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before the
U.S. Senate Committee on
Environment and Public Works
on "Climate Change and Ensuring America
Leads the Clean Energy Transformation"

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Executive Summary

My testimony today makes three main points.

1. Overwhelming evidence shows that we can meet 2020 emissions targets.

The bill recently passed by the House, H.R. 2454, and similar bills in the Senate, have been analyzed by many different sets of economists and engineers. Using different models and different assumptions, these studies all reach the same conclusion: we can reduce U.S. greenhouse gas emissions by 17%, 20%, or more by 2020, as compared to 2005 emissions. One of the most powerful tools for reducing emissions is also the most familiar: energy efficiency.

2. We can achieve these emissions targets at low cost.

The most authoritative study of the House legislation, by the EPA, shows that – even ignoring the costs of doing nothing, which are very large – the bill's annual cost to the average household will be just $80 to $111 (in present value). That's just 22 to 30 cents a day for the average American family – less than the cost of a postage stamp. To put it another way, it's about *a dime a day per person*. And because of special protections for low-income families, the lowest quintile of households will actually see a small net benefit from the bill.

Perhaps even more notably, the EPA analysis projects that under H.R. 2454, consumers will actually *save* money on their utility bills in the short run (through the year 2020), compared to business as usual. That's because even as the bill will keep household energy prices low, it contains other provisions to help boost energy efficiency and reduce energy consumption.

And study after study shows there are readily available tools to achieve emissions reductions at modest cost. One of the most powerful is energy efficiency. McKinsey & Company's latest analysis, for example, focuses solely on energy efficiency measures – and finds that we could achieve the required reductions by 2020 solely through energy efficiency measures, at low or even *no* net cost.

Part of the low cost is because good program design lets you get the biggest bang for the buck. A new Duke University policy brief released this week found that just 1.3% of all U.S.

manufacturers emit enough GHGs to be included under the threshold of 25,000 tons specified in ACES. Yet that 1.3% – about 4,500 of 350,000 manufacturers – is responsible for 82.5% of all manufacturing emissions.

3. **We can create jobs – while we achieve the emissions targets.**

Building a low-carbon economy can be a major – perhaps *the* major – economic driver for the U.S. economy over the next few decades. That's because behind every low-carbon solution is a long supply chain brimming with American jobs. A pioneering set of studies by researchers at Duke University has laid this out in detail. As the Duke studies show, low-carbon solutions – from energy-efficient windows to carbon capture and storage – will spawn new jobs in mining, component manufacturing, final product manufacturing, design, engineering, construction, marketing, and sales.

Introduction

I am honored to be here today as this Committee considers ways to combat climate change and ensure the United States leads the world in the coming clean energy revolution.

The stakes could not be higher. Already we are seeing signs of a changing climate – in the melting glaciers of our mountains, in the open waters of the Arctic, in dying coral reefs off south Florida and in disappearing terrestrial ecosystems. We see those signs in killer heat waves such as those that hit Europe a few years ago, and in droughts and disruption to agriculture in much of the world today. If we fail to act, we will commit our children and our children's children to a planet that is unrecognizable from the one our parents and grandparents knew. Inaction is simply not an option.

And yet my message is one of optimism and hope. As a nation, we've met challenges before and forged a stronger and more vibrant economy as result. That opportunity is before us again. By passing a comprehensive cap-and-trade program to control greenhouse gas emissions, we will unleash the enormous innovation and entrepreneurial drive of the American economy. Building a new energy infrastructure will mean jobs and investment right now, right here at home. And a cap-and-trade program will position us to lead the world into the clean energy economy, providing the technologies and the talent that will be in high demand throughout the world over the coming decades.

With the right policies in place, we can look forward to a fierce battle among brilliant scientists and entrepreneurs to make their names – and their fortunes – by making clean energy more affordable. Last week, for example, Robert Nelsen, co-founder of a venture capital firm, told a House committee that a start-up company's own tests show that it has developed a way to generate solar power at about half the cost of today's technology. Another company, Ausra, is betting that concentrated solar power will be the ticket to clean energy, and recently backed up that bet by building a factory in Las Vegas that has employed as many as 150 people. Still another firm, Verdant Power, is working on harnessing the power of the tides to generate low-carbon energy.

Though the opportunities for innovation and entrepreneurship are vast, the challenge before us can seem daunting. Science tells us we must reduce our emissions of greenhouse gases by 80% below current levels by the middle of this century, if we are to have an odds-on chance of avoiding dangerous tipping points in the climate system. To be on track to achieve that long-term goal, we must start cutting emissions throughout the economy as soon as possible, and bring them down to 17 to 20 percent below 2005 levels by the year 2020.

In my testimony today, I look at the best available evidence on how we can achieve that 2020 target. The record is clear: with known technology, we can meet and exceed that goal. And putting a cap on carbon will stimulate a spate of new technologies – and new business methods, like third-party financing of energy efficiency improvements – that will only strengthen our hand. In doing all this, we will build a stronger and more prosperous American economy.

Below, I provide the details behind those conclusions. I start by looking at the evidence from several different economic analyses of the opportunities for early emissions reductions. Although these studies make dramatically different assumptions, they reach the same conclusion: the potential for reducing emissions is vast. We have the technologies to get started now, and to achieve big reductions in emissions at low cost over the next decade. And with an emissions cap that results in a price on carbon, we will generate new tools that will do so even more efficiently.

In effect, these studies offer a road map to achieve a 2020 target of reducing emissions by 17 to 20% below 2005 levels, even without the innovation that we know will come.

That many independent studies reach the same conclusion gives us enormous confidence that achieving a 2020 target does not depend on a single set of assumptions or a single silver bullet. Rather, there are multiple ways to get to where we need to go. What matters is that we get started now.

After taking stock of the macroeconomic evidence, I then hone in on two particular areas that could make major contributions to achieving our goals: energy efficiency and carbon capture and storage. (Carbon capture and storage, or "CCS," means capturing carbon dioxide at power plants or factories and pumping it into underground geological formations for long-term storage.) Each of these areas can dramatically reduce emissions while creating jobs and establishing American technological leadership.

