it should modify the AEO97 carbon emissions forecast. With a slower improvement in energy efficiency under the lab study assumptions, the 2010 BAU carbon emissions should be greater than the 1722.4 MMTCE in AEO97 (AEO97, p. 120). As we note in the previous comment, by incorporating the AEO97 reference case carbon emissions for buildings and industry, the BAU should be about 1740 MMTCE. This obviously implies that more reductions will be necessary to stabilize emissions at the 1990 level in 2010.

Second, the carbon reductions calculated for the various scenarios in this study are based on this -0.77% E/GDP BAU. This implies that some of the carbon reductions claimed under the efficiency and high efficiency cases actually occur in the -0.86% BAU. This double-counting could be significant. The CEA-generated BAU (0.6 quads case) accounts for 17% of the E/GDP gains assumed in the efficiency case (see attached chart).[4] The alternative CEA-generated BAU (0.9 quads case) accounts for 15% of the E/GDP gains assumed in the efficiency case. Assuming that E/GDP and carbon reductions are perfectly correlated (given that the efficiency case involves no fuel switching, this is reasonable), then the efficiency case over estimates emissions reductions by 18 to 20 MMTCE.

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[3] Art Andersen is the Director of the Energy Demand and Integration Division, EIA.

[4] The AEO97 BAU would capture 25% of the efficiency gains in the efficiency scenario.

The text should explain why the lab study E/GDP ratio differs from the AEO97 ratio since it does not seem to result exclusively from keeping fuel efficiency constant. Further, the 2010 BAU emissions reductions should reflect the E/GDP ratio (whether it is -0.77%, -0.85%, -0.86%, or some other rate) used in the study.

9) 1.11, Table 1.4: It would be valuable to understand the effect of non-price policies and permit prices on the carbon reductions. Could you break down the high efficiency cases into two categories: non-price policy induced and permit induced technology adoption?

10) 1.12, paragraph 1: The discussion on government programs costing 15% of investment costs should include references to the literature that have estimated this percentage. Does the literature describe the marginal costs for government programs, or does it just provide this average cost value? Consistent with the literature on technology adoption, the marginal costs should not be assumed to be the same for all units of adoption. In fact, it is likely that the marginal costs increase for higher rates of adoption.

11) 1.12, paragraph 1: The text in this paragraph notes that government costs in the best estimate case are 15% of total investment costs, while figure A-1.1 on p. A-1.2 indicates that the costs are 7% of investment costs for the end-use sectors and 1% for the electricity sector. Which costs are correct?

12) 1.12, paragraph 1: The text notes that "one could argue that... a social discount rate" of 3% or 7% should be used. Alternatively, one could argue that since these analyses assess private decisions on technology adoption, that private marginal rates of time preference should be used that reflect "current market behavior". This analysis is not attempting to conduct a social benefit-cost analysis. Rather, it is attempting to model the private individual or firm's benefits and costs associated with a technology adoption decision. Since this report projects technology adoption assuming a set of aggressive policies, the rates of time preference used by individuals and firms should be used in assessing the extent of adoption.

Further, the report should not rely on government fiat to lower discount rates. It is very difficult to lower people's time preferences through policy. Government programs do not increase adoption rates by lowering time preferences, but by lowering the costs of adoption or increasing the benefits of adoption. For example, government programs cost-share the adoption of environmentally-benign agricultural production techniques through the Environmental Quality Incentives Program. Farmers still employ the same discount rate, but their stream of costs are lower because of the government subsidy, and so adoption increases. The report should not assume that government policies can lower private time preference rates but that government policies can affect the stream of costs and benefits of an adoption decision.

13) 1.12, paragraph 5: Again, until the complete costs of investment and accurate cost-savings can be estimated, the text on net benefits should be deleted.

14) 1.13, Table 1.5: The estimates of carbon reductions under the alternative view do not match with the carbon reductions in table A-1.2 on p. A-1.5. It seems implausible that discount rates could double and have no effects on any technology adoption decision in this report. Are the numbers in the appendix the right set? Is it true that every single energy efficient technology adoption decision is cost-effective under the "best estimate" discount rate and the "alternative view" discount rate? If these technologies are such big winners, then why aren't people and firms already adopting them?

15) 1.14: Until the costs and cost-savings issues are adequately addressed, estimates of net savings should be omitted.

16) 1.15, paragraph 3: As stated in the executive summary comments, the text should not state "energy efficiency alone can take the nation 30 to 50% of the way to 1990 levels." If energy efficiency could achieve these reductions "alone", there would be no need for an invigorated federal policy effort. The role of policy should be explicitly stated.

Chapter 2

17) 2.6, transportation sector bullet: The text states that the transportation sector analysis uses a 5 year time horizon. However, the description of the best estimate and alternative view cost effectiveness calculations on p. A-1.10 indicate that a time horizon of 14 years was used. Further, the transportation chapter indicates that the cost effectiveness analyses were conducted using a 6% discount rate in combination with a decline in usage and depreciation to calculate fuel savings (p. 5.45). The footnote to table 5.9 implies that the analyses used a 14 year time horizon as well. The report should clarify these inconsistencies.

Chapters 3-7

18) There does not appear to be any discussion of the $25/ton permit scenario in these chapters. Further, the appendices do not explicitly detail this case. The results from this scenario need to be documented in the text and in the appendices. For example, it is impossible to identify the penetration rate for this scenario in the buildings chapter (see p. 3.3). The industry chapter discusses three scenarios: BAU, efficiency, and high efficiency (p. 4.2). The descriptions of the high efficiency case in transportation on p. 5.3 and p. 5.31 do not even mention a permit price. The electricity sector appears to only consider a $50/ton permit (p. 6.9).

19) The results from the alternative view cost analysis should be incorporated in these chapters.

Chapter 3

20) 3.3: In the context of fully incorporating the effects of climate policy on energy prices, the analyses on buildings technologies should be modified. Under the efficiency case, energy consumption declines. This scenario should be changed to reflect the downward effect on prices

resulting from this decreased energy consumption. The high efficiency scenario should reflect two counteracting effects on prices: the decline in energy consumption and the $50/ton permit fee. The study ignores the former effect and insufficiently incorporates the latter effect. For example, in the buildings chapter, the penetration rate is assumed to be 65% instead of 60% of the maximum cost-effective technical potential in this scenario because of the $50/ton permit price. However, the energy-cost savings calculations for buildings technologies assume the same energy price as in the business as usual scenario. Since the study assumes that exogenous, undefined policy influences drive the penetration rates, the penetration rate should be set at 60% and the energy cost-savings should be recalculated with the appropriate energy price. In addition, the assumed energy use for these technologies should be based on consumers' responses to the lower operating costs. For example, if running an air conditioner becomes less expensive with a new energy efficient technology, people will run the air conditioner more. This latter effect decreases the carbon reductions associated with each adoption decision.

21) 3.9 and Appendix C-1: The study uses the average cost of electricity to calculate the energy cost savings of these technologies. Many of the electricity-dependent technologies are cost effective based on the assumption of average, not marginal electricity prices. Since marginal prices may be much lower than average prices, especially in cases where households use less electricity, this may over estimate the extent of cost effective technologies. The analysis should be modified using marginal electricity prices.

22) 3.23, box: The text in the box is not clear on the inclusion of fuel cell technology in the high efficiency scenarios. The first paragraph states that fuel cells were not included in the main building sector scenarios. However, emissions reductions of 3 MMTCE from fuel cells are listed under buildings in Table 1.4 on p. 1.11. Further, the discussion on fuel cells in the text outside of this box implies that fuel cell technology will not be available until 2020 (since it falls in the section "Potential for Advanced Technologies in 2020"). If the study relies on ADL's analysis of fuel cell adoption, then the assumptions of ADL's assessment should be provided in an appendix. Two issues should be addressed here. First, if fuel cells are projected to be adopted under the high efficiency scenarios, then this discussion should be placed in the appropriate section of this chapter (not the 2020 section), and the inconsistencies in the text should be remedied. Second, if fuel cells are adopted, then a discussion of the carbon emissions accounting should be provided to ensure that the study does not double count emissions reductions from energy efficient technology adoption and from switching energy sources to fuel cells.

23) 3.29, summary bullet two: This states that the high efficiency scenario yields 91 MMTCE of carbon reductions from the BAU emissions level. However, Table 1.4 indicates that only 44 MMTCE of reductions occur under the $25/ton permit price and only 62 MMTCE of reductions occur under the $50/ton permit price. Which carbon reduction estimate is correct?

Chapter 4

24) 4.6, paragraph 4: The analysis assumes that the capital recovery factor falls by more than half. This appears to be an arbitrary reduction. Did industry behave as if it operated under a lower CRF during the 1970s oil shocks? There is no discussion of the economic behavior necessary to result in this outcome.

25) 4.6, paragraph 4: The high efficiency penetration rate is assumed to be double the rate used in the efficiency scenario, which is the undefined "normal" rate. It is impossible to determine how much of this doubling of penetration results from undefined, aggressive policy efforts and how much results from the permit price. It would be valuable to understand the relative impacts of both.

26) 4.13, paragraph 4: The text states that the high efficiency case causes an acceleration of capital retirement, but does not estimate these costs. Could you estimate the costs of early retirement? If not, can you provide some information on the extent of early retirement (e.g., percentage of capital retired early under this scenario)?

Chapter 5

27) Does this sectoral analysis consider the impact of a permit price? Neither the $25/ton permit nor the $50/ton permit are mentioned in the entire chapter. Do all improvements in fuel efficiency and cellulosic ethanol result from non-price policy responses? As the report states, a degree of "luck" is required to achieve the necessary technological breakthroughs to result in the projected carbon reductions. However, without a price incentive, the probability of the nation becoming "lucky" appears more unlikely. If this analysis does not incorporate the permit prices, then this should be made explicit in the discussion of the high efficiency case.

28) The methodology for this sector is insufficiently transparent to easily grasp the impact of technology development and adoption on carbon reductions. Further, the appendices for transportation do not provide the details to remedy the shortcomings in the chapter. It is difficult to compute carbon reductions from increases in fuel efficiency. The text should take the reader through the process of piecing together all of these energy efficient technologies, illustrating the final effect on fuel economy, and then translating this into carbon reductions.

29) 5.4, Table 5.1: Why do the energy consumption numbers for this sector in 1997 vary across scenarios? We understand that the start year for the scenario analyses is 1998 (e.g., refer to Table 4.8 on p. 4.12 that implies 1998 as the start year for assessing cumulative incremental investment).

30) 5.21, paragraph 2: Does the assumption about reducing technology costs reflect any empirical analysis on transportation technologies? For example, the 1970s oil shocks and fuel efficient imports spurred domestic fuel efficiency R&D. Does this analysis incorporate

information about accelerating technology development and lowering technology costs that may be available from this earlier period?

31) 5.23, paragraph 3: As we have noted before, it is difficult to modify consumers' preferences. Assuming that the demand for horsepower will decrease because consumers will become "more green" over the next decade appears tenuous. This statement is repeated on p. 5.32. Is there any evidence that concern about global warming has affected consumers' purchase decisions to date?

32) 5.25, paragraph 1: If the turbocompound diesel engine and the advanced LE-55 heat engine are not available in the reference case (which implies that the earliest these are available is 2016), then how are they made available by 2003? Is there any precedent for accelerating transportation technology from a time horizon of at least 18 years to a horizon of only 5 years?

33) 5.25, paragraph 1: The efficiency case assumes that advanced drag reduction in heavy trucks has become available this year, but this is excluded from the reference case. First, has this actually occurred? Second, if it has already occurred, then why is it excluded from BAU?

34) 5.25, paragraph 4: Again, the assumption of reducing a technology price appears arbitrary. What is the basis for assuming that the trigger price for heavy truck technologies will fall?

35) 5.25, paragraph 5: The efficiency analysis assumes penetration rates of 100% for several of the heavy truck technologies over a 20 year period. This seems incongruous with the assumptions in the other sector analyses that imply much lower penetration rates. 100% penetration of a technology within 20 years, that is not expected to be available 18 years from now in the BAU, appears to be an extreme and unsubstantiated assumption.

