Climate Change Policy as an Economic Redevelopment Opportunity: The Role of Productive Investments in Mitigating Greenhouse Gas Emissions

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FOREWORD

This report was designed to examine the long-term economic impacts of cap and trade legislation. Many economic assessments of climate change policies completed to date, especially from opponents of the Waxman-Markey bill (H.R. 2454), make flawed assumptions that guarantee that meeting greenhouse gas emissions goals will result in job losses and economic costs to American families and businesses. Those self-fulfilling projections are the result of several factors including assuming large investments in conventional and inefficient power plants, buildings, and factories; assuming that current markets are perfect and changes by definition will cause suboptimal outcomes; and assuming that all mandated carbon emissions reduction policies must be inherently costly regulations, rather than potential opportunities and incentives for productive investments with positive economic payoffs.

As this report shows, however, the more cap and trade legislation is crafted to spur investments in energy-saving devices, materials, and designs, the more it will lead to increases, not decreases, in the number of jobs in the U.S. economy. Furthermore, it will lead to reductions, not rises, in our energy bills, with negligible impact on the size of the economy.

H.R. 2454, which was passed by the U.S. House of Representatives in June 2009, includes important provisions designed to build energy efficiency increases into some of the nation’s investments in factories, buildings, homes, schools, and hospitals. The enormous economic benefits of provisions promoting energy-efficiency investments, and the extent to which they could be strengthened to generate even more energy savings, have largely been ignored or grossly underestimated by studies produced or funded by opponents of cap and trade legislation.

In this report, ACEEE used its state-of-the-art “DEEPER” energy policy model, which takes into consideration the potential economic benefits of energy efficiency investments, to examine the economic impacts of three cap and trade policy scenarios designed to meet goals for reducing carbon emissions while reducing energy waste in the U.S. economy. These policy scenarios differ with respect to the degree to which they encourage and support cost-effective energy efficiency investments, and range from moderate efficiency provisions (as contained in H.R. 2454) to enhanced efficiency provisions (as now being considered in the Senate) to optimized efficiency investments. As detailed in the report, the analysis finds that the greater the amount of investment in cost-effective efficiency measures, the more money consumers save, while maintaining the size of the U.S. economy at the same level as in a business-as-usual reference case with steadily increasing emissions of greenhouse gases.

While no economic model is perfect and there are large uncertainties when performing an analysis of this type, these results clearly show that stimulating productive investments in energy efficiency is a smart way forward under any reasonable circumstance.

Steven Nadel
Executive Director
American Council for an Energy-Efficient Economy

EXECUTIVE SUMMARY

Over the course of the next 40 years, the U.S. will invest an average of $4 trillion per year to maintain our nation's energy supplies, roads, bridges, factories, offices, homes, schools, and hospitals. By diverting as little as three percent of that ongoing annual investment into more productive technologies and infrastructure, we can increase the economy's overall productivity. More critically, we can generate those productivity increases in ways that achieve substantial but still cost-effective reductions in energy consumption and greenhouse gas (GHG) emissions. In short, greater energy productivity will enable the development of a more robust economy as well as an enhanced environmental quality — including a healthier climate.

An investment-driven climate strategy would harness the productivity gains from semiconductor devices, information and communication technology (ICT) systems, new materials, and new tools and designs for use in our buildings, industrial processes, transportation and power generation systems, and other structures in our economy. The devices, new materials, and new designs would also increase the energy efficiency of the many categories of equipment and appliances needed to maintain a comfortable and productive economy. H.R. 2454, which was passed by the U.S. House of Representatives in June 2009, includes important provisions designed to build energy efficiency increases into some of the nation's investments in factories, buildings, homes, schools, and hospitals.

The enormous economic benefits of provisions that promote or catalyze greater energy-efficient investments, and the extent to which they could be strengthened to generate even more energy savings, have largely been ignored or grossly underestimated by studies produced or funded by opponents of cap-and-trade legislation. In this report, ACEEE used its state-of-the-art "DEEPER" energy policy model to examine the economic impacts of three cap-and-trade policy scenarios designed to meet specific targets for reducing greenhouse gas emissions while reducing energy waste in the U.S. economy. The three policy scenarios involve different levels of policies to encourage and support cost-effective energy efficiency investments.

The first scenario is based on the various energy efficiency provisions included in H.R. 2454, such as improved equipment efficiency standards and building codes, modest energy savings targets for electric utilities, and some investment of emissions allowance income in state, utility, and municipal energy efficiency efforts. The second adds several enhancements to the H.R. 2454 package — stronger utility savings targets, a continuation of state and municipal energy efficiency programs beyond 2030, and a requirement that electric utilities invest one-third of their free emissions allowances to help their customers reduce their energy use (H.R. 2454 already includes such a requirement for gas utilities). The third scenario continues this progression and assumes many of the policies are further enhanced to approximately double efficiency savings relative to the first scenario.

Some of the key findings regarding the baseline scenario and the three climate legislation scenarios analyzed by the DEEPER model are summarized below and reported in Figures ES-1 and ES-2 and Table ES-1, including:

1. *The Baseline Scenario* — If no federal climate legislation were signed into law: energy bills would increase 46 percent by 2030 and nearly double by 2050; energy consumption would increase by 8 percent by 2030 and 28 percent by 2050 (largely the result of inefficient energy use); and greenhouse gas emissions would grow 8 percent by 2030 and 21 percent by 2050.
2. *Scenario 1, climate legislation as passed by the House* — By 2030, this scenario would produce an average net energy spending reduction of $354 per household and an increase of nearly 425,000 jobs. By 2050, the job increase would grow to nearly 1.2 million.
3. *Scenario 2, the "improved" version of H.R. 2454* — Consumer energy costs would drop 23 percent by 2030 and 21 percent by 2050, nearly double the savings from the House-passed bill; and nearly three-quarters of a million extra jobs would be created by 2030 with more than 2 million additional jobs created by 2050 (or nearly double the number of extra jobs that would be created by the House-passed legislation).