A key point in all of this is that, contrary to doomsday predictions from extremist think tanks, the costs to American households of capping greenhouse gases will be minimal: less than the cost of a postage stamp per day. The EPA's analysis of the clean energy bill passed by the House says that, over the entire life of the bill, the annual cost to the average household will be just $80 to $111 (in present value). That is just 22 to 30 cents a day for the average American family – less than the cost of a postage stamp. To put it another way, it's about a dime a day per person. And according to the Congressional Budget Office, the bill's special protections for low-income families mean that households in the lowest income quintile will see an average annual net *benefit* from the bill of about $40 in 2020.[1]

A final word on timing: the rest of the world is watching our political process closely, because our leadership is crucial to achieving an international agreement on reducing greenhouse gas emissions. The key date is this December, when U.S. negotiators will meet with their counterparts from around the world in Copenhagen. I strongly urge the Senate to work with the House and the President to pass a strong climate bill before the Copenhagen conference convenes in December.

1. The potential for low-cost abatement

With just the technology we already have, we can meet a 2020 target of reducing emissions by 17 to 20% below 2005 levels. That conclusion emerges from analyses by the Environmental Protection Agency (EPA), the Department of Energy's Energy Information Administration (EIA), the Massachusetts Institute of Technology (MIT), and McKinsey & Company. Each of these studies projects that the necessary emissions reductions can be made, at marginal costs as low as $18 per ton. In fact, these studies estimate that the abatement potential far exceeds the roughly 1 billion tons needed to meet a 17% target.

In the formal macroeconomic modeling done by EIA, MIT, and EPA, emitters are expected to overcomply with emissions targets in the early years of a cap-and-trade program to build up an allowance "bank" that will keep costs low when targets tighten later on. In fact, while there is ample potential for international emissions reduction credits,[2] the U.S. can meet or beat the 2020 target based on domestic emissions reductions alone.

Crucially, none of these studies take into account the innovation and technological breakthroughs that will be unleashed by putting a cap on carbon. I return to this point below, in my conclusion.

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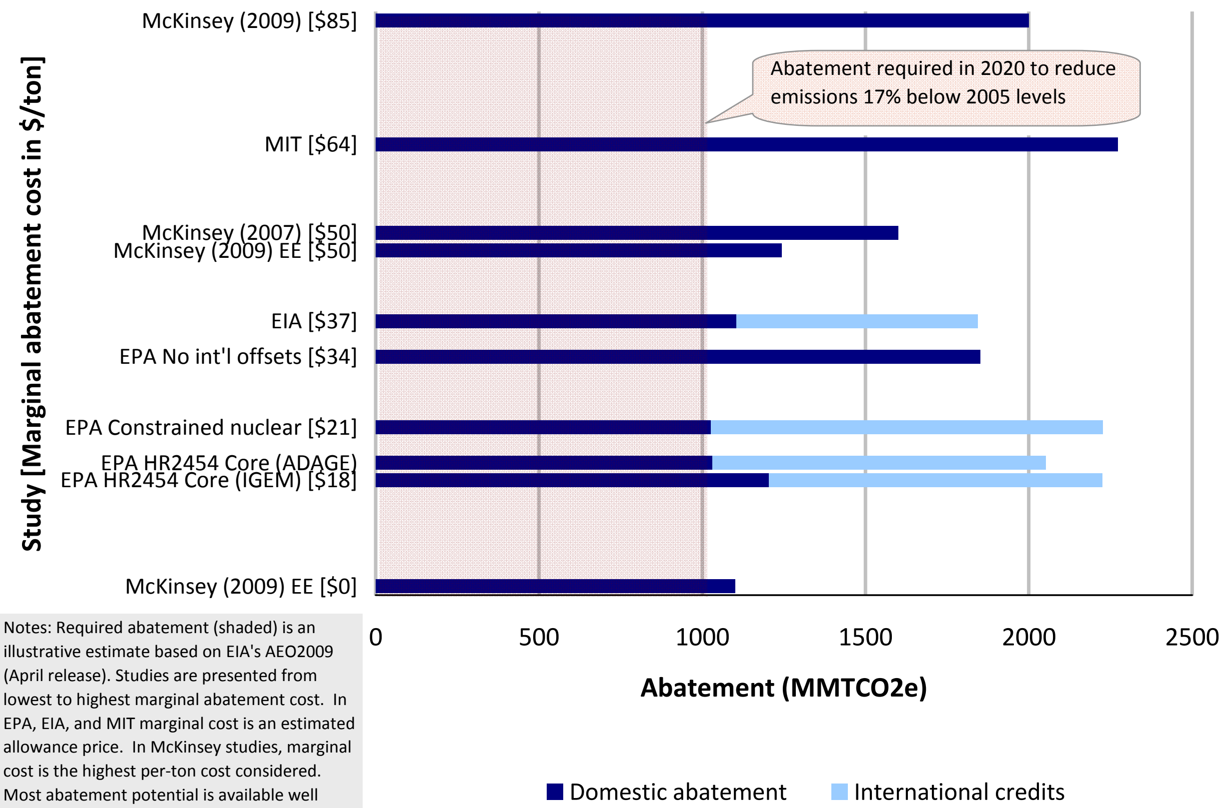
[1] Letter from Douglas W. Elmendorf, Director, Congressional Budget Office, to the Hon. David Camp (June 19, 2009).

[2] International emissions reductions that meet quality standards – i.e., reductions that are additional, measurable, and verified – would result in tradeable credits. These emissions reductions could be achieved, for example, by reducing tropical deforestation below an agreed national baseline.

Figure 1 — Estimated abatement potential in 2020, relative to that required under H.R. 2454.[3]



Notes: Required abatement (shaded) is an illustrative estimate based on EIA's AEO2009 (April release). Studies are presented from lowest to highest marginal abatement cost. In EPA, EIA, and MIT marginal cost is an estimated allowance price. In McKinsey studies, marginal cost is the highest per-ton cost considered. Most abatement potential is available well below these costs.

As Figure 1 shows, each of the EPA, EIA, MIT, and McKinsey studies shows we can achieve a 17% reduction in emissions below 2005 levels relying solely on domestic abatement. And the EPA and EIA studies show that, by using international credits (such as for reducing tropical deforestation), we can achieve much higher levels of emissions reductions, at a lower cost per ton. Note that the marginal abatement cost for the McKinsey 2009 study is the highest per-ton cost considered. Most abatement potential is available well below these costs.

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[3] Source: EDF analysis of EPA, EIA and MIT models and McKinsey studies.

1.1. Results from "top-down" analyses of U.S. climate legislation

Broadly speaking, there are two different ways of looking at the economic impact of a policy such as a carbon cap. One is a "top-down" analysis, using a macroeconomic model of the entire U.S. economy. The other is a "bottom-up analysis," which looks at the likely impact of a policy change on particular industries. I begin by describing the results of the most important top-down analyses.

EPA's Analysis of H.R. 2454

The best single analysis of the House legislation has been done by the Environmental Protection Agency, using two of the most widely respected and credible macroeconomic models: the ADAGE model maintained at the Research Triangle Institute, and the IGEM model run by a team at Harvard and Northeastern Universities.