36) 5.32, paragraph 1: The analysis assumes that fuel cells, because their costs are unknown, will be cost effective. This is an entirely arbitrary assumption, especially for a technology that is not even projected to become available in the BAU scenario. There is absolutely no economic basis for this assumption. This assumption is all the more extraordinary given that this analysis does not (apparently) incorporate the impacts of a carbon permit on fuel prices.

37) 5.36, Table 5.7: If the scenarios over estimate fuel economy, as stated in the footnote, then the numbers should be revised to remedy this error.

38) 5.38, paragraph 2: The modification of assumed improvement of fuel efficiency by multiplying the expected improvement by 0.7 to reflect offsetting performance effects, appears arbitrary. Why wouldn't the fraction be much smaller? The introduction to this chapter indicates that almost all improvements in fuel efficiency are offset by performance effects. Why would only 30% of fuel efficiency improvements in the future be offset?

39) 5.45: The chapter is not explicit about its accounting of fuel efficiency improvements in light duty vehicles and the change in the fuel mix reflecting an increase in cellulosic ethanol and the

use of fuel cell technology. We cannot determine if carbon reductions are double counted, however, there is no discussion of how cellulosic ethanol and fuel cells are accounted for in the energy cost savings description on pp. 5.43-5.45. If the reductions from fuel efficiency and the reductions from cellulosic ethanol and fuel cells do not overlap, then this should be stated explicitly. Again, a more transparent presentation of the methodology would address the readers' uncertainty about this issue.

40) 5.45, Table 5.9: The cost effectiveness estimates assume a constant price of $1.20 per gallon through the life of the vehicles. The gasoline price should be adjusted down to reflect the impact of decreased gasoline consumption due to fuel efficiency. Further, vehicle miles traveled should increase through time as cars become more fuel efficient, consistent with the trend to date, instead of held constant.

Chapter 7

41) 7.1, paragraph 2: If the report has eliminated the double counting in this sector evident in the June 10 draft, then the sentence that states that double counting is "a likely possibility" should be deleted. A reference to appendix G-2 should be inserted.

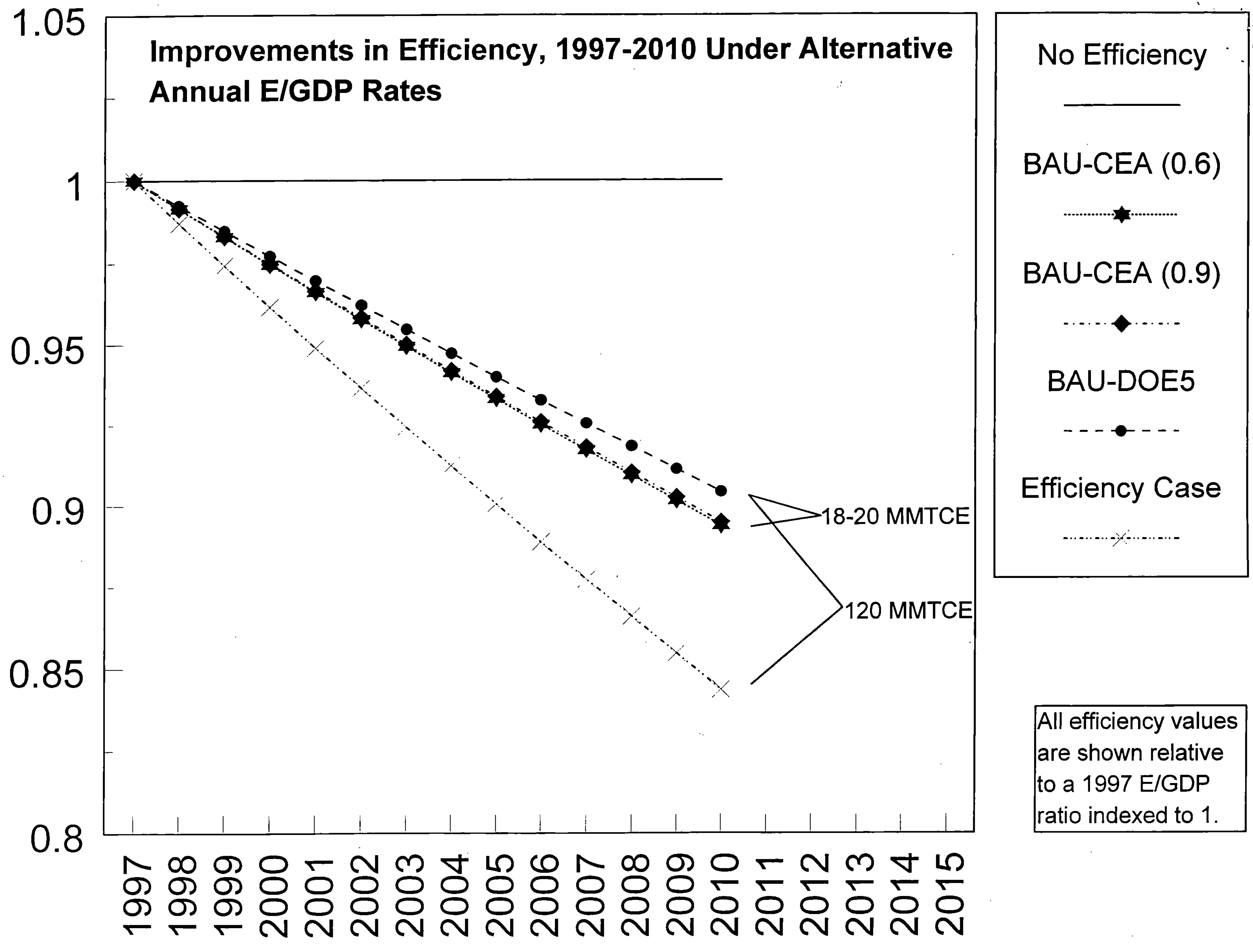
42) 7.2, paragraph 3: Again, if the double counting has been remedied by integrating the dispatching and repowering analyses, then the following sentence should be modified: "The analytical approach was static in that the cost of repowering was computed for each candidate power plant but the analysis did not optimize unit/plant production cost, dispatch, or system load."

43) 7.6, paragraph 5: The reference to appendix G-2 is wrong. This reference implies that appendix G-2 provides a methodology for SO_2 and NO_X benefits. Nothing in the text of chapter 7 reads as if the double counting issue from the June 10 draft has been resolved.

Appendices

44) A-1.9: The alternative view cost-effective estimates for buildings assumes an 18 year time horizon. However, the methodology discussion on p. 2.5 states that a "technology is defined as 'cost-effective' if it delivers a good or service at equal or lower life-cycle costs relative to the current practice". If cost-effectiveness is measured in terms of a technology's life cycle, then shouldn't the time horizon for calculating the stream of benefits be constrained by the life of the product? It is not possible for a technology to generate cost savings beyond its lifetime. In the buildings case, the end uses with the largest potential carbon reductions in the high efficiency case are other uses (10 MMTCE commercial, 6 MMTCE residential) and lighting (7 MMTCE commercial, 6 MMTCE residential). These account for 29 of the 62 MMTCE of reductions for this sector. However, the lifetimes for these end uses are much shorter than 18 years. For other uses, the lifetime ranges from 7 (commercial) to 10 years (residential). For lighting, the lifetime

ranges from 1 (residential) to 12 years (commercial). The cost effectiveness estimates should be recalculated using specific end use lifetimes.



Improvements in Efficiency, 1997-2010 Under Alternative Annual E/GDP Rates
1.05
1
0.95
0.9
0.85
0.8
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
18-20 MMTCE
120 MMTCE
No Efficiency
BAU-CEA (0.6)
BAU-CEA (0.9)
BAU-DOE5
Efficiency Case
All efficiency values are shown relative to a 1997 E/GDP ratio indexed to 1.

APPENDIX A-2

KEY OPPORTUNITIES FOR CARBON SAVINGS FROM END-USE EFFICIENCY IMPROVEMENTS

Each of the three end-use efficiency chapters (Chapters 3-5) assessed the magnitude of carbon savings that could be achieved by the year 2010 from specific submarkets, energy end-uses, and technologies. These key opportunities are summarized in the following table. The table includes those submarkets and end-uses that were estimated to offer the potential for at least 2 MtC of savings by the year 2020. Tables A-2.2 to A-2.4 list some of the key technologies.

Table A-2.1. Key Opportunities for Carbon Savings From End-Use Efficiency Improvements

Submarkets and Technologies with >2 MtC Estimated Reductions in 2010:	Carbon Reductions Estimated by High Efficiency/Low Carbon Case (in MtC)
Buildings	
Miscellaneous electric uses: residential	15.9
Miscellaneous electric uses: commercial	8.5
Commercial lighting	6.6
Commercial electric space conditioning	5.4
Residential lighting	4.4
Commercial gas space conditioning	3.3
Residential electric space conditioning	3.1
Electric water heating	2.9
Gas water heating	2.7
Refrigerators/freezers	2.3
Industry	
Heavy manufacturing industries:	16.1
Petroleum	4.3
Bulk chemicals	4.1
Pulp and paper	2.6
Iron and steel	2.6
Light manufacturing	24.0
Non-manufacturing	10.8
Transportation	
Light-duty vehicles	73.3
Freight trucks	14.1
Air transport	13.9
Freight rail	2.5

Table A-2.2. Illustrative Energy-Efficiency Buildings Technologies

Residential Building End-Uses

- Miscellaneous electricity (efficient motors, variable speed drives)
- Lighting (halogen IR lamps, compact fluorescent lamps, motion sensors)
- Electric water heating (standby loss reduction, horizontal axis clothes washer, heat pump water heater – post 2000)
- Electric cooling (more/improved insulation, spectrally-selective glazings, variable speed compressors, white roofs, reduced infiltration)
- Electric space heating (more/improved insulation, reduced infiltration, low-E argon glazings, superwindows, improved compressors)
- Electric clothes dryers (heat pump clothes dryers at very low penetration)
- Refrigeration (improved insulation, improved compressors)
- Gas water heating (standby loss reduction, horizontal axis clothes washer)
- Gas space heating (more/improved insulation, reduced infiltration, low-E argon glazings, superwindows, condensing furnaces)
- Electric cooking (improved insulation)
- Freezers (more/improved insulation, improved compressors)
- Oil space heating (low-E argon glazings, superwindows, improved insulation, reduced infiltration, condensing furnaces)

Commercial Building End-Uses

- Miscellaneous electricity (variable speed drives, efficient motors, smart redesign)
- Lighting (electronic ballasts, motion sensors, halogen IR lamps, compact fluorescent lamps)
- Electric cooling (system controls, variable speed compressors, switching systems, white roofs)
- Gas space heating (condensing furnaces, fuel cells, system controls)
- Ventilation (variable speed drives, system controls)
- Refrigeration (improved insulation, better compressors)
- Miscellaneous gas (smart redesign, eliminate pilot lights)
- Electric space heating (switch to heat pump, system controls)
- Gas water heating (standby loss reduction, improved burners, flow
- controls)
- Electric water heating (standby loss reduction, flow controls)
- Oil space heating (condensing furnaces, system controls)

Table A-2.3. Illustrative High-Efficiency/Low-Carbon Industrial Technologies

Fuel Switching
- Advanced turbine systems for industrial cogeneration applications
- Integrated gasification combined cycle technologies for the forest products industry

Motors
- Proper load matching
- Variable speed drives

Pulp/Paper
- Impulse drying
- Multiport cylinder drying
- On-machine sensors

Chemicals
- Pinch analytic techniques
- Advanced distillation control techniques

Petroleum Refining
- Utility system improvements
- Process/equipment modifications

Glass
- Oxy-fuel process
- Advanced burner technology
- Glass batch/cullet preheater technology

Aluminum
- New aluminum production cell
- Materials recycling
- Improve furnace efficiency
- Titanium diboride cathodes

Iron/Steel
- Direct smelting/direct reduction
- Scrap preheating
- Hot connection
- Process controls

Metal Casting
- Computer-aided casting design
- Optimized coreless induction melting

Cement
- Cement clinker replacement

Table A-2.4. Key Transportation Technologies Based on the High-Efficiency/Low-Carbon Scenario