4. *Scenario 3, "further improved" version with double the energy savings of the House-passed bill* — Consumer energy costs would decline 27 percent by 2030 and 32 percent by 2050, nearly triple the savings from the House-passed bill, and more than one million additional jobs would be created by 2030 with more than 2.5 million extra jobs created by 2050 (or more than double the additional jobs created by the House bill as it now stands).

These positive impacts of cap-and-trade legislation would occur while the country simultaneously met carbon emissions reduction goals. For each of the three scenarios, greenhouse gas emissions would be roughly cut in half by 2030 and reduced by about three-quarters by 2050. The DEEPER analysis also found that each of three climate policy scenarios would have zero or near-zero impact on the size of the economy.

This report also includes a scenario for climate change legislation that generates energy use reductions only through energy price increases and ignores improvements in energy efficiency. For this policy scenario, the report found that the impacts roughly match the cost-increasing, job-reducing findings of studies by climate bill opponents, illustrating the powerful effect of unjustifiably neglecting to incorporate investments in energy efficiency into such studies.

In conclusion, this report demonstrates that encouraging investments that increase overall energy productivity has tremendous implications for the net economic impacts of climate policies. In fact, ***the findings show that the greater the level of energy-saving investments, the greater the economic benefits for Americans***. By channeling modest investments into energy-saving buildings, technologies, and infrastructure, lawmakers can produce a winning combination for the U.S. economy and the climate. As the report demonstrates, these investments will enable us to meet greenhouse gas reduction goals, create more jobs, and cut energy costs for American businesses and families while maintaining robust economic growth. Studies that ignore these fundamental financial and economic realities inevitably distort the impacts of climate legislation.

Figure ES-1. Net Employment Opportunities from Energy Efficiency Policies

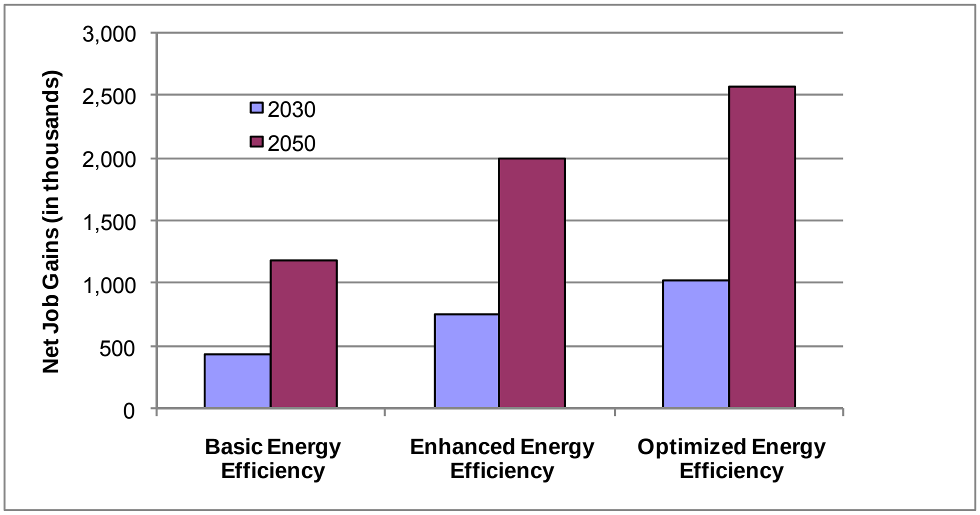
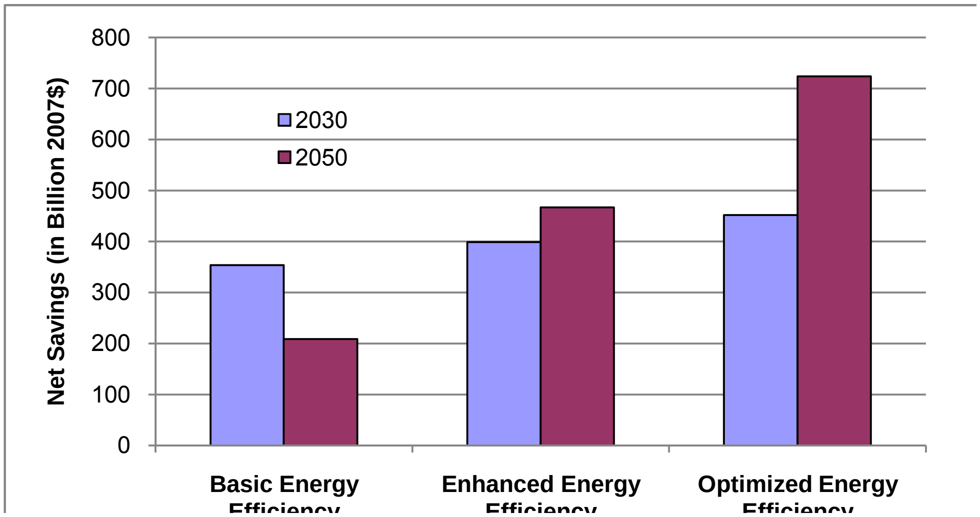


Figure ES-2. Net Consumer Savings from Energy Efficiency Policies



Note: The cost savings for the Basic Energy Efficiency scenario are lower in 2050 than 2030 because the efficiency gains in this version are not quite sufficient to offset the larger amount of domestic and international offsets that will otherwise need to be purchased.