The models look at emissions reductions broken down by three sources: (1) sectors that are covered by an emissions cap (electric and natural gas utilities, major manufacturers, and petroleum), (2) domestic "offsets" (activities on farms and in forests that store more carbon or reduce carbon emissions), and (3) credits for international emissions reduction (such as reducing destruction of tropical forests). Reductions are measured in metric tons of "carbon dioxide equivalent," a measuring tool that puts other greenhouse gases, such as methane and nitrous oxide, on the same scale as CO_2. (The term $MMTCO_2e$ means million metric tons of CO_2-equivalent.) <u>All reductions are measured relative to the models' "Reference" case, which represents business as usual – that is, in the absence of any new climate legislation.</u>

For 2020, the results of the ADAGE and IGEM models are as follows:

- Emissions reductions from sectors covered by an emissions cap: 808 million metric tons of carbon dioxide equivalent (ADAGE) and 1,028 $MMTCO_2e$ (IGEM), or an average of 918 $MMTCO_2e$;
- Emissions reductions from domestic offsets: 186 $MMTCO_2e$ (ADAGE) and 176 $MMTCO_2e$ (IGEM), or an average of 181 $MMTCO_2e$; and
- International emissions reductions, such as from reducing tropical deforestation: 1,021 $MMTCO_2e$ (IGEM).

These numbers are from the EPA's "Core" policy scenario, embodying a central set of assumptions about how the legislation will be implemented. Of course, model outcomes often depend heavily on the underlying assumptions. For that reason, EPA also runs alternative scenarios to test the sensitivity of model results. In particular, EPA analyzed a scenario in which nuclear power under climate legislation is constrained to be the same as in the reference case, and another scenario in which international credits are assumed to be completely unavailable. As

Figure 1 shows, the underlying conclusion remains: even in these alternative and highly constrained scenarios, the EPA analysis identifies abundant abatement opportunities, well beyond what is required to meet the targets in the legislation.

Comparable macro studies show similarly large potential

I summarize here the results of two other top-down, macroeconomic studies of cap-and-trade legislation. Both studies echo the EPA analysis in finding the abatement potential at hand to meet 2020 targets for emission reductions – and to do so affordably. (Again, these studies are conservative in that they do not account for future technological innovation that a cap would unleash.)

The Energy Information Administration (EIA) has not yet released its analysis of H.R. 2454. The numbers presented here are from its analysis of the 2008 Lieberman-Warner bill, which would have required cumulative abatement over the period 2012-2050 at levels similar to H.R. 2454.

For the Lieberman-Warner bill, the EIA modeled emissions reductions of about 1,844 $MMTCO_2e$ by 2020. Abatement would be achieved from a combination of new clean energy sources, carbon capture and storage, and energy efficiency. In particular, EIA estimates that in 2020, abatement from covered entities would be about 825 $MMTCO_2e$, offset purchases would amount to 1,019 $MMTCO_2e$, and abatement from CCS would be about 147 $MMTCO_2e$. Domestic and international offsets will cover 55% of required abatement by 2020 and the rest will come from known technologies, including 8% from CCS.

A modeling team at MIT also analyzed the 2008 Lieberman-Warner bill, finding that the required emissions reductions could be achieved from a mix of nuclear power, carbon capture and storage, and renewable energy such as wind and solar.[4] The MIT team then re-ran new scenarios with updated costs for CCS and without a direct CCS subsidy.[5] Even so, the MIT model shows only small increases in nuclear – and no coal with CCS use until after 2020. Until that year, the MIT model shows CCS being used only for natural gas – and even there, only if the most stringent emissions limits are in place. In other words, the MIT model achieves large near-term emissions cuts without significant reliance on CCS or new nuclear power.

A close look at the electric power sector

In the near term, a substantial fraction of domestic emissions reductions are expected to come from the electric power sector, which accounts for over one-third of total U.S. emissions (and roughly 40% of the emissions that would be covered by H.R. 2454). A close look at projections

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[4] Paltsev et al. 2008, *Assessment of U.S. Cap-and-Trade Proposals*, MIT Joint Program on the Science and Policy of Global Change, at 146, Appendix D.

[5] Paltsev et al. 2009. *The cost of climate policy in the U.S.*, at 173.

for electricity generation provides additional insight into the modeling results – and additional confidence that we can meet the emissions targets in the legislation. While all of these models rely on the same basic building blocks – nuclear power, renewable energy, carbon capture and storage, and energy efficiency – they combine them in very different ways to get the same end result.

- The ADAGE model identifies considerable abatement potential from biomass (its share rising from 0.6% of generation in the reference case to 4% in the policy case) as well as wind and solar power (increasing from 1.8% to 2.8%). New state-of-the-art coal plants (integrated gasification combined-cycle) equipped with carbon capture and storage are projected to come online, providing roughly 5% of power generation under the policy scenario (versus zero in the reference case). But the single biggest contribution comes from energy efficiency: the reduction in energy demand under the program amounts to roughly 10% of energy demand, or roughly twice the contribution of CCS.

- The EIA model relies somewhat more heavily on nuclear power (its share increasing from to 22% of generation in the policy scenario versus 20% in the reference case) and renewable sources (jumping from less than 13% to over 17% of generation). On the other hand, energy demand does not fall by nearly as much, so that energy efficiency accounts for much less of the abatement in the sector. (CCS plays an important role by 2030, but its growth in the near term is not detailed in the EIA report.)

- In contrast, MIT's model shows very little increase in electricity from renewables – only 10% more than business as usual. Likewise, the MIT model projects only small increases in nuclear power. The largest impacts come from fuel-switching and from reduced use (energy efficiency) – which account for around 20% in the MIT analysis of Lieberman-Warner, and over 10% in MIT's latest modeling run.

In short, the top-down macroeconomic models take a range of approaches and employ a range of assumptions. But all of them find abundant abatement potential to meet and even exceed a near-term emissions reduction target of 17% below 2005.

Finally, I should point out what may be obvious: what models predict today is not precisely what the market will select in the future. But the models provide valuable insight into the range of market results that we can expect.

1.2. "Bottom-up" studies confirm 2020 abatement potential

The macroeconomic studies I just described take a top-down approach to modeling the U.S. economy. These studies capture broad patterns of substitution inside the economy, along with major areas of emissions reduction. They explicitly account for the interactions of markets for labor, capital, materials, and outputs. That's in many ways the right approach, but these models do not attempt to represent in detail the technologies that will actually do the job of emissions reduction. For that task, we can turn to "bottom-up" studies, which tell the story from the perspective of the businesses that will actually do the heavy lifting.