Light-Duty Vehicles
- Direct-injection stratified charge (DISC) gasoline engine
- Turbocharged direct-injection clean diesel engine (TDI diesel)
- Hybrid vehicles (gasoline and diesel)
- Gasoline fuel cell vehicle
- Materials substitution, advanced drag reduction, engine friction and pumping loss reductions, and transmission improvements
- Cellulosic ethanol as a blending component with gasoline

Truck Freight
- LE-55 diesel engine
- Turbocompound diesel engine
- Improved tires
- Advanced drag reduction
- Electronic controls

Rail
- Flywheels
- Alternative fuels
- Fuel cells
- Operational efficiency improvements

Air
- Ultra-high bypass turbofans
- Material improvements
- Aerodynamic drag reduction
- Propfans
- Laminar flow control

Potential Reductions in Carbon Emissions in 2010 (MMTCE)

		Non-Price Response	Price Response
Buildings	**Total**	**54.5**	**7.5**
Commercial	**Total**	**26.7**	**2.3**
	Other uses	9.2	0.8
	Lighting	6.5	0.5
	Space heating	3.7	0.3
	Space cooling	3.7	0.3
	Water heating	1.8	0.2
	Refrigeration	0.9	0.1
	Ventilation	0.9	0.1
	Office equipment/non-PCs	0.0	0.0
	Kerosene	0.0	0.0
	Office equipment/PCs	0.0	0.0
	Cooking	0.0	0.0
	Biomass	0.0	0.0
Residential	**Total**	**30.1**	**2.9**
	Other uses	14.8	1.2
	Water heating	4.5	0.5
	Lighting	4.5	0.5
	Space heating	1.8	0.2
	Cooking	1.8	0.2
	Refrigeration	0.9	0.1
	Space cooling	0.9	0.1
	Clothes dryers	0.9	0.1
	Kerosene	0.0	0.0
	Freezers	0.0	0.0
	Biomass	0.0	0.0
Other	**Total**	**0.0**	**3.0**
	Fuel Cells	0.0	3.0
Utilities	**Total**	**0.0**	**136.0**
	Dispatching	0.0	55.0
	Conversion to Natural Gas	0.0	40.0
	Co-firing with Biomass	0.0	17.0
	Power plant efficiency	0.0	8.0
	Wind	0.0	7.0
	Nuclear plant life extension	0.0	5.0
	Hydro-power expansion	0.0	4.0

		Non-Price Response	Price Response
Transportation	**Total**	**103.0**	**0.0**
Cellulosic ethanol	**Total**	**16.0**	**0.0**
Transportation efficiency	**Total**	**87.0**	**0.0**
	Materials substitution		
	Aerodynamic drag reduction		
	Improved automatic transmissions		
	Engine friction reduction		
	Variable valve timing		
	Lean burn engines		
	Advanced tires		
	Hybrid electric power trains		
	DISC gasoline engines		
	TDI diesel engines		
	Fuel cell power trains		
	Fuel cells in trucks and locomotives		
	Train flywheels		
	Train oxygen enrichment		
	Natural gas locomotives		
	Plane ultrahigh bypass turbofans		
	Intelligent transportation systems		
Industry	**Total**	**51.0**	**31.0**
Heavy manufacturing	**Total**	**16**	**0**
	Pulp and paper	2.6	0.0
	Bulk chemicals	4.1	0.0
	Petroleum	4.3	0.0
	Glass	0.4	0.0
	Cement	0.5	0.0
	Iron and steel	2.6	0.0
	Aluminum	0.3	0.0
	Other	1.2	0.0
Light manufacturing	**Total**	**24.0**	**0.0**
Non-manufacturing	**Total**	**10.8**	**0.0**
Other	**Total**	**0.0**	**31.0**
	Advanced turbine systems	0.0	17.0
	Biomass and black liquor gasification, cement clinker replacement, aluminum technology	0.0	14.0
Total		**210.6**	**175.2**

Romm 8/19/97

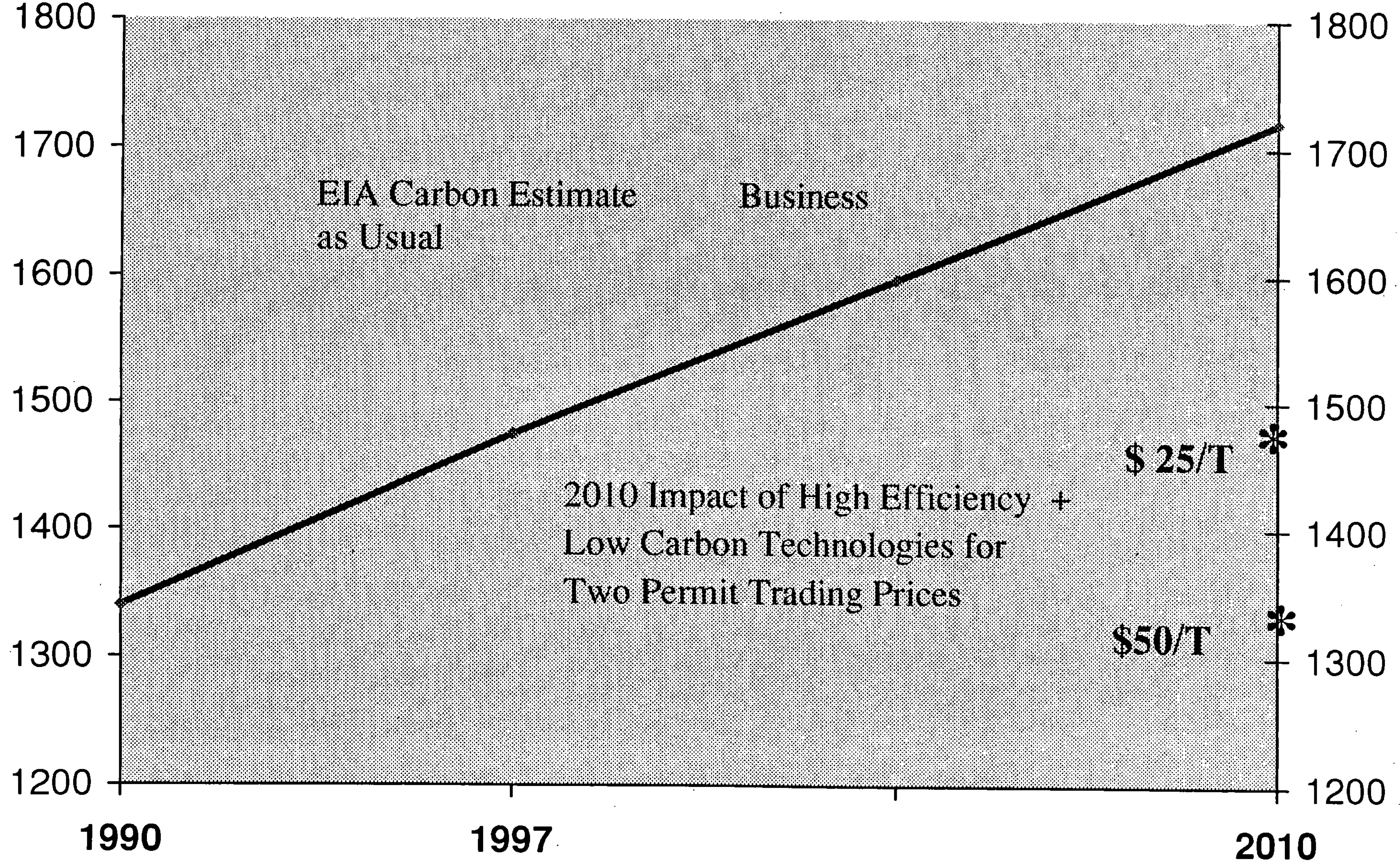
The Five Lab Study

- Five National Labs Assess Potential of Energy Technologies to Reduce Carbon Emissions
  - **LABS: Lawrence Berkeley, Oak Ridge, Argonne, Renewable Energy, Pacific Northwest**
  - Externally Peer Reviewed: U.Tenn, Monsanto, EPRI, GRI, Harvard, NAS, Stanford (Huntington), UNC ORNL (Link), and UCSB (DeCanio)

- Assumes
  - Expanded Technology Strategy (R&D and Diffusion)
  - Carbon Dioxide has a price and is traded

Lab Study Results

US Carbon Emissions in MMTCE



Low-Carbon Technologies

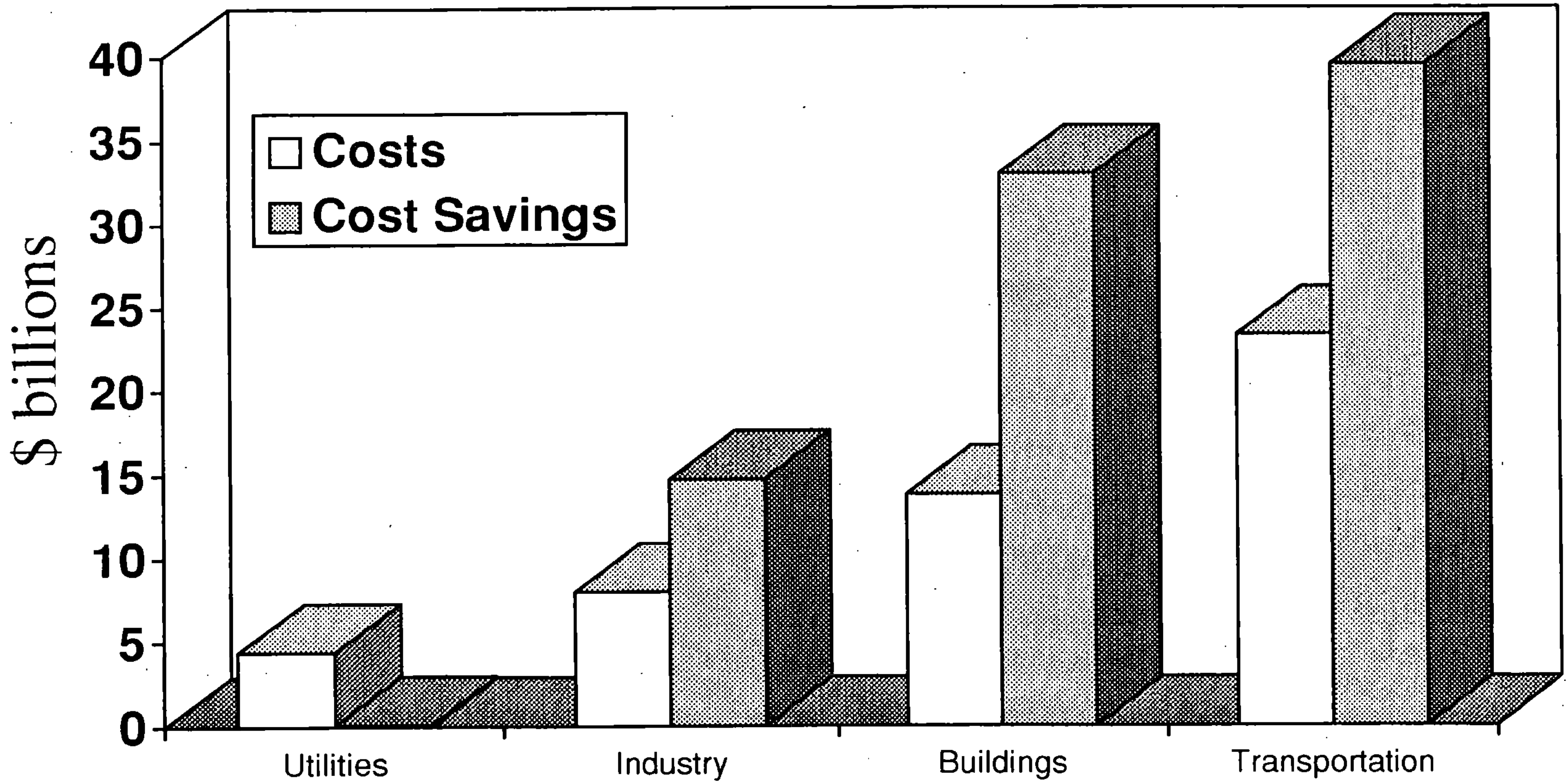
Technology	Cost to Generate *cents/kWh	Incremental Cost $/ton Carbon	Carbon Reduction Potential (MMT)	
• Utilities				
– Carbon Dispatch	--	$30	**55**	
– Gas Repowering	2.5 - 3.2	$30	**40**	(24-83+)
– Biomass co-firing	2.7 - 3.2	$38	**17**	(16-24+)
– Wind	2.5 - 3.5	$42	**7**	(6-20+)
– Other	--	$25	**9**	(7-12)
• Industry				
– Advanced Turbine	2.5 - 3.5	$40	**17**	(15-26)
– Industry Specific	--	$40	**14**	(13-16)
• Buildings				
– Fuel Cell	5.0 - 6.0	$30	**3**	
• Transportation				
– Non-corn Ethanol	--	--	**16**	
Total (rounded)			**180**	(160-250)

*Average costs as of 2005

Energy Efficient Technologies

Technology	Carbon Reduction Potential (MMT)	
• Utilities		
– Generation Efficiency	8	(7-13)
• Industry		
– R&D and Diffusion	51	
• Buildings		
– Standards and Diffusion	59	
• Transportation		
– Passenger Cars	28	
– Light Trucks	28	
– Heavy Trucks	14	
– Aircraft	14	
Total (rounded)	**200**	

Business and Consumer Annual Costs and Cost Savings in 2010



Review of DOE Labs Study, August 1 Draft

We review *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond* (DOE Labs Study, August 1 draft). The report identifies carbon reductions from the adoption of specific identified technologies in the buildings, industry, transportation, and electric power sectors. The study finds that unspecified "very aggressive policies" and a $50/ton permit price would stabilize carbon emissions at 1990 levels by 2010. We believe several limitations of the study should be highlighted; some of these are serious.