Table ES-1. Impacts of House-Passed H.R. 2454 and Two Improved Versions of the Legislation

Financial and Economic Indicators	H.R. 2454 Basic EE (Scenario 1)		H.R. 2454 Enhanced EE (Scenario 2)		H.R. 2454 Optimal EE (Scenario 3)	
	2030	2050	2030	2050	2030	2050
Baseline Scenario Emissions (MMTCO$_2$e)	7,954	8,879	7,954	8,879	7,954	8,879
Carbon Price ($/tCO$_2$e)	$47	$239	$41	$185	$35	$128
Policy Scenario Reductions (MMTCO$_2$e)						
Energy-Related	3,392	4,551	3,480	4,638	3,636	4,875
Other Domestic	399	1,122	366	1,028	323	795
International Offsets	253	1,112	253	1,112	253	1,112
U.S. Policy Scenario Emissions (MMTCO$_2$e)	3,911	2,095	3,855	2,102	3,742	2,098
Percent Reduction from Baseline Scenario	51%	76%	52%	76%	53%	76%
Financial Impacts (Billion 2007 Dollars)						
Policy and Program Cost	12	17	16	20	23	31
Annual Payments on Investments	119	94	133	112	161	171
Energy Bill Savings	$485	$321	$548	$600	$637	$926
Net Consumer Savings	$354	$209	$399	$467	$452	$724
Macroeconomic Impacts						
Change in Employment (Thousand Jobs)	424	1,176	743	2,001	1,017	2,577
Percent Change from Baseline Scenario	0.2%	0.4%	0.3%	0.7%	0.4%	0.9%
GDP (Billion 2007 Dollars)	2	-129	0	-93	4	-38
Percent Change from Baseline Scenario	0.0%	-0.3%	0.0%	-0.2%	0.0%	-0.1%

ABOUT ACEEE

The American Council for an Energy-Efficient Economy (ACEEE) is a nonprofit research organization dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. For more information, see www.aceee.org. ACEEE fulfills its mission by:

- Conducting in-depth technical and policy assessments
- Advising businesses, policymakers, and program managers
- Working collaboratively with businesses, public interest groups, and other organizations
- Organizing technical conferences and workshops
- Publishing books, conference proceedings, and reports
- Educating consumers and businesses

Projects are carried out by staff and selected energy efficiency experts from universities, national laboratories, and the private sector. Collaboration is the key to ACEEE's ongoing success. We collaborate on projects and initiatives with dozens of organizations including international, federal, and state agencies as well as businesses, utilities, research institutions, and public interest groups.

Support for our work comes from a broad range of foundations, governmental organizations, research institutes, utilities, and corporations.

ACKNOWLEDGMENTS

Both the American Council for an Energy-Efficient Economy and I would like to express our deep appreciation to the Energy Foundation and the Sea Change Foundation for their active support of the research and work that went into this analysis, and to our many allies and collaborators who have contributed to our deeper understanding of the critical role that more productive investments can have in reducing our nation's dependence on conventional energy resources and also reducing overall levels of greenhouse gas emissions. I gratefully acknowledge the individual contributions of my peer reviewers including James Barrett, Irving Mintzer, and Don Hanson. Each of them provided useful insights that have been incorporated into this final report. And also, I extend thanks to my ACEEE colleagues Steven Nadel, Rachel Gold, Therese Langer, Karen Ehrhardt-Martinez, Jennifer Amann, Neal Elliott, and Jacob Talbot for their background discussions and materials.

I would also like to gratefully acknowledge the many insights of colleagues who participated with me in a half-day, mid-September discussion about the preliminary findings of the DEEPER Model that is at the heart of this analysis. In that respect I would like to add my further thanks to (in no particular order) Chad Stone, Jim Barrett, John Tepper Marlin, Carol Werner, Shirley Neff, Fran Sussman, Jon Anda, Alexander Golub, Laurie Johnson, Suzanne Watson, and John Atcheson. Their individual participation in the spirited mid-September discussion in no way constitutes an endorsement of the findings in this report. Moreover, it is the nature of economic policy modeling that not every element or suggestion can be mapped into any single assessment framework. Yet the collective insights from everyone in that dialogue profoundly shaped this overall analytical effort. Thank you all. And, finally, I would like to acknowledge ACEEE's Editor Renee Nida whose patience and careful proofing made it easier to get it done. As always, the responsibility for the analysis, the findings, and the resulting narrative remain with the author.

I. INTRODUCTION

At the July 2009 summit in L'Aquila, Italy, G8 leaders called for at least a 50 percent reduction of global greenhouse gas emissions by 2050. Indeed, the G8 declaration also supported an 80 percent or more reduction of aggregate greenhouse gas emissions by 2050 in developed countries compared to 1990 or more recent levels (G8 Leaders 2009). At the same time, the U.S. Congress is now actively considering legislation that will achieve similar reductions in greenhouse gas emissions. The recent legislation passed by the House of Representatives in June 2009, for example, sets a cap so that no more than 17 percent of 2005 "covered emissions" would be allowed in the year 2050.[1]

Over the next 40 years, the United States economy is likely to grow at a reasonably robust level of 2.6 percent annually. Based on estimates from Economy.com (2009), the Gross Domestic Product (GDP) will increase from $14 trillion in 2010 to perhaps $38 trillion in 2050 (with all values expressed in constant 2007 dollars to eliminate the effects of inflation). This is nearly a tripling of the overall scale of our economy.[2] While economic activity is expected to slow compared to the growth we witnessed in previous decades (the growth in GDP averaged more than a percentage point higher in the preceding 30 years, for example), the level of GDP per capita that we saw in 2008 is still expected to increase by about 85 percent in real terms by 2050. This projected level of overall economic activity presumes, among other things, a conventional pattern of energy production and consumption. It also presumes a straightforward extension of current production patterns of our nation's goods and services.

As business leaders and policymakers respond to growing concerns about global climate change, they are looking for insights into how new climate policies might impact the U.S. economy. The question of, course, is: Will the economic changes required by potentially steep reductions in greenhouse gas emissions result in an increase or a decrease in the nation's economy? In other words, if the United States were to change its mix of energy and technology investments away from historically typical patterns, and toward (more productive) energy efficiency and renewable energy technologies, would this new mix of investments yield a higher rate of return for the economy? And would that rate of return be high enough to offset the costs inherent in making the fundamental economic transition that would be required to achieve an 80 percent or more reduction in greenhouse gas emissions? Finally, if businesses and households were to substitute other production processes that eliminate or sequester non-energy-related greenhouse gas emissions, how would that impact overall economic activity within the nation?

As it turns out, over the course of the next 40 years, the U.S. will invest an average of $4 trillion per year to maintain our nation's energy supplies, roads, bridges, factories, offices, homes, schools, and hospitals. By diverting as little as three percent of that ongoing annual investment into more productive technologies and infrastructure, we can increase the economy's overall productivity. More critically, we can generate those productivity increases in ways that achieve substantial but still cost-effective reductions in energy consumption and greenhouse gas (GHG) emissions. In short, greater energy productivity will enable the development of a more robust economy as well as an enhanced environmental quality — including a healthier climate.