In a series of recent studies, the management consulting firm McKinsey & Company has been a leader in applying this approach to the emissions reduction potential of the U.S. economy. The message from McKinsey's work is clear, and confirms what I discussed above: we have the technologies to meet ambitious 2020 abatement targets at a very low cost. Happily, in many cases, the technologies identified by McKinsey could even provide cost *savings*.

In fact, history tells us that businesses will usually find ways to do even better than analysts predict at the outset. Adoption of a cap-and-trade system for sulfur dioxide in the 1990s, for example, meant that utilities had to come up with results – but it left up to the utilities how to achieve them. The result was to redirect R&D towards scrubbers that removed more pollution, while giving electric utilities a strong economic incentive to adopt more cost-effective scrubbers.[6] And the biggest changes spurred by cap-and-trade were process innovations that cut pollution at much lower cost than anyone had expected.[7] Thanks to all this, the cost of reducing acid rain pollution proved to be only about a third of what was projected at the time of enactment.

The same has happened as the United States has regulated a wide range of different pollutants. The details are set forth in the attached EDF fact sheet, "Air quality measures consistently cost less than predicted."

McKinsey's economy-wide analysis of costs (or savings) from moving to a low-carbon economy

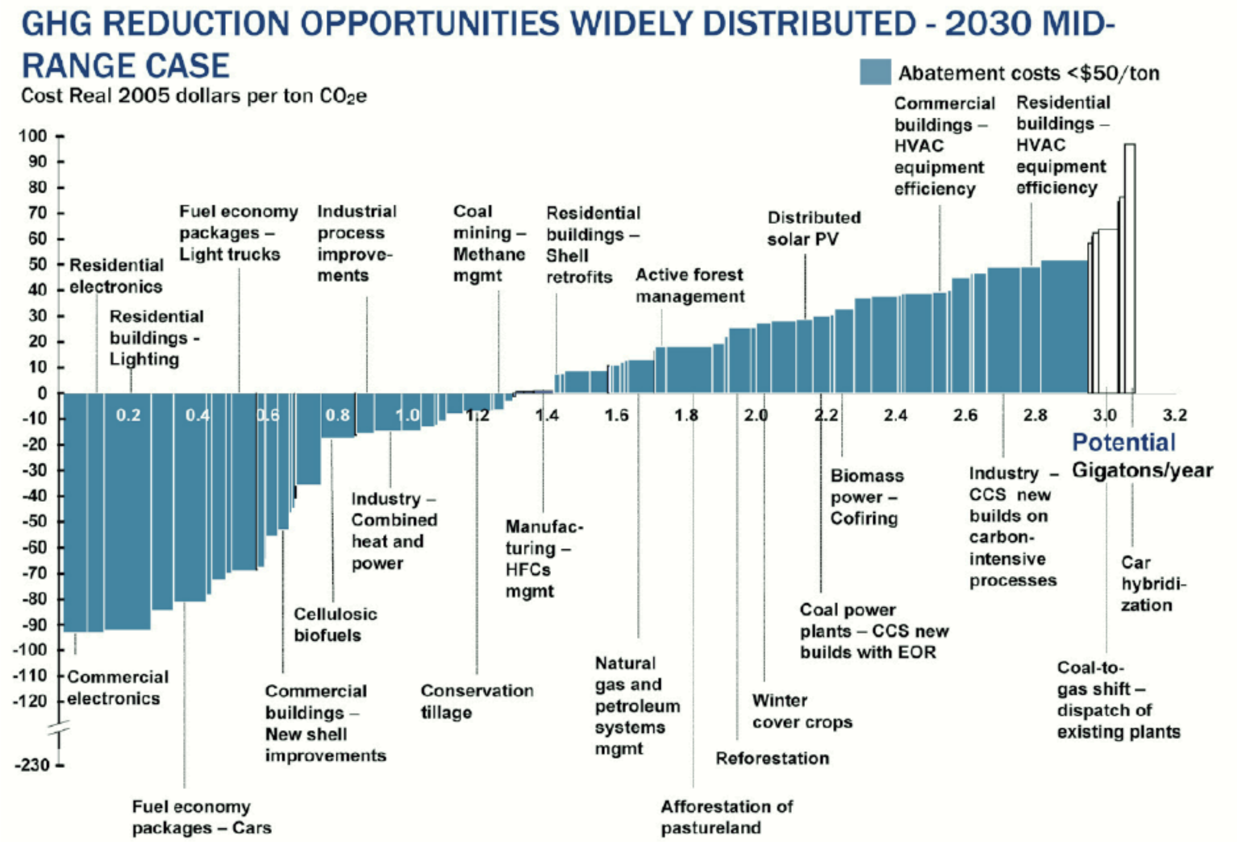
In 2007, McKinsey published a survey of abatement opportunities in the United States that could be available at a cost under $50 per ton by the year 2030. The McKinsey survey catalogued 250 abatement options, grouped in 75 categories in five sectors: buildings, industry, power, transport, and agriculture, waste and forestry (as a group). In its mid-range case – which does not assume aggressive deployment of technologies or the impact of an economy-wide cap-and-trade program – McKinsey estimated that U.S. emissions could be reduced by 3,000 $MMTCO_2e$ in 2030. Much of this abatement potential is likely to be available quickly.

McKinsey estimated that half of the total abatement potential (1,500 $MMTCO_2e$) would be available with carbon prices below $10/ton, while over 60% (1,860 $MMTCO_2e$) would be available under $25/ton. Moreover, many of these low-cost technologies achieve considerable savings in energy costs once installed. As a result, we can expect to see early deployment of many

6 David Popp, *Pollution control innovations and the Clean Air Act of 1990*, Journal of Policy Administration and Management, 22(4): 641-60 (Fall 2003); Nathaniel O. Keohane, *Environmental Policy and the Choice of Abatement Technique: Evidence from Coal-Fired Power Plants*,, working paper (2005).

7 Dallas Burtraw, *Innovation Under the Tradable Sulfur Dioxide Emissions Permits Program in the U.S. Electricity Sector*, Resources for the Future Discussion Paper 00-38 (September 2000).

of these abatement opportunities as market participants seek to reduce their exposure to the possibility of higher energy costs.