- First, the authors do not estimate the costs or even describe the programs necessary to stimulate the adoption of the new energy-efficient technology they find could reduce emissions of 197 million metric tons of carbon equivalent (MMTCE) by 2010. These reductions correspond to about ½ of the reductions needed to attain 1990 levels by 2010. In the absence of cost estimates this information is of little use in the evaluation of alternative policy options.

  --The recent history of CCAP suggests that nearly a half billion dollars of government investment achieved just 14 million tons of carbon reductions. There are important unanswered questions about emissions reductions in the outyears, and the extent of diminishing returns associated with the expansion of existing government programs. We believe, however, that

  o reasonable assumptions about answers to these questions would imply that government programs to achieve emissions reductions of 197 million tons of carbon may cost many tens of billions of dollars per year above the costs of existing programs. (See below for an illustrative calculation.)

  o The marginal cost of emissions reductions, including the cost to the taxpayer of the government program, is likely to greatly exceed the permit price. As a result these programs may be less cost-effective than a cap-and-trade emissions control program.

  --The efficiency improvements in the vehicle sectors and in the building sectors appear to be so large as to be likely to be achievable only with substantially more stringent new mandatory national standards, i.e., corporate automobile efficiency standards, or national building codes. In addition, the phase in periods for these codes may be quite rapid.

  have to be?

- Second, the analysis appears to ignore the behavioral changes that offset the energy efficiencies promised by the new technologies. For example, more efficient windows lead to houses with more glass, and more efficient cars lead to more vehicle miles traveled. Thus these innovations offer real value to consumers, but smaller energy savings than engineers might forecast.

- Third, the analysis appears to ignore the value of delaying investments in capital goods which are rapidly improving in efficiency. The price of compact fluorescent lights has declined by nearly 50 percent over the last decade; the energy efficiency of refrigerators has improved at a similar pace. Given these changes, accepting a few years of the high energy bills associated with an existing capital stock, and investing later in a mature new technology, may be less costly than investing earlier in innovations that are better than the old technology, but have rapidly declining prices or improving efficiencies.

  Similarly, many of the innovations in electrical use appear to assumed to be cost effective based on an assumption of average, not marginal electricity prices. The marginal prices may be half as much as the average prices.

- Fourth, the industry sector analysis ignores the costs of accelerating capital retirement.

- Fifth, the transportation sector requires "luck" in terms of technological innovation to achieve the projected emissions reductions.

- Sixth, the utilities sector analysis resulted in double counting of emissions reductions.

- Seventh, the labs study double counts 22 MMTCE in reductions in the efficiency case that will occur under the business-as-usual case.

Upon receiving the final version of the report and documentation of the analyses, we will update this review.

Overview of Report

The study provides emissions reductions for three scenarios: 1) "efficiency"; "high efficiency/low carbon with $25/ton permits" and 2)"high efficiency/low carbon with $50/ton permits", over the period 1998-2010. The study describes neither the policies necessary to achieve emissions reductions nor the costs of federal programs for these scenarios, only their outcomes: increased adoption rates and better technologies through technology development and adoption and fuel switching.

The Study employs the Energy Information Administration's 1997 baseline (AEO97) for the buildings and industry sectors. For the transportation sector, the authors changed the AEO97 assumption of increasing fuel efficiency in automobiles to constant fuel efficiency. For the utility sector, the baseline was modified to reflect a fully competitive bulk-power market in the year 2010. Discharge, shutdown, repowering, and new construction decisions were optimized to select the amount of capacity that minimized the cost of the power-supply system plus the cost of unserved energy. Compared to AEO97, the final baseline has slightly lower energy prices, larger electricity sales, and a greater share of gas generation.

Efficiency Scenario

This case assumes that all technologies adopted are at zero or negative net cost to the user given more aggressive federal policies to stimulate development and diffusion of energy efficient technologies. The Study estimates that in this scenario 120 MMTCE will be reduced at negative net cost. We believe that the methodology inappropriately neglects the greater cost savings from adopting more efficient innovations later. None of these reductions occur in the utility sector as a function of fuel switching or the adoption of technologies to increase combustion efficiency.

High Efficiency/Low Carbon Scenarios[1]

This case assumes a "greater commitment" to reduce emissions through federal policies, in concert with state and private activities and either a $25/ton permit price or a $50/ton permit price to stimulate low carbon technologies (read: primarily fuel switching). The policy is announced in 2000 and the policy's restrictions are phased-in through 2010. There is an assumed announcement effect (although an autonomous energy efficiency index (AEEI) is not specified), increased domestic and international R&D in low-carbon technologies, and a "change in psychology". The Study estimates reductions of 152 MMTCE from the baseline through energy efficient technology adoption under the $25/ton permit and 197 MMTCE under the $50/ton permit. The carbon permits will yield an additional 74-186 MMTCE of reductions through low-carbon technology adoption (the range is based on the $25/ton and $50/ton permits).

Carbon Emissions (MMTCE): 1990 - 2010

1990	2010 Baseline	2010 Efficiency	2010 High Efficiency/Low Carbon + $25/ton permit	2010 High Efficiency/Low Carbon +$50/ton permit
1340	1720	1600	1490	1340

Estimated Costs

The study calculates two sets of costs: "best estimate" and an "alternative view". The best estimate case employs discount rates of 7% for buildings, 10% for transportation, and 12.5% for industry. The study assumes that the total costs of government programs to promote energy efficiency are 7% of technology costs. The alternative view case uses discount rates of 15% for buildings, and 20% for transportation and industry. Government programs are assumed to cost 15% of technology costs in this case. The study does not provide discount rates for the utility sector.

Under the best estimate case, the study calculates annual total costs of $50 billion and annual total benefits from energy-savings of $87 billion. In the alternative view, the study estimates annual total costs of $81 billion and annual total benefits of $87 billion. Note that under the alternative view, U.S. carbon emissions in 2010 would be 1383 MMTCE.

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[1] We combine our discussion on both permit prices here because the 8/1/97 draft does very little to distinguish between the two scenarios. In fact, the chapters on buildings, industry, and transportation do not mention a $25/ton permit price.

Review

The Lab Study employs several important assumptions in the analyses. We discuss several of the most significant assumptions below.

The Study Does Not Specify Policies to Achieve Carbon Reductions

> "Cost effectiveness is improved because R&D, in combination with increased deployment efforts, result in declining capital costs. We do not specify the policies, economic conditions, or exogenous events that could precipitate such changes" (p. 1.4).

The entire study is premised on two sets of undefined policies: an "aggressive" or "invigorated" public sector effort to stimulate energy efficient technology adoption (efficiency case) and a "very aggressive" public sector effort to stimulate technology development and adoption (high efficiency/low carbon case). The only specific policy instrument mentioned in the report is a tradeable permit at prices of $25/ton and $50/ton. The study merely asserts that these unidentified policies would result in: 1) "better technology" (p. 1.5); 2) "higher penetration rates" (p. 1.6); 3) "changing the capital recovery factor [in industry sector] from 33% to 15%" (p. 4.8); and 4) "technological breakthroughs" (p. 5.3). These policy effects would result in reductions of 180 MMTCE for "free": firms and individuals receive energy cost-savings greater than or equal to technology adoption costs. ?

The report specifically states that the efficiency case reduces, but does not eliminate, market barriers (p. x) and that implementation costs are ignored (p. xvi). Policy intervention to eliminate a market barrier cannot make society better off and generally makes society worse off to the extent that it imposes costs. In particular, a set of climate change policies to stimulate technology adoption could increase efficiency, but only because they also decrease the effect of a market failure (carbon emissions). Social welfare is improved because the net benefits of indirectly fixing the market failure exceed the costs of removing the barriers. If carbon emissions are appropriately priced (assuming in this case that $50/ton is the correct carbon price), a policy to remove a barrier will generate negative net benefits. High adoption rates will be realized once prices rise enough for some technologies to clear the barriers.[2]

The economics literature has identified several barriers that help explain the slow rate of technology adoption.

- Qualitative attributes of technologies can affect adoption. Consumers of technology prefer ~~technologies~~ products because of a set of characteristics, not just energy efficiency. For example, some consumers may purchase a product with a lower efficiency because the former is more reliable than the efficiency-superior product.

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[2] In contrast, policy intervention to address a market failure (such as unpriced carbon emissions) may make society better off, depending on the stringency of the intervention.

- New technologies may be costly to integrate with existing ones. Until all components of a complex system are fully depreciated it may make sense to replace energy inefficient components with another like-wise inefficient component.

- Uncertainty of future energy prices, or constraints on ability to borrow capital may make households act as if they have implausibly high implicit discount rates.

- Just because a technology is cost-effective on average does not mean that it is cost-effective for all individuals. Those who may use the device less intensively may find it optimal to purchase a less efficient model.

These barriers clearly demonstrate that investments to minimize energy costs are different from investments to minimize the total costs of production.

The Labs Study does not provide an estimate of the costs to government to lower market barriers to achieve the estimated emissions reductions. A sense of the likely costs can be derived by evaluating the experience of the Climate Change Action Plan (CCAP). CCAP promotes carbon reductions through a broad array of voluntary programs that stimulate "cost-effective" technology adoption by private firms. Participation by a firm in a CCAP program is supposed to reduce carbon emissions and to offer financial returns.[3] We do not address an important threshold question of why cost-minimizing firms would ever need any [redacted] help from government programs to take actions that would lower their costs. CCAP received appropriations totaling $494 million (1995$) during the FY95 - FY97 period. We assume that these costs are distributed uniformly over the three years. During this period, the Department of Energy and the Environmental Protection Agency can account for reductions of 14 MMTCE (see attached table). Evaluating the cost effectiveness of these programs requires an assumption about emissions reductions in the outyears. Since the programs are persuading firms to adopt innovations that offer financial returns, we believe that the firms would soon have adopted them in the absence of the programs. Thus the emissions reductions might last for several years. To develop illustrative cost estimates we assume between 2 and 7 years of emissions reductions. We describe our estimates given the assumption of 2 years; the method for the assumption of 7 years is identical.[4] Assuming constant effectiveness of program expenditures, the emissions reductions attributable to past expenditures would grow from 2.8 million tons in the first year to 5.6 million in the second year and third years, and then decline to 2.8 million tons in the 4th year, before falling to 0 in the 5th and subsequent years. The ratio of the present value of these costs and of these tons is $33/ton using a 7 percent discount rate. Thus taking into account the lag

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[3] Note that CCAP efforts are incorporated in the AEO97 baseline.