An investment-driven climate strategy would harness the productivity gains from semiconductor devices, information and communication technology (ICT) systems, new materials, and new tools and

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[1] H.R. 2454, the American Clean Energy and Security Act of 2009, also known as the Waxman-Markey Bill, was passed by the U.S. House of Representatives by a vote of 219–212 on June 26, 2009. The U.S. Senate now has several different bills under consideration, including H.R. 2454. The emission limits set forth in section 702 of H.R. 2454 are: (i) 97 percent of the 2005 emissions in 2012, (ii) 80 percent of 2005 emissions in 2020, (iii) 58 percent of 2005 emissions in 2030, and (iv) 17 percent of 2005 emissions in 2050. These limits apply to what are termed "covered emissions," which account for about 85 percent of total greenhouse gas emissions. With the anticipated growth in emissions by 2050, the 17 percent of 2005 covered emissions implies a roughly 76 percent reduction in the 2050 projected level of total greenhouse gas emissions in the U.S.

[2] The current forecasts now available from Economy.com extend out to the year 2039. With some judgment applied to that data set, in effect assuming a post-2039 population growth of just over 0.9 percent and a productivity growth slightly larger than 1.7 percent annually, we can provide a reasonable projection out to the year 2050.

designs for use in our buildings, industrial processes, transportation and power generation systems, and other structures in our economy. The devices, new materials, and new designs would also increase the energy efficiency of the many categories of equipment and appliances that are further needed to maintain a comfortable and productive economy.

The U.S. economy has an annual energy bill that will approach one trillion dollars in 2010. This covers all energy-related expenditures that range from heating our homes and driving our cars, to lighting our stores and powering our factories. The bad news is the nation's energy bill is expected to more than double, reaching $2.3 trillion by 2050 according to one estimate. Much of that projected growth in the nation's energy expenditure is driven by an inefficient use of energy. As we will see in subsequent sections of the report, the major driver of emission reductions is a substantial growth in energy productivity that builds on an investment-led climate policy which, in turn, generates a growing energy bill savings. Both the investments and resulting energy bill savings generate a small but net-positive impact on jobs. All of these gains are enabled by productive technology investments as they are complemented by motivated and informed behavior of both consumers and businesses.

Despite the enormous promise of existing technologies, and the even more productive ones yet to come, most of the economic assessments of climate change policies completed to date tend to overlook the role of productive investment in helping achieve the twin goals of a healthy economy and a healthy climate. As this study suggests, a productivity-enabled outcome would provide more job opportunities, not fewer. The unwritten assumption in most modeling exercises is that controlling greenhouse gas emissions is all about cost containment rather than redirecting investments toward more productive technologies. This analysis is markedly different in that respect. It draws from an investment-based perspective rather than a cost-constrained analysis, and it assumes imperfect markets and information flows that might be better informed through complementary policies that are embedded and expanded within the H.R. 2454 policy framework. It asks the question, how can we increase the robustness of the U.S. economy while positively impacting the global climate? The evidence suggests that smart technology investments can protect the climate and maintain a robust economy — if we choose to develop that opportunity.

In the analysis that follows, we find important, positive changes in the magnitude and patterns of overall spending for a climate strategy of the type that is outlined in H.R 2454. These changes range from a greater level of more productive investments to greater spending on complementary programs and policies that ease the transition to a low-carbon future. More critically, the program spending and the changed pattern of investments have significant benefits. In effect, a climate policy scenario represents a different recipe of technology investments compared to the assumed reference case. Yet the evidence points to a productive return on those investments — ones that enable the economy to substantially reduce the level of aggregate greenhouse gas emissions. And as it turns out, the job and value-added benefits are slightly greater for the climate policy initiatives characterized in this report than they are for our current energy path.

In short, the available evidence and the historical record indicate that we should expect to see a small but net positive gain for the U.S. economy both in terms of employment and income — all as a result of increased levels of investment in innovation and emissions-reducing technologies. Changing our investment mix away from traditional, energy-intensive patterns toward one that emphasizes more productive technologies and behaviors, greater energy efficiency, and more labor-intensive activities can yield higher rates of economic growth along with lower economic and environmental costs. In many ways, the effect is much like the rebalancing of a retirement portfolio to take advantage of changing market conditions and new growth opportunities. While it is important to focus on the potential gains from such a rebalancing, it is equally important to acknowledge the other side of the coin: that remaining on our traditional investment pathway will likely lead to lower growth, fewer employment opportunities, and higher environmental costs (see, for example, Ayres and Ayres 2010–*forthcoming*).

The balance of this report tries to accomplish four things. First, it provides the critical findings of our modeling assessment and discusses how those findings might inform the ongoing discussion about the nation's emerging climate policies — with a focus on how energy efficiency investments could positively impact economic and environmental outcomes. Second, it describes and documents the potential for greater energy productivity and its resulting impact on the larger economy. The presentation illustrates how this information might be properly integrated into the framework of the climate policy legislation now before Congress and how that information might be appropriately mapped into more traditional economic models. Third, this report highlights the critical modeling assumptions and algorithms that enable an appropriate economic assessment of current climate policy legislation. To achieve this latter result, this report includes an assessment of H.R. 2454 as it passed the U.S. House of Representatives. It also examines the impact of both an "enhanced" and what is termed an "optimal" level of energy efficiency investments within the H.R. 2454 framework. Finally, the report offers additional insights to further underscore the suggestion that the U.S. economy does, indeed, have the opportunity to transition its energy and greenhouse gas emissions markets into a more sustainable system of production and consumption, and to do so in ways that benefit the economy and the climate. The technical details associated with the various economic assumptions are highlighted in a short appendix to this report.