Although the 2007 McKinsey study did not estimate the abatement opportunity that might be available in 2020, EDF derived the numbers above from McKinsey's analysis for the mid-range case, for which EDF has access to the underlying data. EDF considered each of the 75 McKinsey abatement categories individually and excluded all that do *not* represent low-cost, readily available technologies. We were left with four categories of near-term abatement opportunities: agricultural and forestry offsets; energy efficiency gains in residential and commercial buildings; fuel economy improvements in automobiles; and process changes in industrial and power sectors. These total 1,600 $MMTCO_2e$ of annual abatement opportunities, available at a cost below $50 per ton. And because these opportunities appear to be low-cost, *early availability* technologies, their full annual abatement potential should be available by 2020. Excluded entirely from this total were *all* new alternative power sources, *all* industrial processes assumed to require major capital expenditures, and *all* ambiguous categories, as well as carbon capture and sequestration and expansions in nuclear power.

Earlier this year, McKinsey published a new survey of global potential for reducing emissions. In that study, McKinsey updates its estimates for total abatement opportunity in the United States. It identifies 2,000 $MMTCO_2e$ of abatement potential per year by 2020 at a cost below

€60/TCO_2e (or about $85/ton).[8] Some 1,500 $MMTCO_2$e are available at €20/TCO_2e ($30/ton) or below, 850 $MMTCO_2$e are available at *zero* net cost, after accounting for savings over the lifetime of the investment. This total includes some categories left off before, such as new alternative power sources, nuclear power, and carbon capture and sequestration.

The McKinsey studies find that the United States is likely to have the necessary technologies available, at low or even no cost, to meet and even exceed the *total* abatement that would be required to reduce emissions in 2020 by 17% or even more below 2005 levels. That is true even though these studies assume little innovation in the application of low-carbon technologies. Indeed, McKinsey is highly conservative: it considers only abatement opportunities either available on a commercial scale or already developed and awaiting deployment.

2. Energy efficiency

Energy efficiency has long played a critical role in economic growth. Since 1970, U.S. economic output has expanded by more than three-fold, per capita incomes are twice as large today, and yet energy and power resources have grown by only 50% over the same period.[9] California has seen even larger increases in economic output with – remarkably – no increase in per-capita electricity consumption.

Nevertheless, energy efficiency has been difficult to capture in top-down macroeconomic modeling. If we look at the historical trends, energy efficiency has often played a much larger role than originally estimated.[10] Even the most credible current models (like those in EPA models effort) may continue to underestimate the potential role of energy efficiency in achieving low-cost reductions in energy use.

McKinsey's report on energy efficiency potential

Energy efficiency is the cheapest and most often overlooked resource for reaching our emission reduction targets. In July 2009, McKinsey published a new study focused on energy efficiency potential in the United States.[11] The analysis looks *only* at investments that pay for themselves

8 Exhibit A.V.1 of the 2009 McKinsey *report*, *Pathways to a low-carbon economy: version 2 of the global greenhouse gas abatement cost curve*.

9 Laitner, John A., *The Positive Economics of Climate Change Policies: What the Historical Evidence Can Tell Us,* American Council for an Energy-Efficiency Economy, Washington, D.C., July 2009. http://aceee.org/pubs/e095.pdf?CFID=3136298&CFTOKEN=29476767

10 For example, a 1979 National Research Council report estimated that if the size of the U.S. economy were to double, and if energy prices adjusted for inflation remained the same, energy consumption would rise from about 72 quads in 1975 to 135 quads in 2010. The NRC model projected that if energy prices were instead to double, energy demand might grow to only 94 quads by 2010. However, in the past 35 years the economy has instead nearly tripled, and energy prices have grown on average about 70%, but total energy use is estimated to be just under 100 quads next year. In other words, energy use under an economy that has tripled in size is far below what was predicted if the economy were merely to double.

11 The study is available at www.mckinsey.com/clientservice/electricpowernaturalgas /US_energy_efficiency.

over their lifetime (so-called "NPV[Net Present Value]-positive opportunities"),[12] and only at energy savings opportunities (as opposed to improvements in generating energy). Despite these constraints, McKinsey identifies emissions reductions totaling 1,100 $MMTCO_2e$ by 2020.

Happily, McKinsey reports that these energy efficiency measures pay for themselves even without any additional incentives. The savings in energy costs – $1.2 trillion in present value – exceeds their upfront cost of $520 billion. As a result, we could achieve these emissions reductions by 2020 and at the same time save $680 billion through 2020. And these calculations are based on a carbon price of *zero*. With a carbon price of $30 per ton of CO_2e, energy savings potential would increase by 8%, while at $50 per ton it would grow by 13%. With these carbon prices, the energy efficiency measures described in the McKinsey study would result in emissions reductions by 2020 of 1,188 $MMTCO_2$ (at $30/ton) and 1,243 $MMTCO_2e$ (at $50/ton).

To be sure, there are obstacles that interfere with capturing all of these savings For example, home builders typically try to minimize their upfront costs, which may mean skimping on technology (such as highly efficient HVAC equipment) that costs a bit more but would save buyers large amounts of money over time. Similarly, owners of commercial builders may be on the hook to pay for capital upgrades (such as more efficient lighting) while tenants pay the utility bills (and thus would enjoy the resulting savings). In addition, some energy efficiency opportunities must overcome engrained habits – or require people to make changes in behavior that they may resist. To overcome those obstacles, McKinsey argues for a comprehensive, holistic approach combining purely market-based approaches – such as putting a cap on carbon – with standards, education campaigns, innovative financing instruments, and other measures.

Analysis by Synapse Energy Economics

A May 2009 analysis by Synapse Energy Economics Inc. (and commissioned by EDF) confirms many of these energy-efficiency results. The Synapse study shows that the emissions reduction targets in H.R. 2454 could be cost-effectively achieved – and even surpassed – through proven energy-efficiency measures and modest implementation of agriculture and forestry offsets. For example, Synapse found that implementing policies to achieve 2% annual, cumulative savings from energy efficiency would result in avoidance of 1,120 $MMTCO_2e$ annually by 2030. This represents a 40% reduction below 2010 greenhouse gas emission levels for the electricity sector, and can be achieved very cost-effectively. The average cost of electric utility efficiency programs is often only about 3 to 4 cents per kilowatt-hour, compared to the national average electricity price of 9 cents per kilowatt hour. In other words, it can be much cheaper to avoid using energy than to generate more of it.

[12] McKinsey assumes a 7% discount rate in its base case.