[4] This analysis was conducted based on the June 10 draft that stated 180 MMTCE of reductions associated with government programs could be expected under a "very aggressive" set of policies. Since the August 1 draft notes that 197 MMTCE of reductions would be expected, the cost estimates provided in this discussion underestimate the program costs associated with this greater number of reductions.

between program expenditures and emissions reductions, the average cost effectiveness is $33/ton (with a 7 year assumption the cost effectiveness is $13/ton). Assuming constant program effectiveness would imply Federal costs of $5.9 billion per year (with the 7 year assumption the total cost estimate would be half as much.) We believe that there are several good reasons to think that the cost of reducing emissions will rise, however, as these or similar programs are expanded. For example, if the potential adopters differed in terms of their cost savings (or willingness to adopt innovations) then the government program would encounter diminishing returns as it tried to reach the less receptive users of technology. Suppose that the (marginal) program cost effectiveness deteriorated by 10 percent every time the annual reductions in emissions grew by as much as the annual reductions implied by the current program. In this instance the marginal cost of achieving 180 million tons of emissions reductions would be about 21 times greater than the marginal cost of the existing program, and far in excess of reasonable values for a ton of carbon emissions averted. In this case the total cost of the program would be $45 billion per year. Similar assumptions for the 7 year case would lead to total costs of nearly $7 billion per year, and marginal costs of $80/ton. Thus we believe that the cost of a government program to ensure energy reductions of 180 million metric tons of carbon could easily run into many tens of billions of dollars per year. In addition, the marginal cost-effectiveness of these programs could substantially exceed reasonable estimates of the value of carbon emissions reductions.

Of course the government might choose to achieve these reductions using command and control type regulations, such as national building codes, or increasingly stringent CAFE standards. These would substitute private sector costs for government administrative costs.

Price Declines Resulting from Reductions in Energy Demand Are Not Taken into Account

> "The model runs for each of the three end-use sectors were not integrated and therefore may overstate the effects of technology penetration. In an integrated modeling effort, fuel prices might fall as consumption declines, resulting in less penetration of energy-conserving technologies" (p. 1.1).

The analyses of the various sectors assume that the reduction of 197 MMTCE occurs through energy efficient technology adoption without any energy price effect. This implies that, with government programs, private agents will adopt technologies because the benefits (energy cost-savings) exceed the costs of adoption. The authors claim that these reductions occur at zero or negative net costs. However, if the energy prices fall due to the decline in energy demand, some of those adoptions would no longer generate positive net benefits for private consumers. The Study indicates that energy consumption will decline from the baseline by 11.6% under the high efficiency/low carbon case (p. xi). This decrease in demand should result in a decrease in the price of energy, and cause some energy efficient technologies to become unattractive to private agents.

The efficiency scenario should be modified to reflect the downward effect on prices resulting from decreased energy consumption. The high efficiency scenario should reflect two counteracting effects on prices: the decline in energy consumption and the $50/ton permit fee.[5] The Study ignores the former effect and insufficiently incorporates the latter effect. For example, in the buildings chapter, the penetration rate is assumed to be 65% instead of 60% of the maximum cost-effective technical potential in this scenario because of the $50/ton permit price.[6] However, the energy-cost savings calculations for buildings technologies assume the same energy price as in the business as usual scenario. Since the study assumes that exogenous, undefined policy influences drive the penetration rates, the penetration rate should be set at 60% and the energy cost-savings should be recalculated with the appropriate energy price. In the industry chapter, the high efficiency penetration rate is assumed to be double the rate used in the efficiency scenario, which is the undefined "normal" rate. It is impossible to determine how much of this doubling of penetration results from undefined, aggressive policy efforts and how much results from the permit price.

The Industry Sector Analysis Ignores the Costs of Accelerated Retirement

> "When the economic losses of accelerated retirement are accounted for this means that, at the margin, all investments are not likely to be cost effective at our assumed 15% CRF [capital recovery factor]. Since we do not have a model to account for this potential early retirement and the economic losses, we must caveat our estimates of investment and net costs. ...the investment cost may be understated by the amount of loss due to any early retirement ~~that may occur~~" (p. 4.15).

The omission of costs related to the early retirement of capital implies that either

- the projected emissions reduction should be revised downward, because less technology will be adopted; or
- the cost of reducing emissions should be revised upward; or
- the cost of government programs to somehow force down the CRF from 33% to 15%

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[5] The August 1 draft does not mention the $25/ton permit in the chapters or appendices on buildings, industry, and transportation. It is impossible to identify how energy prices may have been incorporated in this scenario. We only address the available details on the $50/ton permit scenario here.

[6] The assumptions about penetration rates cast more doubts about the "true" cost-effectiveness of energy-efficient technologies. Why would an aggressive policy effort (efficiency scenario) result in the adoption of only 30% of cost-effective technologies between now and 2010? Why would a very aggressive policy effort (high efficiency/low carbon scenario) result in only a 65% rate of adoption -- and this is with a $50/ton permit fee? Clearly, these penetration rates demonstrate that the cost-effective technical potential ignores real costs of technology adoption.

would increase.

The Transportation Sector Requires "Luck" to Achieve Carbon Reductions

> "[B]ecause the [transportation sector] outcomes postulated in the high efficiency/low carbon scenario require technological breakthroughs, they require a certain degree of luck to be achieved by 2010. There are no credible methods to accurately gauge the probability of such breakthroughs -- we believe they stand a decent chance of occurring with an intensification of research efforts, but we stop short of claiming they are a likely outcome of such an intensification" (p. 5.3).

Note that this statement includes two qualifications: luck on top of intensified research efforts. These intensified research efforts may require two to ten times existing funding on transportation (p. 5.3). For perspective on what this might mean, it is worth keeping in mind that the Partnership for a New Generation of Vehicles (PNGV) alone is funded at the federal level at $263 million, and there are substantial additional private sector costs.

The "luck" apparently pertains to a number of tenuous technological assumptions: commercial development of the fuel cell for passenger cars, commercial availability of cellulosic ethanol (and the elimination of the ethanol excise tax exemption), and an apparently arbitrary 30% reduction in costs for "certain key technologies" (p. 5.24). These technologies are not identified, and the report does not provide documentation for the NEMS model runs conducted for the transportation sector.

Interactions Ignored, Double Counting "Likely" in Utilities Sector Analysis

> "Chapter 7 considers other electricity supply technology options, including: converting coal-based power plants to natural gas; cofiring coal with biomass; efficiency improvements in generation and transmission and distribution systems; extending the life of existing nuclear plants; increasing generation and capacity of existing hydropower plants; and constructing new powerplants using advanced coal technologies. Each of these options is assessed independently. Thus, interactions between the options are not taken into account, and the possibility of double counting is therefore likely" (p. 7.1).

The emissions reductions in the electricity sector come from two sources. First, utilities undertake fuel switching at the $50/ton permit price through carbon-ordered dispatching. Utilities would change their fuel mix by dispatching more electricity from their lower carbon-emitting facilities (e.g., nuclear, hydropower, and natural gas) and less from coal plants. Second, utilities modify their capital stock through several technology options such as those listed in the above quotation. As electricity production moves away from coal through modified dispatching, fewer and fewer plants (and therefore potential emissions reductions) will be available for conversion to natural gas or cofiring with biomass. The second set of analyses were "static" and did not optimize unit/plant production cost, dispatch, or system load. Conversations with one of the co-authors (Stanton Hadley of Oak Ridge National Laboratory) indicate that 10 GW of coal-to-gas conversions (approximately 9 million tons of carbon reductions, or 7% of reductions for dispatching and conversions) were double-counted.[7]

Study Double Counts Emissions Reductions Occurring Under Business-As-Usual

E/GDP Ratios for Business-As-Usual Case

AEO97 BAU	Labs Study BAU	CEA-Adjusted BAU
0.9%	0.77%	0.87%

The study states that it employs the Annual Energy Outlook business-as-usual (BAU) forecast for the buildings and industry sectors, with modifications that are "not greatly different from the EIA case" (p. 1.2) for the transportation sector.[8] The one modification stated in the study affects the fuel efficiency of the light duty vehicle fleet. While AEO97 assumes that fuel efficiency will increase in the future, the labs study assumes that fuel efficiency will remain constant. This change should result in a slower rate of energy efficiency improvement in the economy under business as usual conditions.

It's hard to tell what they're doing.

The AEO97 BAU forecast assumes an improvement of energy efficiency of 0.9% per year through 2015 (annual E/GDP = -0.9%). The study assumes energy efficiency improvement under BAU occurs at a rate of 0.77%. This difference appears to be somewhat significant. CEA contacted Art Andersen at the Energy Information Administration to determine how much of an effect holding fuel efficiency constant would have on the E/GDP ratio.[9] According to Andersen, constant fuel efficiency would be "rounding error" on the E/GDP ratio. He stated that this assumption would result in energy use increasing by 0.6 quads in 2010 over the BAU case. CEA recalculated the E/GDP ratio used in the AEO97 BAU to account for this extra energy use (assuming GDP remains the same across these cases), and found that annual E/GDP would decrease 0.87% under the constant fuel efficiency assumption. The labs study BAU assumes fewer energy efficiency improvements than should be expected under the appropriate BAU.

The labs study BAU has two implications. First, it should have a higher estimate of BAU emissions in 2010, since it assumes a smaller E/GDP ratio than AEO97. However, the lab study uses the AEO97 emissions estimate. The study assumes that this analysis results in emissions stabilization at 1990 levels in 2010 when the levels are actually above 1990 levels. Second, by

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[7] Hadley noted that a subsequent draft of the report should address at least some of the double counting, but he did not provide details. We could not identify any changes made to the analysis to account for changes in the dispatch that may affect the calculated emissions reductions by retooling coal plants to operate on natural gas.

[8] The labs study also modified the electricity sector forecast, but that modification is not relevant to our discussion of the energy efficiency of the economy.

[9] Art Andersen is the Director of the Energy Demand and Integration Division, EIA.

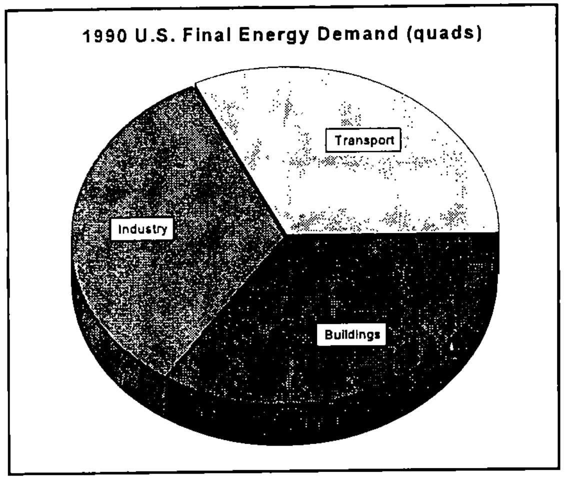
This section unclear.

calculating emissions reductions from the inappropriate BAU, the labs study double counts emissions reductions that will occur under the appropriate BAU. The CEA-generated BAU accounts for 18% of the E/GDP gains assumed in the efficiency case.[10] Assuming that E/GDP and carbon reductions are perfectly correlated (given that the efficiency case involves no fuel switching, this is reasonable), then the efficiency case overestimates emissions reductions by 22 MMTCE. Overestimates in the high efficiency cases would be greater than this.

[10] The AEO97 BAU would capture 25% of the efficiency gains in the efficiency scenario.

draft
7-22-97 Shooting for late next week

PROFILE OF U.S. CARBON EMISSIONS BY INDUSTRIAL SECTOR



Energy Profiles

- Three sectors each had approximately one-third of U.S. final energy demand in 1990 — transportation, commercial and residential buildings, and industry.
- The electric utility sector supplies about one-third of this final demand, virtually all in the buildings and industrial sectors, and consumes fuels to generate that power.
- Growth in carbon emissions parallels U.S. energy growth in general.

Re LDG
Clear w/ Dan what's the only thing to do putting politics aside. (1st half of mtg.)
1. Tim Gilbert background
2. L.S. perspective of LDG
3. JY comment
4. what should we be doing
Nontradable
Ramshaw will equal w/s

Joe Romm DOE study saying need ≥ 45/ton to get utilities to switch from coal, in addition to technology figures.