II. LIKELY ECONOMIC IMPACTS OF PRODUCTIVE INVESTMENTS IN ENERGY EFFICIENCY

A large number of recent studies highlight the potential role for energy efficiency as a critical and productive component of a balanced national climate strategy (InterAcademy Council 2007; Ehrhardt-Martinez and Laitner 2008; Lovins 2008; American Physical Society 2008; Furrey et al. 2009; Cleetus, Clemmer, and Friedman 2009; McKinsey & Company 2009; Laitner 2009b; AEF 2009; Gold et al. 2009; Houser 2009; Cooper 2009; Ayres and Ayres 2010–*forthcoming*). As this report previously suggested, most economic modeling assessments appear to overlook the net positive benefit that would likely accrue from a national commitment to invest in the vast array of technically feasible and cost-effective efficiency behaviors and technologies that are now increasingly available. In this section we review three critical aspects of policy assessments that, if properly integrated into climate policy models, are likely to lead to a small but net-positive outcome in terms of energy bill savings and employment benefits. It then compares a set of policy scenarios based on H.R. 2454 that illustrate how changing assumptions can critically affect the level of economy-wide benefits. As a first step forward, we review the key elements of H.R. 2454, especially as they impact assumptions about technology costs and benefits. Second, we examine the magnitude and cost-effectiveness of the energy efficiency resource as indicated by the recent set of studies referenced above. Next, we explore three of the more significant changes within policy models that are likely to have an impact on modeling outcomes. Finally, we look at the kind of modeling results that would logically follow from the implementation of the productive (i.e., cost-effective) investments and actions that might be undertaken within the context of a balanced and effective climate policy.

A. Summary of the Key Elements of Climate Legislation

The passage of the American Clean Energy and Security Act of 2009 (known more formally as H.R. 2454, or simply as ACES) is a unique milestone in the climate change policy debate. In effect, it provides a declining cap on greenhouse gas emissions so that by 2050 the so-called "covered emissions" are no more than 17 percent of the actual emission levels generated in the year 2005. Two points are important in terms of how we implement this cap in the DEEPER Model. First, according to the EPA (2009a), total GHG emissions in 2005 are estimated to be 7,109 million metric tons of carbon dioxide emissions equivalents (MMTCO$_2$e). Assuming 85 percent of those emissions are covered and subject to the 17 percent cap, then total emissions in the year 2050 are limited to about 2,094 MMTCO$_2$e.[3] The DEEPER Model also reflects the full efficiency provisions within H.R. 2454 as summarized in Gold et al. (2009).

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[3] The calculation is 7109 * 0.85 * 0.17 for covered emissions + 7109 * 0.15 for all other emissions. Since DEEPER also benchmarks the "uncovered emissions" to 2005 levels, rather than allow growth in that set of emissions, the resulting cap is perhaps a little tighter than might be required.

As we show later in the discussion, the energy efficiency investments drive a strongly positive result compared to the other modeling assessments that have been released to this point. This is seen in the discussion of Table 2 in which we also explore other scenarios that extend efficiency investments beyond the current levels now embedded in H.R. 2454.

In addition to examining the impact of efficiency investments, DEEPER also integrates domestic non-energy related emissions as well as allows the purchase of international offsets to ease the transition to a low-carbon economy. While the international offsets become an important part of the overall modeling solution, DEEPER currently limits their availability to about 1,100 $MMTCO_2e$. Because the focus on this modeling exercise is on productive investments that generate significant returns for businesses and consumers, DEEPER does not implement the other flexibility mechanisms such as banking and borrowing.

B. The Energy Efficiency Resource and Other Options

The U.S. Department of Energy's *Annual Energy Outlook 2009* (EIA 2009a) projects a 10 percent increase in energy-related carbon dioxide (CO_2) emissions between now (i.e., 2009) and 2030. Total greenhouse gas emissions — including energy-related CO_2 emissions that account for about 80 percent of total CO_2 emissions, and a variety of other gases including methane, nitrous oxide, and several fluorinated gases — are projected to rise by about 30 percent by the year 2050. The key assumption that underpins most economic policy models is that these emissions arise from a set of technologies that cannot be cost-effectively improved. A related assumption is that, more generally, the economy is operating at peak efficiency and there is little room for improvement in overall productivity gains. Yet, the evidence points to a large array of alternative and more productive investments that can provide a cost-effective reduction in greenhouse gas emissions but which are not deployed because of inherent barriers that "lock out" these productive returns. New studies, like the ones cited above, suggest a smart climate policy — one that provides both a price signal and a complementary set of programs and policies to ease the transition to an energy-efficient, low-carbon future — might reduce total energy use and greenhouse gas emissions well below current or previously projected levels.

An analysis by the Consumer Federation of American suggested that the Energy Efficiency Resource Standard (EERS) and the Renewable Energy Standard referenced in the provisions of H.R. 2454 could be viewed as aggressive but would be highly cost-effective. This analysis indicated that consumers could save over $200 billion per year (Cooper 2009) as the result of investments made in more efficient and productive technologies. Reaching a similar conclusion, a highly detailed assessment by McKinsey & Company (2009) characterized energy efficiency as "a vast, low-cost energy resource for the U.S. economy." Moreover, "if executed at scale," the McKinsey analytical team concluded, "a holistic approach (to unlocking the full energy efficiency potential of the U.S. economy) would yield gross energy savings worth more than $1.2 trillion, well above the $520 billion needed through 2020 … (to recover the) upfront investment in efficiency measures."[4] Equally important, such a program would reduce energy consumption in buildings and industry by "roughly 23 percent of projected demand, potentially abating up to 1.1 gigatons of greenhouse gases annually."