Potential for job creation

In its pioneering study, *Manufacturing Climate Solutions*, Duke University's Center on Globalization, Governance & Competitiveness has analyzed a variety of low-carbon technologies to look at the business and job opportunities they will create.[13] The Duke team examines the value chain behind these technologies, and finds they will create a wide range of new jobs, from mining of raw materials, to manufacturing of components, to finished product manufacturing, and finally to installation and (in some cases) monitoring. To date, the Duke team has examined 11 low-carbon technologies, seven of which are in energy saving technologies: LED lighting, high performance windows, anti-idling truck technology, electric heat pump water heaters, industrial waste heat recovery systems, hybrid drivetrains for trucks, and insulation. (In addition, the study details supply chains for concentrated solar power, Super Soil systems for methane capture, carbon capture and storage, and wind power.)

In each case, a single low-carbon solution generates a complex web of economic activity – and of American jobs. Just an illustrative list of component manufacturers in the supply chain for electric heat pump water heaters counts 43 companies in 19 states. Thirteen component manufacturers in six states in the supply chain for high-performance windows alone have over 100,000 employees; and this does not yet count other portions of the supply chain from raw materials such as aluminum, vinyl and lumber to window manufacturers, wholesalers, retailers and contractors. On the whole, the seven energy efficiency supply chains account for hundreds of thousands of jobs all across the United States. Projected conservatively, looking at all the technologies for all the states, there are tens of thousands of small businesses poised to benefit from a cap on carbon.

3. Carbon capture and storage

3.1. CCS is "Ready to Roll"

The successful deployment of carbon capture and storage solutions, including geologic sequestration, is a critical path for adapting coal, the world's most abundant but carbon-intensive fossil fuel, to a carbon-constrained future. According to an IEA study released in 2006, CCS could rank, by 2050, second only to energy efficiency as a way of cutting greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) projects that CCS could, by 2100, contribute 15 to 55% of the greenhouse gas reductions needed to avert catastrophic climate change.

As a technical matter, CCS is ready to begin deployment today. In fact, Gardiner Hill, BP's Director of CCS Technology, calls it "ready to roll." Four full-scale CCS projects exist today –

[13] http://www.cggc.duke.edu/environment/climatesolutions/

one of which, the Sleipner project in Norway, has been in operation since 1996.[14] The Department of Energy recently announced that projects by Basin Electric Power Cooperative in North Dakota and Hydrogen Energy International in California have been selected for up to $408 million in funding from the American Recovery and Reinvestment Act for advanced technologies to reduce CO2 emissions. One project is for an existing power plant, while the other is for a new facility. Many other large-scale CCS projects are also pending in the U.S. and around the world.[15]

To achieve greater deployment, what is really needed is a market driver and a clear regulatory framework for the technology. CCS is currently expensive, and to reduce costs we need more experience at integrating the various technologies at large scale. But these are just more reasons to adopt a carbon cap now – to prompt more investment and advance the technology. A recent Harvard study says that "the cost premiums for generating low carbon electricity with CCS are found to be broadly similar to the cost premiums for generating low carbon electricity by other means." The study also suggests that costs are likely to drop 65% by 2030.[16]

On the storage side, geologic sequestration of carbon dioxide is clearly feasible under the right conditions. It has been successfully demonstrated in a number of field projects, including several large projects. The IPCC Special Report on Carbon Capture and Storage concluded in 2005 that the fraction of CO2 retained in "appropriately selected and managed geological reservoirs" is likely to exceed 99% over 1000 years. Although determining the suitability of a particular site requires extensive homework (such as geologic characterization) about specific sites, it is clear that the total storage capacity is huge. The IPCC estimates there is enough capacity worldwide to permanently sequester 1,100 gigatons of CO2. (For comparison, global emissions from large stationary sources are approximately 13 gigatons per year.)[17] A preliminary estimate in the Department of Energy's Carbon Sequestration Atlas suggests that storage capacity in the U.S. and Canada might handle 1,100 years of emissions from stationary sources.

The IPCC also concluded that the local health, safety, and environmental risks of CCS are comparable to the risk of current activities such as natural gas storage, enhanced oil recovery, and deep underground storage of acid gas if there is "appropriate site selection based on available subsurface information, a monitoring program to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO2 releases if they arise." (Enhanced oil recovery involves pumping a gas (such as carbon dioxide) underground to make it easier to extract oil.) The IPCC and others also find that the risk of leakage will tend to decrease with time.

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[14] The other CCS projects are the In Salah project in Algeria, the Snohvit project in Norway, and the Weyburn projects in Wyoming and Canada.

[15] A recent International Energy Agency study includes a survey of existing and planned projects. IEA, *CO_2 Capture and Storage: A Key Carbon Abatement Option* (2008).

[16] http://belfercenter.ksg.harvard.edu/files/2009_AlJuaied_Whitmore_Realistic_Costs_of_Carbon_Capture_web.pdf

[17] IPCC Special Report on Carbon Dioxide Capture and Storage (2005).

On the regulatory front, EPA is on track to adopt rules about geologic sequestration within the next few months. And many states are currently writing their own rules as well.