Carbon Emissions Trends — 1990 - 2020

- The profile in U.S. carbon emissions parallels the pattern of energy demand — the three sectors, transportation, buildings, and industry, each account for approximately equal shares
- Electric utility emissions in the chart at the right are double-counted in the end-use sector in which the electricity is used — and can only be reduced by either reducing end-use electricity demand or by switching to lower carbon content fuels
- The EIA growth projections show transportation likely to be the fastest growing sector of emissions out to 2020....up 53% over 1990
- The buildings sector is expected to increase emissions by % over 1990, or mm tons
- The industrial sector is projected to increase emissions by % over 1990, or mm tons
- Electric utility emissions are forecast to grow by % over 1990 levels, or mm tons

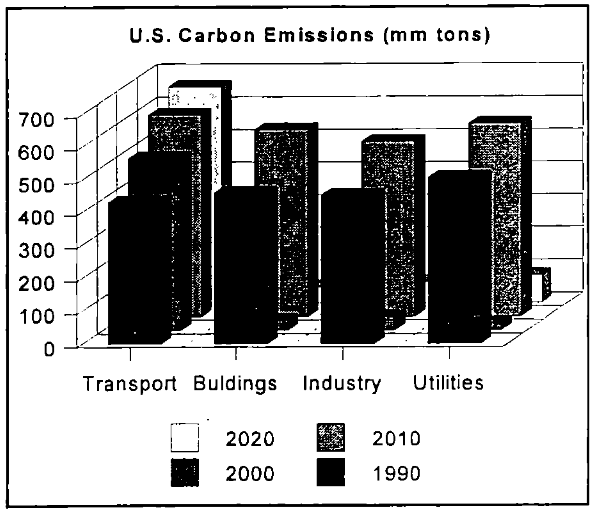


Figure 1

Dan Reicher Aside from price, Elect. dereg & Clean Air Act will do a lot. 5-lab study, PCAST

LONG-TERM TECHNOLOGY STRATEGY

Major long-term reductions in carbon emissions, and in many cases in energy usage, can be achieved if technological advances such as the following can be achieved and made commercially competitive:

Transportation
- Full PNGV vehicles..........80 mpg at today's performance and price
- Hydrogen fuels........through fuel cells for heavy trucks, rail, autos
- Electric vehicles

Electric Utility Systems
- Renewable energy systems...........solar, wind, biomass
- Future baseload technologies.........................

Buildings
- High efficiency technologies, intelligent building management systems

Industry
- ....

<u>Cost Issues</u>
- ....

<u>Long-term Market and Economic Uncertainities</u>
- Electricity deregulation, international competitiveness
- Lifestyle trend changes (eg, telecommuting, consumer preference for light trucks)

<u>Policy Issues</u>
- Federal and private R&D funding
- Role of public/private and international partnerships
- Incentives.........funding, prices, emissions trading allocations, partnerships, public relations, published performance data, required performance standards, other

MEDIUM-TERM, TECHNOLOGY PROVIDES A BRIDGING STRATEGY

In the medium-term, technology can serve a "bridging" function to allow time for the long-term R&D developments and the commercialization of various technologies to reach significant levels. For example, one scenario for returning U.S. carbon emissions to 1990 levels by 2010 would allow:

Transportation

- Energy usage can still grow, but technology would slow the increase to 16% vs. Business as usual 30%
- PNGV demonstration must succeed, and improvements must be gradually integrated into standard new vehicles

Commercial and Residential Buildings

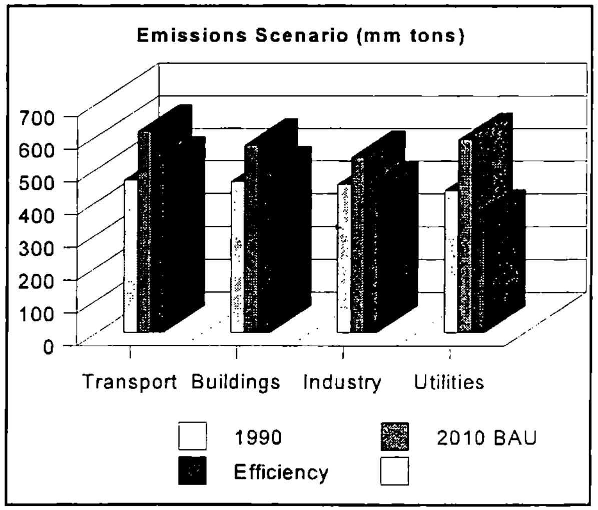
- Energy usage slows sharply — up 5% compared to 24% under BAU
- On one-third of normal replacement cycles and new installations, high efficiency equipment is used

Industry

- Energy usage essentially flat— down 2% vs. increase of 18% under BAU
- ....

Electric Utility Systems

- Would require absolute reductions in energy usage and emissions below 1990 levels in order to offset the increases in other sectors above
- Through a combination of reductions in end use demand growth in other sectors and increased use of natural gas in place of coal, overall electricity output would still increase, but emissions would drop 30% from 1990 levels



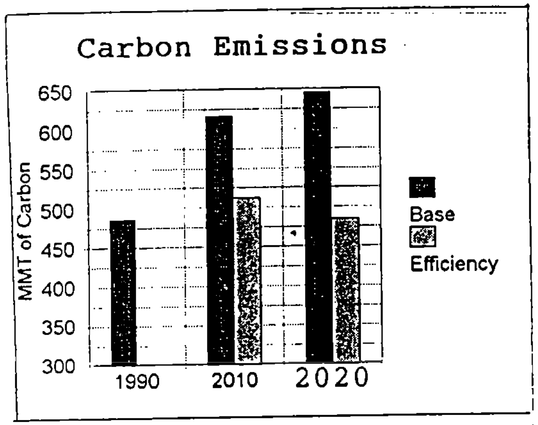
Costs

- ....

Policy Issues

- Incentives for commercialization and to spur capital stock turnover ....funding, prices, emissions trading allocations, partnerships, public relations, published performance data, required performance standards, other

Autos and Light Trucks



Source: EIA, Markal Model

Key Trends -- 1990-2010

- 33% of US carbon emissions are in the overall transportation sector, with autos and light trucks accounting for 20%.
- Fuel economy of new automobiles has been regulated at 27.5 mpg since 1985 and is projected to be 31 mpg in 2010. New minivans, sport utility vehicles and other "light trucks" get 20.6 mpg now and are projected to get ____ mpg in 2010.
- Light trucks were 20 percent of the personal vehicle market in 1974, 44% in 1996, and are projected to be ___ % by 2010, resulting in declining overall fuel economy performance.
- Vehicle miles traveled have been growing 2-3%/year for the past 30 years and are expected to be __%/year between 1997 and 2010.

Needed Technological Improvements

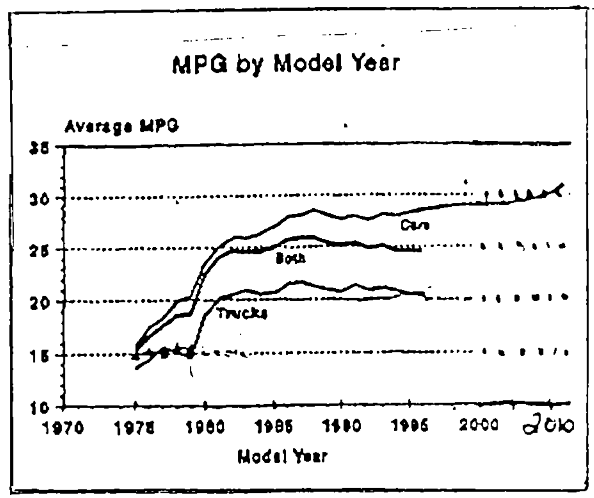
- Key technologies needed are weight reduction (advanced materials and design), hybrid/electric drivetrain (batteries, advanced turbines/fuel cells, electric controls), and aerodynamics.
- PNGV must succeed -- a production prototype at 80 mpg by 2004 with equal performance.
- Then, new cars by 2010 need to incorporate at least 30 percent of those improvements -- to reach 43 mpg.
- New light trucks by 2010 need ____ % of those gains -- to reach 31 mpg.
- Long term potential -- electric cars, hydrogen fuel cells.

Costs

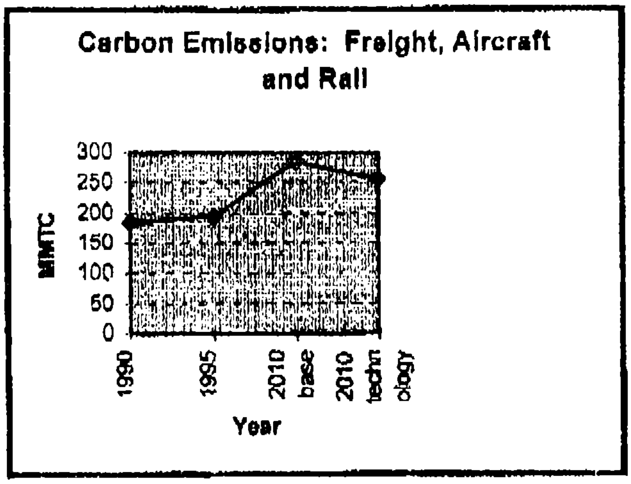
- At current technology costs, new autos would cost $800-$1,200 more, and would pay back in 3.5-5.3 years at current fuel prices.
- PNGV R&D costs, public and private $_______.

Policy Challenges

- Ensure success of PNGV.
- Incentives for commercialization -- prices, emissions trading credits, promotion, regulation, and financing.



Freight, Aircraft and Rail



Key Trends: 1990-2010

- Freight, aircraft and rail together accounted for 185 million tons of carbon dioxide emissions in 1990, nearly 40 percent of all emissions from transportation.
- All modes of freight transport have improved their energy efficiency. However, increased freight tonnage and shifts toward more energy-intensive modes have meant very little change in the total amount of energy used to haul freight since 1972. In 1995, about three times as much freight was transported as in 1972.
- Opportunities to reduce carbon emissions from freight are expected to come mainly from trucking and air transport.

Needed Technological Improvements

- Key technologies to reduce energy intensity in truck freight in the next 10-15 years include vehicle weight reduction through materials substitution, improved tires, electronic engine and transmission controls. More significant reductions are possible beyond 2010 if hydrogen-powered, fuel cell powertrains are developed and commercialized for truck transport.
- PNGV is a key to reducing energy intensity in truck transport in both the medium and long term. It is likely that hybrid powertrains could be significantly advanced if PNGV is continued and funding increased.
- NASA programs have helped to reduce energy intensity in air transport for over 20 years. Ongoing NASA and DOD programs are also working to improve fuel efficiency in aircraft engines and laminar (e.g. nonturbulent) flow of air over airframes. NASA's high performance turbine engine technology program aims to achieve a 40 percent increase in fuel efficiency by 2003, and such engines could conceivably be on commercial aircraft within 15 years.

Costs

- DOE estimates that annual costs needed to achieve emissions reduction in transportation range from $25-40 billion, and could save $35-40 billion annually in fuel costs.
- PNGV is funded at $_______________, and to succeed in achieving the kinds of emissions reduction sketched above, might need two to ten times this funding.

ADDITIONAL PAGES ON SECTORS

RESIDENTIAL AND COMMERCIAL BUILDINGS

INDUSTRY

ELECTRIC UTILITIES

cc: JA
Rl

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

FAX

Date:	August 26, 1997	Total Pages:	2
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MEMORANDUM

To: T.J. Glauthier (OMB), Jeff Frankel (CEA), Jon Gruber and Robert Gillingham (Treasury), and Peter Orszag (NEC)

From: Mark D. Levine (LBNL) and Marilyn Brown (ORNL)

Date: August 26, 1997

Subject: Response to the Economic Review of the Draft Report "Scenarios of U.S. Carbon Reductions, 2010"

The purpose of this memo is to note the ways in which we intend to respond to the review that was conducted in the multiagency meeting (EPA, CEA, Commerce, DOE, NEC, OMB, OSTP, Treasury) on August 19.

First, we noted the concern that the report, as written, could be picked up and misunderstood or misrepresented by the press. In particular, as Jeff Frankel articulated, there might be a sense that the carbon reduction scenarios could be achieved easily, and that it would only be necessary to check some box for policies to go into place to bring it about.