In a separate assessment of the energy-efficiency related provisions of H.R. 2454, the American Council for an Energy-Efficient Economy found that total cost-effective primary energy savings might rise to as much as 9 quads by 2030. What ACEEE characterized as an enhanced set of efficiency provisions enacted through H.R. 2454 might increase that efficiency gain to as many as 17 quads by 2030. This would generate a cost-effective reduction in total primary energy use of nearly 15 percent

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[4] These costs do not include program costs necessary to catalyze the necessary investment in the full spectrum of energy efficiency devices, equipment, buildings, and other structures. McKinsey estimates this to range between $50 to $150 billion. This, of course, would increase the overall cost of developing the efficiency resource. Still, even at the high end the net savings are on the order of $530 billion — a reasonably inexpensive way to reduce greenhouse gas emissions.

by 2030 — with a concomitant reduction in energy-related carbon dioxide emissions (Gold et al. 2009).[5]

As big as the documented savings are shown to be in these studies, two significant insights emerge. First, most energy and economic models have been unable to reflect the full cost-effective potential of the energy efficiency resource in their various policy assessments. As a result, their findings suggest an unjustifiably negative shock to the economy. Second, and perhaps not surprisingly, there have been a number of thoughtful analyses that are finding that innovation and behavioral shifts can generate an even larger reduction in the nation's energy expenditures. For example, studies that explore the frontiers of behavioral actions have shown that informed and motivated consumers might reduce household and personal transportation energy use on the order of 25 percent over current patterns (Laitner, Ehrhardt-Martinez, and McKinney 2009; Gardner and Stern 2008). The American Psychological Association also released an extensive review that documented the importance of a psychological and social perspective to enable an effective response to climate change (Swim et al. 2009). A number of researchers, in fact, argue that social learning is a prerequisite for sustainable energy use (see, for example, Laitner, DeCanio, and Peters 2000; Darby 2006; Ehrhardt-Martinez 2008). They suggest, among other things, that a purely technology-driven perspective may overlook sources of motivation and information other than "the price signal." Moreover, energy and climate policies incorporating such features as awareness-raising, cooperative action, and active feedback into measures intended to spur technology deployment are likely to achieve more positive behavioral outcomes — as well as higher economic returns — on social action and investments.

In addition, studies that explore both a technology and a systems perspective find what might seem at first an astonishingly large energy savings potential. As one very recent example, Cambridge Systematics earlier this summer completed the first-ever comprehensive analysis of transportation system efficiencies and their relationship to greenhouse gas reductions and consumer savings. The study examined nearly 50 transportation strategies and found that transportation greenhouse gas emissions could be reduced by approximately one-half by 2050, with savings outweighing costs by nearly two to one over that period (Cambridge Systematics 2009). Long-term land-use planning that encourages a more compact urban development — but one that maintains essential access to amenities, goods, and services — is an essential step toward enabling a significant reduction in vehicle miles traveled, a key to reducing transportation-related GHG emissions (Ewing et al. 2008).

What may be an especially intriguing aspect of these new studies, as they compare more favorably to the modeling assumptions underpinning more conventional results, is that the findings of even this new generation of studies do not rely on any of the emerging and potentially breakthrough technologies that may change the entire dynamic of the modeling policy outcomes. Breakthroughs in catalysis, nanotechnologies, piezoelectric materials, and light emitting polymers, for example, are entirely overlooked.[6] As one recent example, EPA funded an assessment on the potential contribution of waste-to-energy or recycled energy (Bailey and Worrell 2005). Yet their models do not reflect any reference to the potential economic benefits of such technologies even though many are now commercially available and making money today (Casten and Ayres 2008). Based on the complete body of available evidence, a new National Academy of Sciences study, *America's Energy Future* (AEF 2009), highlighted the potential for significant energy productivity gains that could reduce total primary energy consumption by as much as 32–35 quads by 2030. This is a 30 percent reduction that would offset all of the Energy Information Administration's (EIA 2009a) projected

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[5] Note that when they discuss primary energy savings, most studies measure energy in terms of quadrillion Btus, or quads. Such consumption refers not only to the energy used directly in homes and businesses, and by transportation systems, but also to the significant losses of energy created in the generation, transmission, and distribution of electricity. The Energy Information Administration (EIA 2009a), for example, projects the U.S. reference case energy consumption in 2012 at 102 quads of primary energy. Since the main purpose of this analysis is to examine greater end-use efficiencies, the DEEPER model references end-use or delivered energy consumption. In that context, EIA reports end-use energy requirements to be 73 quads in 2012. This and other reference case data are summarized in the first table in the appendix.

[6] Even a cursory but regular reading and review of magazines like MIT's *Technology Review*, *Scientific American*, *Popular Science*, and *Popular Mechanics* may leave an entirely different impression about these and many other technology breakthroughs and opportunities.

growth in energy demand by a factor of nearly three. It would, in fact, reduce energy demand below 1987 levels. Extending this thinking out to the year 2050, but building equally the set of new studies as well as the established historical record of earlier studies (in some cases dating back to pre-1980 assessments), Laitner (2009a) indicated a very real possibility of approaching or reducing total demand to 65 quads of energy by that year.

C. Modeling Design to Accommodate Energy Efficiency Investments

Recent modeling analysis points to a much greater level of cost-effective emissions reductions than is typically presented in reports to Congress and to the public. The result of models that assume a constrained capacity to deliver such reductions is either a smaller level of domestic reductions than scientists now believe important to achieve, and/or a much higher set of emission and energy prices that negatively impact the economy. Confronted with a restrained modeling framework, the question might then be asked, how might we modify the model structure, the technology characterization, and the market and/or behavioral assumptions to reflect the reality that larger resource opportunities are available to the market? A recent assessment by Laitner (2009a) highlights three areas of improvements that might enable a more positive modeling outcome to emerge. The areas include:

(1) A robust characterization of the technology opportunity, including an even-handed mapping of the costs and benefits of superior levels of energy productivity.

If investments are seen only as costs to be born by consumers and businesses, then negative impacts will certainly follow that assumption. To the contrary, if models recognize that there are large-scale investments that generate a return — whether those returns are in the form of energy bill savings for households and businesses, or more general increases in energy-related productivity — the possibility then emerges for a small but net positive impact on the economy. Such improvements might enable a clearer picture to emerge on how productive investments could reduce greenhouse gas emissions in ways that also catalyze the development of a more robust economy. And meaningful advances in technology characterization should be mapped into policy models for both the demand and the supply-side of the resource equation.

(2) A realistic portrayal of behaviors, by both individuals and firms or business entities, would show that businesses and consumers can change their minds and adjust their expectations.