3.2. CCS: a jobs engine

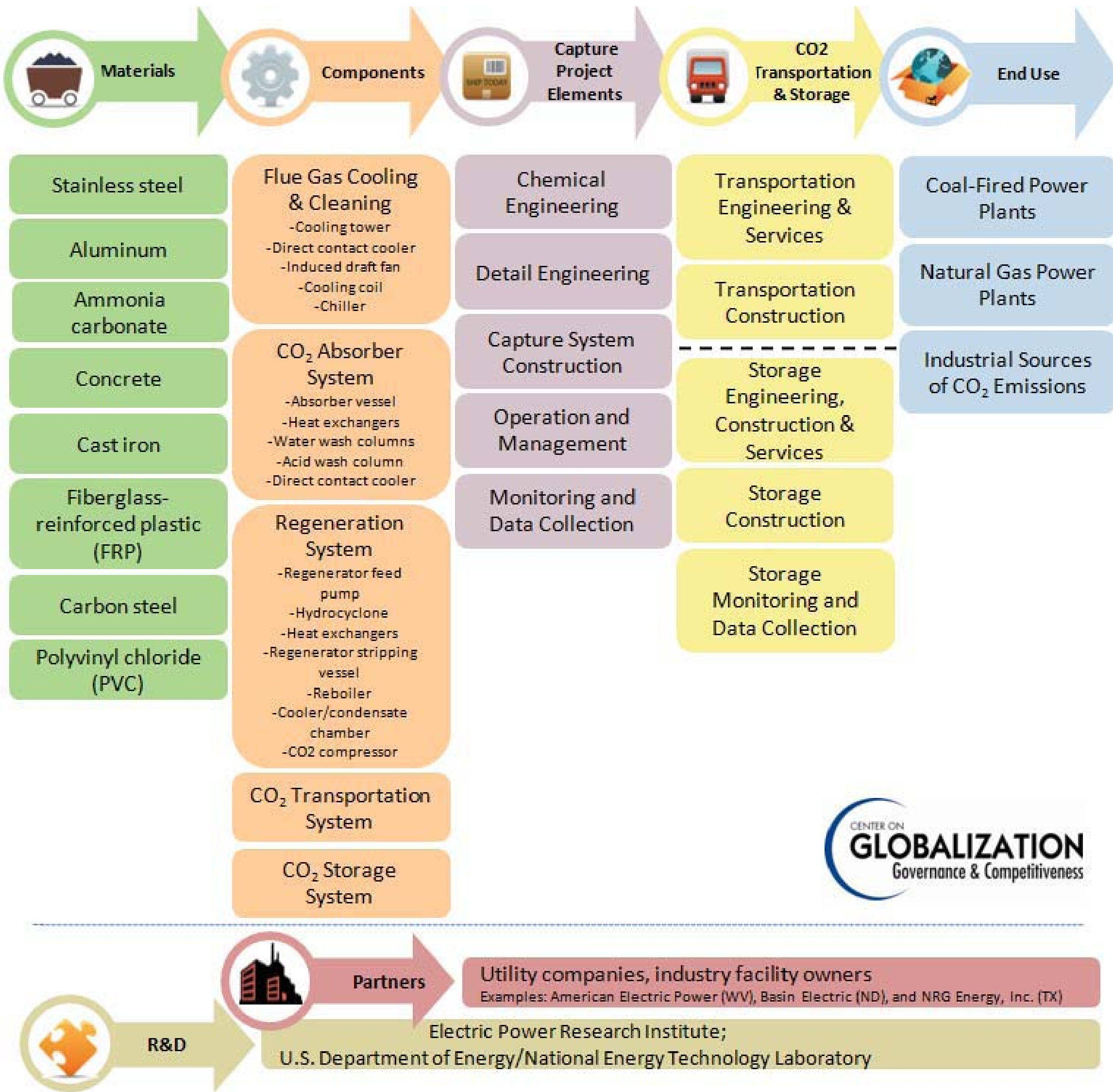
As described above, capturing and storing carbon dioxide would enable continued use of fossil fuel combustion for power generation and industry use while limiting the release of CO2 into the atmosphere. But deployment of CCS technology at large scale will do more: it will spur development of an entire new industry, with a large and robust supply chain.

There are three general processes for CO2 capture: pre-combustion, post-combustion, and oxy-fuel capture. These processes separate and condense CO2 so it can be transferred in liquid form to a long-term storage location.

I commend to you the latest chapter of the Manufacturing Climate Solutions report by Duke University.[18] That report illustrates the economic potential of CCS by detailing the value chains for one particular technology – the chilled ammonia capture process. This chart – a simplified value chain for this technology– will give you the idea:

[18] The complete report is available at www.cggc.duke.edu/environment/climatesolutions/

**Simplified Value Chain for a CO_2 Capture Technology:
The Chilled Ammonia Process**



Note that the value chain includes raw materials (which need to be mined or collected), component parts (which need to be manufactured), processes (which need to be engineered), and transportation and storage (which require a variety of service workers). Each of these points along the value chain is an opportunity to create jobs for skilled workers such as steel workers, manufacturing technicians, welders, pipefitters, chemical and civil engineers, and construction workers. Looking just at construction, Alstom estimates that building a chilled ammonia process facility for a 600 MW power plant would take three years and require 2,000 construction jobs. And Powerspan officials estimate that a CCS facility for a 100 MW power plant would take between three and four years to construct and create up to 500 jobs at its peak.[19]

[19] Procopis, 2009.

These jobs would be created all over the country. And these examples are for just one part of the value chain for just one of the three types of capture technologies. Each way of capturing carbon will have its own value chain of materials, components, project elements, transportation and storage, and end use.

The Duke researchers have shown the same thing for 10 other low-carbon technologies. It turns out, for example, that American manufacturers are world leaders in making energy-efficient windows – and that those manufacturers, in turn, rely on a long American supply chain of component manufacturers and providers of raw materials. The Duke research shows the same story again and again, for technologies as diverse as LED lighting and methane capture from animal wastes.

4. Conclusion

I've summarized the results of many different economic studies. All show we can reach ambitious emissions reduction targets by 2020 with known technology at an affordable cost. In fact, although H.R. 2454 calls for a 17% reduction target, the economic evidence I've discussed here shows that a 20% reduction is easily within reach.

But reducing emissions is only half the story.

We will also see tremendous innovation. At the turn of the last century, the largest environmental problem facing large cities such as New York was horse manure. Tens of thousands of horses produced more than 1,000 tons of manure each day. That meant that hundreds of horses were needed just to haul the manure away, not to mention the land necessary to house and feed the horse population. The fight between food and fuel was very real even then, and the model of cities looked unsustainable. We know, of course, what came next: the combination of Henry Ford and John D. Rockefeller saved the day, and oil-powered cars replaced horses as the main means of transport in New York and across the United States.

Fast forward 100 years, and we face a new problem: weaning ourselves off of oil. We know that the tools are already out there to do so – we just need to use them. We also know that markets have proven time and time again that they are the most powerful way to unleash that innovative potential and make the impossible possible. Cap-and-trade with ambitious emissions reduction targets establishes such a market and enables us to use the power of markets as an unambiguous force for good.

What's driven progress in the U.S. economy is technological innovation – in the context, of course, of a market economy that has provided incentives for that innovation. We've led the way in the major economic transitions of the past century: wide-scale mass production; the development of semiconductors; the space age; the Internet age. The smashing success of semiconductors illustrates the central importance of technology to U.S. economic growth. From the invention of the transistor in 1948, to the development of integrated circuits in the 1950s and

1960s, to the emergence of microchips in the 1990s – at every stage, the United States has led the world, and our leadership in this area has led to our phenomenal postwar growth.

For the upcoming decade, clean energy can play the same role in the U.S. economy that building a powerful military machine to win World War II did in the 1940s – and that the computer revolution did in the 1990s. Putting a ceiling on carbon emissions will inspire American innovation that will position the United States competitively for growth in the worldwide transition to a low-carbon economy. Though Europe and Japan have already started down this road, we will start before China, India and other emerging economies. But eventually all countries will join the international system to limit carbon emissions.

The nations that lead the hunt for low-carbon technologies will find that a huge market awaits them. Will we develop and export the coming wave of low carbon technologies – like carbon capture and sequestration, next-generation solar panels, and powerful lightweight batteries – so that jobs and businesses stay in America? Or will we sit back and wait, only to find ourselves importing those technologies from overseas?