We also noted two related concerns: first, that the results were presented as scenarios with point estimates rather than ranges. Second, we note the belief that was stated that the economic analysis was incomplete, and that the study may have not included costs associated with achieving the carbon reductions.

We agree with the first concern. We do not believe that the results we obtained mean that achieving 1990 carbon emission levels in 2010 is either easy to do or even reasonably achieveable in the policy environment in which we now find ourselves. We do believe that, if policies were put in place and effectively implemented, the net cost of the scenario could be low or even negative. But that depends (among other things) on the ability to reach concensus in Congress and the White House on a number of matters.

Regarding the presentation of point estimates of both carbon reductions and costs: we agree that these point estimates can easily lead the reader to assume the these results are known much better than they are. It is a feature of scenario analysis that one often "pretends" certainty for a given scenario, in order to illustrate simply the consequences of a set of assumptions. One then deals with the uncertainty through (1) sensitivity analyses to the scenarios or (2) offering different scenarios. However, we are sensitive to the concern that leaving the results as they are will increase the likelihood of misinterpretation by the press and others.

Finally, regarding the comments on the economics: in our view, we have done a great deal of work on the microeconomic costs of bringing energy efficiency and low carbon technologies into the market. We will respond more fully on this when we respond to the memo from Robert Gillingham and Jonathan Gruber to T.J. Glauthier of August 21 entitled "Comments on the 5-labs Study." Nonetheless, we do agree that there is more uncertaintly in the economic analysis than the reader might believe reading the report, and we will strive to make that clear in the next version.

In conclusion, we intend to respond to the comments in the meeting by modifying the executive summary and chapter 1. Analysis Results, by either eliminating point estimates or presenting sensitivity analyses and in other ways (more and better caveats) to try to avoid misunderstandings of our results. We will also respond to the written comments separately, thus permitting a more in-depth exploration of the other issues that were raised about the study.

Office of Economic Policy

Department of the Treasury • Washington, D. C. 20220

Cmn to Shogren Luter Aldy Frankel

FAX

5 Labs

Date: August 12, 1997

Number of pages including cover sheet:

	Name	FAX Number	Phone Number
To:	Jeff Frankel	395-6947	
	Jay Shogren	395-	
From:	David Wilcox	202-622-2633	2-2200

REMARKS: ☐ Urgent ☐ For your review ☐ Reply ASAP ☐ Please comment

Attached are partial comments. Having an advance look may be useful.

Wilcox

MEMORANDUM

TO: Jay Shogren

FROM: Joe Aldy and Quindi Franco

DATE: August 11, 1997

RE: Review of DOE Labs Study, June 10 Draft

We provide an assessment of *U.S. Carbon Reductions by 2010 and Beyond: The Potential Impact of Energy-Efficient and Low-Carbon Technologies* (DOE Labs Study, June 10 draft). The report identifies carbon reductions and their associated costs in the buildings, industry, transportation, and electric power sectors under two hypothetical climate policy scenarios. The study finds that, with unspecified "very aggressive policies" and a $50/ton permit price, carbon emissions can be stabilized at 1990 levels by 2010. ~~In reviewing the report,~~ we believe ~~it is beneficial to highlight~~ several limitations of the study should be highlighted. First, the authors do not ~~provide~~ describe ~~descriptions of~~ the government programs ~~necessary to~~ that would stimulate the necessary technology adoption to reduce emissions of 180 million metric tons of carbon equivalent (MMTCE). Based on the actual history of CCAP, we estimate the costs of government programs to achieve these reductions could total $45 billion (1995$), depending on the form of the marginal cost curve. We annuitized this figure and found that government programs could cost $1.1 billion annually into perpetuity. These are costs in addition to existing program costs to improve energy efficiency technology development and adoption. Second, the analyses across sectors are not integrated. Therefore, the penetration rate of energy efficient technologies may be overestimated because the separate sectoral analyses do not account for declines in fuel prices. Third, the industry sector analysis ignores the costs of accelerating capital retirement~~, resulting in either an overestimate of reductions or an underestimate of costs~~. Fourth, the transportation sector requires "luck" in terms of technological innovation to achieve the projected emissions reductions. Fifth, the utilities sector analysis resulted in double counting of emissions reductions. ~~These examples of the qualifications can provide additional insight into the projections of emissions reductions and costs.~~ Upon receiving the final version of the report and documentation of the analyses, we will update this review.

I find this alarmingly small

yes

Doesn't the analysis also ignore implementation costs?

Overview of Report

The Labs Study estimated the carbon emissions reduction opportunities available through technology development and adoption and fuel switching. The Study employs the Energy Information Administration's 1997 baseline (AEO97) for the buildings and industry sectors. For the transportation sector, the authors changed the AEO97 assumption of increasing fuel efficiency in automobiles to constant fuel efficiency. For the utility sector, the baseline was modified to reflect a fully competitive bulk-power market in the year 2010. Discharge, shutdown, repowering, and new construction decisions were optimized to select the amount of capacity that minimized the cost of the power-supply system plus the cost of unserved energy. ? Compared to AEO97, the final baseline has slightly lower energy prices, larger electricity sales, and a greater share of gas generation. The study provides emissions reductions from this baseline for two scenarios: 1) "efficiency" and 2) "high efficiency/low carbon" over the period 1998-2010. The study describes neither the policies necessary to achieve emissions reductions nor the costs of federal programs for these scenarios, only their outcomes: increased adoption rates and better technologies.

With more electricity and more gas generation and more gasoline consumption, aren't we consuming a lot more energy in the baseline?

Efficiency Scenario

This case assumes that all technologies adopted are at zero or negative net cost to the user given more aggressive federal policies to stimulate development and diffusion of energy efficient technologies. The Study estimates that 120 MMTCE will be reduced at negative net cost in this scenario. None of these reductions occur in the utility sector as a function of fuel switching or technology adoption to increase combustion efficiency.

Does this make sense with lower prices?

What is this sentence saying?

High Efficiency/Low Carbon Scenario

This case assumes a "greater commitment" to reduce emissions through federal policies, in concert with state and private activities and a $50/ton permit price that stimulates low carbon technologies (read: primarily fuel switching). The policy is announced in 2000 and the policy's restrictions are phased-in through 2010. There is an assumed announcement effect (although an ? AEEI is not specified), increased domestic and international R&D in low-carbon technologies, and a "change in psychology". The Study estimates reductions of 180 MMTCE from the baseline through energy efficient technology adoption at negative net cost (see high efficiency without low carbon technology in chart below). The carbon permits will yield an additional 150-200 MMTCE of reductions through low-carbon technology adoption. Given that these occur at a permit price of $50/ton, the Study estimates the upper limits of these costs to be $10 billion per year in 2010.

Carbon Emissions (MMTCE): 1990 - 2010

1990	2010 Baseline	2010 Efficiency	2010 High Efficiency (w/o Low Carbon Tech)	2010 High Efficiency/Low Carbon
1340	1720	1600	1540	1340 - 1390

Review

The Lab Study employs several important assumptions in the analyses. ~~Learning about these~~ qualifications can enhance one's ~~understanding of the estimates regarding cost-effectiveness and~~

~~emissions reductions in this study~~. We ~~present~~ discuss several of the most significant assumptions ~~and discussions of their impact~~ below.

The Study Does Not Specify Policies to Achieve Carbon Reductions

> "Cost effectiveness is improved because R&D, in combination with increased deployment efforts, result in declining capital costs. We do not specify the policies, economic conditions, or exogenous events that could precipitate such changes" (p. 1.4).

The entire study is premised on two sets of undefined policies: an "aggressive" or "invigorated" public sector effort to stimulate energy efficient technology adoption (efficiency case) and a "very aggressive" public sector effort to stimulate technology development and adoption (high efficiency/low carbon case). The only specific policy instrument mentioned in the report is a $50/ton tradeable permit. The study ~~makes vague references to policies and only provides details~~ merely asserts that ~~on what~~ these unidentified policies would result in: 1) "better technology" (p. 1.5); 2) "higher penetration rates" (p. 1.6); 3) "changing the capital recovery factor [in industry sector] from 33% to 15%" (p. 4.8); and 4) "technological breakthroughs" (p. 5.3). These policy effects would result in reductions of 180 MMTCE for "free": firms and individuals receive energy cost-savings in excess of technology adoption and implementation costs. I thought these were ignored?

This is too text-bookish.

The report specifically states that the efficiency case reduces, but does not eliminate, market barriers (p. x)~~, and that implementation costs are ignored (p. xvi). First, we will discuss the implications of reducing market barriers, and then we will address the cost issue.~~ "Market barriers" can occur even in well-functioning~~, but occasionally complex~~, private markets. ~~Information is fully transmitted among all those in the market, although some information may seem incomplete to non-participants (read: policy or market analysts). A person addresses all real costs, but these costs can go undetected by analysts, hence the term "hidden costs". For market barriers, private costs match social costs, and~~ Even in the presence of such barriers resource allocation is efficient. Policy intervention to eliminate a market barrier cannot make society better off and usually makes society worse off, regardless of the implementation mechanism.[1]

* could insert material here from next page.

The economics literature has identified several barriers that may help explain the slow rate of technology adoption~~: 1) qualitative attributes differ across technologies; 2) private attributes of information; 3) private discount rate diverges from social rate and 4) heterogeneous usage levels~~. ?

Indent
- Energy efficiency is not the only thing that matters to consumers. ~~Qualitative attributes of technologies can affect adoption. Consumers of technology prefer technologies because of a set of characteristics, not just energy efficiency.~~ For example, some technology consumers may purchase a product with a lower efficiency than another product because the former is more reliable than the efficiency-superior product.

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[1] In contrast, policy intervention to eliminate a market failure (such as carbon emissions) may make society better off, depending on the costs of the intervention.

- New technologies may be costly to integrate with existing ones. Until all components of a complex system are fully depreciated, it may make sense to replace an energy-inefficient component with another likewise-inefficient component.
~~Private attributes of information include the tasks of learning how a new technology works with one's existing suite of technologies and identifying technology suppliers. Transaction costs exist with these tasks. If opportunities for economic gains in supplying this information exist, one would expect arbitrage to occur where middlemen consultants would assess the needs of potential adopters and match them with the appropriate suppliers.~~

No

The social discount rates to evaluate new technologies may not fully capture the uncertainty and risks faced by individuals and firms. These private actors may use a much higher discount rate reflecting the uncertainty of future energy prices, the reliability of the technology, the irreversibility of a technology investment, and the constraints on their ability to borrow capital.
If investment is irreversible, social = private, doesn't it?

~~Heterogeneous use of energy-intensive technology can affect who benefits from efficiency investments and who does not. If~~ Just because a technology is cost-effective on average, ~~it may not be~~ does not mean that it is cost-effective for all individuals~~, who do not use much energy~~. Those who may use the device less intensively may find it optimal to purchase a less efficient model.

~~These four types of market barriers illustrate the economic behavior that explains the apparent under adoption of energy efficiency technology (the "efficiency gap").~~ These barriers clearly demonstrate the difference between the technological maximum adoption (which only assumes technology costs) and the economic maximum adoption (which assumes total costs). ~~A set of climate change policies to stimulate technology adoption could increase efficiency, but only because they also decrease the effect of a market failure (carbon emissions). Social welfare is improved because the net benefits of indirectly fixing the market failure exceed the costs of removing the barriers. If carbon emissions are appropriately priced (assuming in this case that \$50/ton is the correct carbon price), a policy to remove a barrier (e.g., lower the capital recovery factor from 33% to 15%), will generate negative net benefits. High adoption rates will be realized once prices rise enough for some technologies to clear the barriers.~~

could move some of this to previous page.