Let us imagine, for example, that a consumer today might not want to adopt a new technology unless it pays for itself in three years or less. This implies that energy prices might have to jump 67 percent to bring a 5-year payback down to three years. But if that consumer knows that his or her actions will reduce the impact of climate change, that person might be very happy with even a 4-year payback — in which case energy prices would only have to increase by about 25 percent to meet a given climate target. And if those savings from reduced energy use are greater than the 25 percent price increase, say 35 percent, then he or she is not only saving money but may also end up feeling very good because his or her family is helping to protect the global climate system. The evidence strongly suggests that both producers and consumers can shift their preferences in significant ways as more information and changing attitudes among their peers begin to shape their decisions.

(3) An improved economic accounting of investments and technology choices to reflect their positive contributions to employment and the nation's value-added services that builds up GDP at a slightly greater rate than do conventional energy sectors.

With this initial discussion of these three critical aspects of energy and climate policy models, the discussion now moves a little DEEPER by providing more of a foundation for each of these points.

How Big Energy Efficiency?

Economist William Baumol and his colleagues (2009) once wrote, “for real economic miracles one must look to productivity growth.” As it turns out, energy efficiency investments have been a critical resource in promoting ongoing economic productivity throughout all levels of the economy. Indeed, the emerging research suggests that if the U.S. and the world more generally are to sustain any level of a robust economy, then we will need to look for even greater gains in energy efficiency, not less (see, for example, Ayres and Warr 2009; Hall and Day 2009).

But some might ask the question, “Just how big is energy efficiency?” As it turns out, energy efficiency in all of its forms has met 75 percent of the new demands for energy services since 1970, while new energy supplies have met only 25 percent of these new service demands (Ehrhardt-Martinez and Laitner 2008). Perhaps the surprising news is that the opportunity for gains in energy efficiency (energy productivity) is bigger than we imagine, although perhaps harder to achieve than we might think. Let’s review some of the more credible estimates.

A study published by the National Renewable Energy Laboratory (Griffith et al. 2007) suggested that if all commercial buildings were rebuilt by applying a comprehensive package of energy efficiency technologies and practices, they could reduce their typical energy use by 60 percent. Adding the widespread installation of rooftop photovoltaic power systems could lead to an average 88 percent reduction in the use of conventional energy resources. Even more intriguing, many buildings could actually be producing more energy than they consume (see also Martinez 2009).

The current electricity generation and transmission system in the U.S. now operates at an efficiency of about 32 percent. That is a level of performance that is essentially unchanged since 1960. What the U.S. wastes in the production of electricity today is more than Japan uses to power its entire economy (author calculations using various data from the Energy Information Administration). At the same time, a study published by the Lawrence Berkeley National Laboratory (Bailey and Worrell 2005) suggested that a variety of waste to energy and recycled energy systems could pull enough waste heat from our nation’s industrial facilities and buildings to meet 20 percent of current U.S. electricity consumption. And that is only the beginning of potentially large efficiency gains in power generation. So combining even a 50 percent efficiency gain in our nation’s buildings with a minimum 25 percent productivity improvement in power production provides a total 60 percent efficiency gain (author calculations).

MIT research scientist Daniel Cohn (2008) suggests that new plasma gasification technologies could provide up to 40 billion gallons of liquid fuels from municipal and industrial wastes. That is about one-quarter of current gasoline consumption. In September 2009, Volkswagen introduced a sleek new two-passenger prototype car that achieved a phenomenal 240 miles per gallon (mpg). But even if the typical cars in 2050 achieve only a 50 mpg rating, but we also have new incentives to reduce driving by 20 percent, and that also increases the typical passenger load from 1.6 to two persons per car, fuel consumption would decrease 72 percent (author calculations).

Moving beyond component or device efficiency improvements, there are significant system efficiencies that contribute to future solutions as well. One new study completed for the Urban Land Institute identified a package of some 50 programs and policies that could reduce transportation-related greenhouse gas emissions by 24 percent by 2050 by acting to change travel behavior and land-use patterns. The emissions reduction hit 47 percent by adding road pricing techniques, ranging from pay-as-you-go insurance to charging Americans for every mile driven (Cambridge Systematics 2009). Adding improved fuel performance standards beyond what might occur through these behavioral and system efficiencies would further enhance these savings.

Management consultant Jeffrey Luke (1998) suggested that individuals have “a natural tendency to choose from an *impoverished option bag* (emphasis in the original). Cognitive research in problem solving shows that individuals usually generate only about 30 percent of the total number of potential options on simple problems, and that, on average, individuals miss about 70 to 80 percent of the potential high-quality alternatives.” The question here might be whether prior assessments of climate policies have also been limited by a similarly impoverished option bag?