In my view, it's not a difficult choice: let's harness American ingenuity now to rebuild our economy and protect the planet at the same time.

APPENDIX

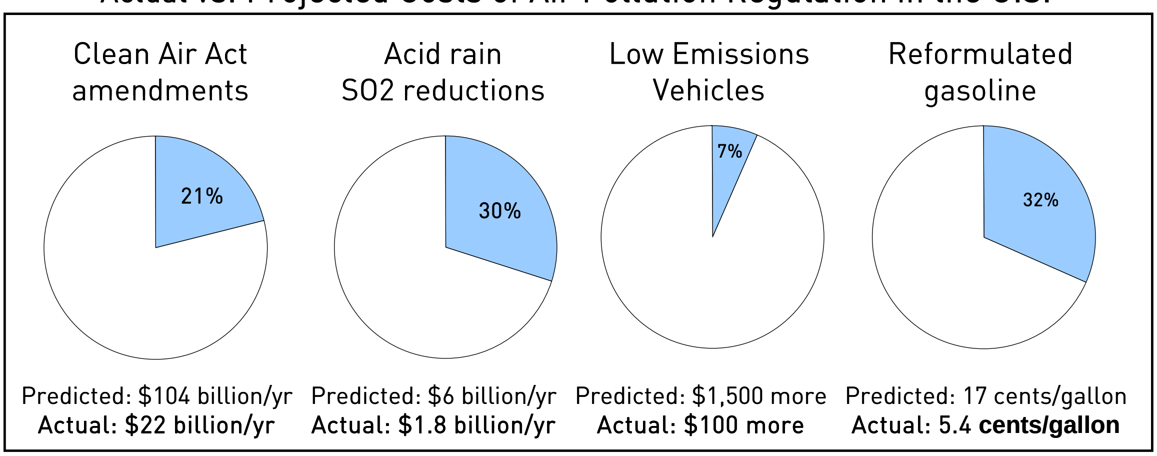
Air quality measures consistently cost less than predicted

In December 1970, the Clean Air Act became law. A triumph of bipartisanship, the statute has delivered cleaner, healthier air to millions of Americans. It has also proved to be one of the most cost-effective regulatory programs in American history. The U.S. Environmental Protection Agency (EPA) valued the total health benefits through 1990 at $22.2 trillion and the total compliance costs over the same years at $0.5 trillion, resulting in net monetary benefits of $21.7 trillion. The Clean Air Act continues to deliver these benefits, supplemented by the considerable health and environmental gains from the Clean Air Act Amendments of 1990.

Dire predictions and cost-effective results

Each time EPA has considered new clean air standards, it has been challenged with claims that meeting the new standards would not be feasible, practical or affordable. Yet time after time, the reverse has proved true. Benefits have overwhelmed the costs, which have been consistently lower than predicted. (See the figure below and the table on the reverse side).

Actual vs. Projected Costs of Air Pollution Regulation in the U.S.



The cost of cleaning America's air has been consistently lower than projected. This figure shows the actual cost of air pollution regulation as a percentage of initial predicted costs.

Cap-and-trade is the best approach to reducing emissions

One of the most innovative aspects of the Clean Air Act is its cap-and-trade approach to reducing emissions of sulfur dioxide, a precursor to acid rain. Initial analyses of the program warned of high costs, but these fears were not realized. In fact, the program demonstrates that properly designed market-based approaches can reduce emissions ahead of schedule and at far lower cost than conventional command-and-control regulation. The cap-and-trade approach provides incentives to reduce emissions, leads to low-cost environmental results and turns pollution reductions into marketable assets. Since its inception, the program has achieved 100% compliance in Phase I, reduced emissions at least 35% below 1990 levels and cost far less than projected.

Comparison of predicted costs of clean air programs with actual costs

Program	Predicted costs	Actual costs
Clean Air Act (CAA) amendments	**1990:** "The study we are releasing today estimates that the cost of the various proposed amendments . . . could be as high as **$104 billion** per year."[a]	**1995:** Five years after implementation, EPA estimated that the CAA amendments cost **$22 billion** per year.[b]
Acid rain	**1990:** The EPA estimated that Phase II costs would be **$6 billion** per year.[c] **1990:** The Edison Electric Institute estimated that SO2 reductions would cost the electric utility industry **$3.6–4.5 billion** per year.[e]	**2005:** The Office of Management and Budget estimated that the annual cost of reducing SO2 is **$1.1–1.8 billion**.[d]
Low emissions vehicles	**1994:** Automobile manufacturers estimated that low emission vehicles would cost **$1,500** more than comparable car models.[f] **1990:** The California Air Resources Board estimated the average incremental cost of a low emissions vehicle to be **$170**. Industry estimates in California were **$788**.[h]	**1995:** One year after this estimate, Honda placed a Civic subcompact model on the market that emitted less than half of what was permitted under California law. This vehicle cost only **$100** more than comparable models.[g] **1998:** The actual incremental cost of low emission vehicle technology was **$83**.[i]
Reformulated gasoline in California	**1991:** The California Air Resources Board predicted that reformulated gas would lead to a price increase of **12–17 cents** per gallon.[j]	**1998:** The actual price differential was **5.4 cents** per gallon.[k]

a Business Roundtable. "Clean Air Act Legislation Cost Evaluation." January 18, 1990.
b E.H. Pechan & Associates, Inc., contracted by EPA. "Clean Air Act Section 812 Prospective Assessment—Cost Analysis Draft Report". September, 1995.
c National Acid Precipitation Assessment Program. "Report to Congress: An Integrated Assessment." 2005. Available at: http://www.al.noaa.gov/AQRS/reports/napapreport05.pdf.
d Ibid.
e Materials sent to editors and writers by the Edison Electric Institute describing the impact of the Clean Air Act Amendments on the electric utility industry. December 17, 1990.
f Sierra Research, Inc., "The Cost Effectiveness of Further Regulating Mobile Source Emissions." February 28, 1994.
g *The New York Times,* "Honda Meets a Strict Emission Rule." August 30, 1995.
h W. Harrington, R. Morgenstern, P. Nelson (Resources for the Future), "On the Accuracy of Regulatory Cost Estimates." January 1999. Citing Cackett,"The Cost of Emission Controls on Motor Vehicles and Fuels: Two Case Studies," presented at the 1998 Summer Symposium of the EPA Center on Airborne Organics, MIT Endicott House, Dedham, Mass. July 9–10, 1998.
i Ibid.
j Ibid.
k Ibid.