~~From the literature on market barriers, we know that the costs of reducing barriers are greater than their benefits. In this case, the authors of~~ the Labs Study does not provide an estimate of the costs to government ~~to lower~~ of lowering market barriers ~~to achieve these substantial reductions (and they only provide benefits in terms of projected emissions reductions)~~. We ~~calculated~~ estimate ~~of~~ the costs of emissions reduction ~~programs~~ based on the government's experience with the Climate Change Action Plan (CCAP). CCAP promotes carbon reductions through a broad array of voluntary programs that stimulate "cost-effective" technology adoption by private firms. ~~Participation by a firm in a~~ Firms participating in CCAP program ~~implies that carbon is reduced and the firm gains financially~~ benefit financially in return for reducing emissions.[2] CCAP received appropriations totaling \$494 million (1995\$) during the FY95 - FY97 period. During this period, the Department of Energy and the Environmental Protection Agency can account for reductions of 14 MMTCE (see attached table). Each ton of carbon reduced in CCAP cost the federal government, on average, \$35.29 (1995\$) over this three year period. Assuming a flat marginal cost curve (MC = AC of CCAP), ~~to reduce 180 MMTCE beyond the baseline,~~ the ~~government~~ costs of ~~the unidentified policies in the Labs Study would~~

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[2] Note that CCAP efforts are incorporated in the AEO97 baseline.

Need footnote questioning why any gov't action is required to attain truly "cost effective" reductions.

I think stocks & flows are confused here.

attaining the 180 MMTCE reduction per year

exceed $6.3 billion. ~~To account for the opportunity cost of capital through time, we annualized this value and found that government costs would run about $150 million annually into perpetuity.[3] However~~ If—as is almost surely the case—, the marginal costs of technology adoption in the efficiency and high efficiency/low carbon scenarios are ~~definitely~~ higher than the average cost of 14 million metric tons reduced in the baseline scenario, —aggregate costs could be much higher. ~~especially as more and more efforts to reduce emissions are undertaken~~. Assuming that costs increase 10% for every 10 million metric tons of carbon reduced, then the government cost would total $16.1 billion per year ~~(annuity of $375 million)~~. This is a slowly increasing marginal cost curve given baseline assumptions of gains in energy efficiency. Assuming that costs increase 20% for every 10 million metric tons of carbon reduced, then the cost to government would exceed $45.2 billion (~~annuity of $1.1 billion~~) (see attached chart).

The Sectoral Analyses Are Not Integrated

> "The model runs for each of the three end-use sectors were not integrated and therefore may overstate the effects of technology penetration. In an integrated modeling effort, fuel prices might fall as consumption declines, resulting in less penetration of energy-conserving technologies" (p. 1.1).

The analyses of the various sectors assume that the reduction of 180 MMTCE occurs through energy efficient technology adoption without any price effect. This implies that, with government programs, private agents will adopt technologies because the benefits (energy cost-savings) exceed the costs of adoption. The authors claim that these reductions occur at zero or negative net costs. By failing to account for the effect of decreased energy demand due to energy efficiency technology adoption, some of those adoption decisions that occur on the margin would no longer generate positive net benefits for private consumers. The Labs Study indicates that energy consumption will decline from the baseline by 11.6% under the high efficiency/low carbon case (p. xi). This decrease in demand should result in a decrease in the price of energy, and cause some energy efficient technologies to become unattractive to private agents.

In addition, the absence of an integrated analysis precludes an assessment of the economy-wide effects of a tradeable permit system. As previous studies have indicated, the nature of the permit allocation (e.g., grandfathering, auction, or a hybrid) and the characteristics of the revenue recycling (e.g., various adjustments to existing taxes) can affect economy-wide investment. Understanding the effects on investment is instrumental in assessing the likelihood of success of these scenarios, given that they rely on substantial R&D and technology adoption.

The Industry Sector Analysis Ignores the Costs of Accelerated Retirement

> "When the economic losses of accelerated retirement are accounted for this means that, at the margin, all investments are not likely to be cost effective at our assumed 15% CRF [capital recovery factor]. Since we do not have a model to

[3] We employed a 7% discount rate to calculate the annuities in this paper.

> account for this potential early retirement and the economic losses, we must caveat our estimates of investment and net costs. ...the investment cost may be understated by the amount of loss due to any early retirement that may occur" (p. 4.15).

This assumption implies that one of three results should be accounted for in the analysis. First, the projected emissions reduction should be revised downward, because the assessment of the industry sector overestimates technology adoption by ignoring these costs. Second, the cost of reducing emissions, if the reduced carbon from this sector remains constant, should increase, with some technology adoption decisions occurring at positive net costs. Third, if the authors maintain the same costs and emissions estimates, then the costs of government programs to somehow force down the CRF from 33% to 15% would increase.

The Transportation Sector Requires "Luck" to Achieve Carbon Reductions

> "[B]ecause the [transportation sector] outcomes postulated in the high efficiency/low carbon scenario require technological breakthroughs, they require a certain degree of luck to be achieved by 2010. There are no credible methods to accurately gauge the probability of such breakthroughs -- we believe they stand a decent chance of occurring with an intensification of research efforts, but we stop short of claiming they are a likely outcome of such an intensification" (p. 5.3).

Note that this statement includes two qualifications: luck on top of intensified research efforts. To achieve just the efficiency level of emissions reductions for this sector (73 MMTCE), these intensified research efforts may require two to ten times existing funding on transportation (p. 5.3). To gain a sense of the magnitude of what such an increase in funding might be, consider that the Partnership for a New Generation of Vehicles (PNGV) alone is funded at the federal level at $263 million. Private sector costs of participating in the PNGV are in addition to this large sum. Further, the estimates of costless (on net) carbon reductions relies on a series of tenuous assumptions: commercial development of the fuel cell for passenger cars, commercial availability of cellulosic ethanol (and the elimination of the ethanol excise tax exemption), and an apparently arbitrary 30% reduction in costs for "certain key technologies" (p. 5.24). These technologies are not identified, and the report does not provide documentation for the NEMS model runs conducted for the transportation sector.

Interactions Ignored, Double Counting "Likely" in Utilities Sector Analysis

> "Chapter 7 considers other electricity supply technology options, including: converting coal-based power plants to natural gas; cofiring coal with biomass; efficiency improvements in generation and transmission and distribution systems; extending the life of existing nuclear plants; increasing generation and capacity of existing hydropower plants; and constructing new powerplants using advanced coal technologies. Each of these options is assessed independently. Thus,

interactions between the options are not taken into account, and the possibility of double counting is therefore likely" (p. 7.1).

The emissions reductions in the electricity sector come from two sources. First, utilities undertake fuel switching at the $50/ton permit price through carbon-ordered dispatching. Second, utilities modify their capital stock through several technology options such as those listed in the above quotation. As electricity production moves away from coal in the first analysis, fewer and fewer plants (and therefore potential emissions reductions) will be available for conversion to natural gas or cofiring with biomass. The second set of analyses were "static" and did not optimize unit/plant production cost, dispatch, or system load. Conversations with one of the co-authors (Stanley Hadley of Oak Ridge National Laboratory) indicate that 10 GW of coal-to-gas conversions (approximately 9 million tons of carbon reductions) were double-counted.[4]

Furthermore, the analysis of specific options did not examine the effect of increasing fuel prices (from gas demand due to coal-to-gas repowering). Given the range of assumptions considered in the study, the authors actually estimated that repowering coal plants for natural gas could result in carbon reductions between 5 million and 269 million tons (p. 7.2), depending on the gas/coal price differential, the cost of carbon, and the costs of sulfur dioxide and nitrous oxide emissions. This is quite a substantial range. The Labs Study estimates that natural gas consumption will increase 14% to 191% above 2010 baseline consumption. However, the DRI 1.25 run in the IAT report indicates a 16% decline in natural gas consumption, while the SGM run resulted in only a negligible decline and Markal-Macro generated a 6% increase in natural gas consumption. These three models indicate that a non-integrated analysis that does not account for the price change in natural gas may overestimate natural gas substitution for coal and emissions reductions from fuel switching.

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[4] Hadley noted that a subsequent draft of the report should address at least some of the double counting, but he did not provide details.

Summary of Greenhouse Gas Emissions-Reduction Actions

Million Metric Tons of Carbon Equivalent
Source: U.S. Climate Action Report—1997

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
Residential & Commercial Sector Actions		**26.9**	**10.3**	--
New	Rebuild America	2.0	1.6	--
1 and 2	Expanded Green Lights and Energy Star Buildings	3.6	3.3	--
3	State Revolving Fund for Public Buildings	1.1	Terminated	
4	Cost-Shared Demonstrations of Emerging Technologies			
5	Operation and Maintenance Training for Commercial Building Facility Managers and Operators	3.8	0.0	--
6	Energy Star Products	5.0	4.3	--
7	Residential Appliance Standards	6.8	0.2	--
8 and 11	Energy Partnerships for Affordable Housing			
9	Cool Communities	4.4	0.4	--
10	Update State Building Codes			
New	Construction of Energy-Efficient Commercial and Industrial Buildings		0.1	--
New	Superwindow Collaborative		0.0	--
New	Expand Markets for Next-Generation Lighting Products		0.2	--
New	Fuel Cells Initiative		0.0	--
Industrial Sector Actions		**19.0**	**4.8**	--
12	Motor Challenge	8.8	1.8	--
13	Industrial Golden Carrot Programs	2.9	Merged Into Action 12	
14	Accelerate the Adoption of Energy-Efficient Process Technologies		Terminated	
15	Industrial Assessment Centers	0.5	CCAP Component Terminated	
16	Waste Minimization	4.2	2.1	--
17	Improve Efficiency of Fertilizer Nitrogen Use	2.7	0.8	--
18	Reduce the Use of Pesticides		Terminated	
Transportation Sector Actions		**8.1**	**5.3**	--
19	Cash Value of Parking			
20	Innovative Transportation Strategies	6.6	4.6	--
21	Telecommuting Program			
22	Fuel Economy Labels for Tires	1.5	0.7	--
Energy Supply Actions		**10.8**	**1.3**	--
23	Increase Natural Gas Share of Energy Use Though Federal Regulatory Reform	2.2	Terminated	

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
24	Promote Seasonal Gas Use for Control of Nitrogen Oxides	2.8	0.5	–
25	High-Efficiency Gas Technologies	0.6	Terminated	
26	Renewable-Energy Commercialization	0.8	0.3	--
27	Expand Utility Integrated Resource Planning	1.4	Terminated	
28	Profitable Hydroelectric Efficiency Upgrades	2.0	0.0	--
29 30	Energy-Efficient Distribution Transformer Standards Energy Star Distribution Transformers	0.8	0.5	--
31	Transmission Pricing Reform	0.8	Terminated	
New	Green Power Network	Not included	0.0	--
Land-Use Change & Forestry Actions		10.0	2.4	–
43	Private Depletion of Nonindustrial Private Forests	4.0	Terminated	
44	Accelerate Tree Planting in Nonindustrial Private Forests	0.5	0.4	–
16	Waste Minimization	4.2	2.0	--
9	Expand Cool Communities	0.5	To be determined	
Methane Actions		16.3	15.5	–
32	Expand Natural Gas STAR	3.0	3.4	--
33	Increase Stringency of Landfill Rule	4.2	6.3	--
34	Landfill Methane Outreach Program	1.1	1.9	--
35	Coalbed Methane Outreach Program	2.2	2.6	–
36	RD&D for Coal Mine Methane	1.5	Terminated	
37	RD&D for Landfill Methane	1.0	Terminated	
38	AgSTAR Program	1.5	0.3	--
39	Ruminant Livestock Efficiency Program	1.8	1.0	--
Actions to Address Other Greenhouse Gases		16.3	25.4	–
17	Improved Fertilizer Management	4.5	5.3	--
40	Significant New Alternatives Program	5.0	6.4	--
41	HFC-23 Partnerships	5.0	5.0	–
42	Voluntary Aluminum Partnership	1.8	2.2	--
New	Environmental Stewardship Initiative	Not included	6.5	--
Foundation Actions			11.3	–
	Climate Wise	Not estimated	1.8	--
	Climate Challenge	Not estimated	7.6	--
	State and Local Outreach Programs	Not estimated	1.9	–
Total GHG Emission Reductions From CCAP		108.6	76.0	14.0

Data is not readily available for cumulative emissions reductions for many CCAP programs. Emissions reductions of about 5 MMTCE can be attributed to DOE's CCAP programs. EPA's Office of Air and Radiation is responsible for emissions reductions of about 9 MMTCE through their CCAP programs.

Costs of Reductions ($/ton)