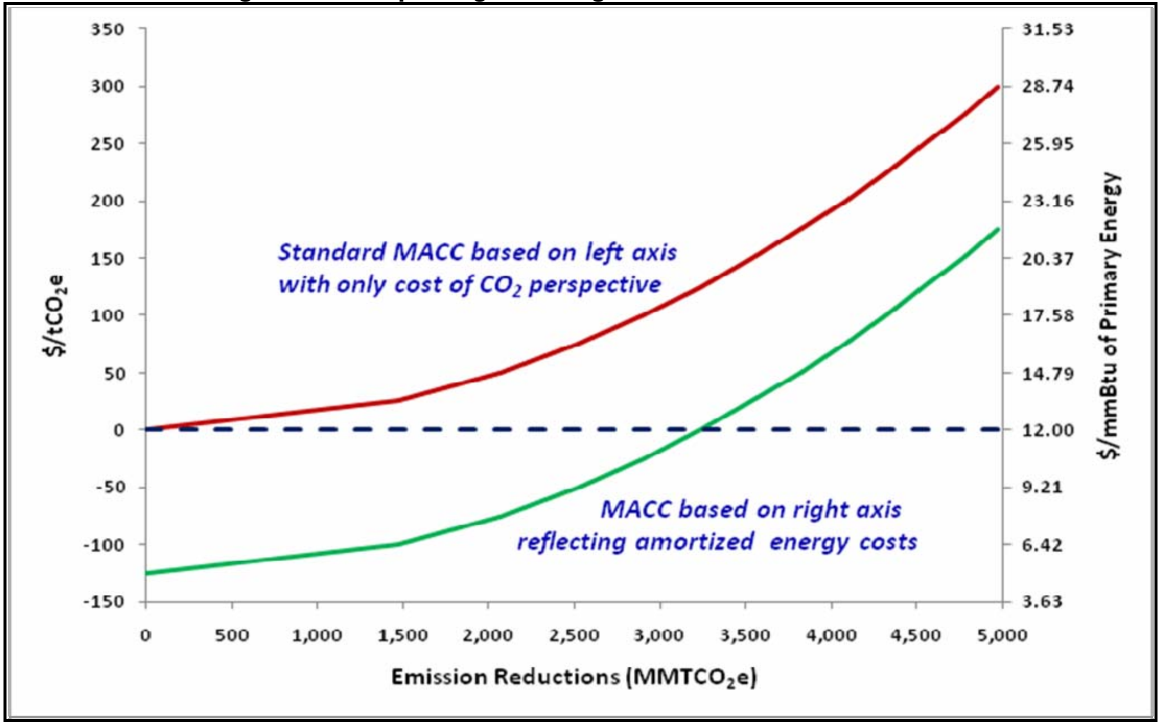
Jacobson and Delucchi (2009) observe the possibility of efficiency, wind, water, and solar technologies providing 100 percent of the world’s energy, eliminating all fossil fuels by 2030. They acknowledge the numbers are large but note that “society has achieved massive transformations before.” They the World War II transition when “the U.S. retooled automobile factors to produce 300,000 aircraft, and other countries produced 486,000 more.” In other words, we have the technical capacity to move in this direction. Harvey (2009) notes that the opportunity may not be limitations of technology; rather, he suggests, it may be more about the lack of a trained, motivated, and properly equipped professional and construction workforce. Laitner (2004) observes that rather than practical limits on further efficiency gains, it might be more the limits of public policy to encourage further innovations.

1. Mapping Cost-Effective Technology Options

A typical assumption used in economic policy models is that all resources available in a given reference case are fully utilized and efficiently allocated. This so-called "full employment" assumption implies an optimal set of markets and production processes that delivers the very best in the way of goods and services demanded by consumers.[7] If this assumption then extends into the future, any departure from the existing pattern of production — however critical the policy objective might be in some alternative policy scenario — will imply a suboptimal outcome for the economy. The technology analog of this assumption, as it might be represented in climate policy models, is the marginal abatement cost curve.

Figure 1, below, illustrates the conventional abatement cost curve with the conventional view of emission reductions. It then contrasts this conventional technology representation with a more appropriate characterization of the technology opportunity, implying that a productive investment can generate a meaningful return for consumers of energy services.[8]

Figure 1. Interpreting the Marginal Abatement Cost Curve



Source: Author's illustration of supply curves showing comparability of CO_2 costs on the Y1, or the left axis, with the equivalent energy costs on the Y2, or the right axis.

With the full employment assumption firmly in place, the standard marginal abatement cost curve (by definition) must start at zero, and it can only rise as more of the abatement opportunities are used up. Many economic modelers are uncomfortable with the idea of negative costs and tend to assume that

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[7] By "full employment," the economist refers not to jobs but to the use of all factors of production. This broader reference includes all labor, capital, and energy. In other words, it is an assumption that all available resources are used with maximum effectiveness to produce a nation's goods and services, i.e., there are no slack resources in the economy.

[8] The marginal abatement cost curve is what this author will sometimes refer to as "the Big MACC." While the two curves shown in Figure 1 are not drawn to represent any specific set of technologies, the red abatement curve reflects the approximate typical analysis used in conventional policy models that assume no returns from investments in abatement technologies. The green abatement curve reflects an assumption that up to 40 percent of GHG emissions might be reduced by implementing certain efficiency improving technologies with a significant net savings — given today's technologies and prices. Presumably, greater investments in research and development, coupled with greater levels of innovation over time, might shift both curves to the right (i.e., yielding over time even greater benefits compared to costs).

all abatement measures have only positive costs. Figure 1 also illustrates, however, the availability of a large supply of emission reductions that could be achieved today at negative cost; that is, with economic savings that result from the value of reduced energy expenditures, based on currently available technology and current costs.

Of perhaps real interest is that when one compares the cost of carbon dioxide reductions shown on the left or Y1 axis in Figure 1 with the cost of energy highlighted on the right or Y2 axis, in fact, there is not really a negative cost. Any investment in an energy-efficient technology has a positive energy cost, as suggested by the data in Figure 1. The difference is that the levelized or amortized cost of the technology is less than the purchased price of energy. This simply means that consumers and businesses are saving money when they invest in cost-effective energy-efficient technologies. Hence, what appears as a negative cost on the left or axis of Figure 1 is really an amortized cost of energy efficiency on the right axis.

There are two other aspects of technology investments that might lead to recognition of productive returns rather than pure costs. The first is associated with the non-energy benefits that typically accrue to energy efficiency investments. The second reflects the changes one might normally expect in the cost and performance of technologies over time. The evidence for these two added benefits is summarized next.

When energy efficiency measures are implemented in industrial, commercial, or residential settings, several "non-energy" benefits such as maintenance cost savings and revenue increases from greater production often result in addition to the anticipated energy savings. Often, the magnitude of non-energy benefits from energy efficiency measures is significant. These added savings or productivity gains range from reduced maintenance costs and lower waste of both water and chemicals to increased product yield and greater product quality. Worrell et al. (2003), for example, analyzed 52 industrial efficiency upgrades, all undertaken in separate industrial facilities, and found that these non-energy benefits were sufficiently large that they lowered the payback period for energy efficiency projects from 4.2 years to 1.9 years. Typically, these non-energy benefits from energy efficiency measures are omitted from conventional performance metrics. This leads, in turn, to overly modest payback calculations and an imperfect understanding of the full impact of energy efficiency investments.

Several other studies have quantified non-energy benefits from energy efficiency measures; numerous others have reported linkages from non-energy benefits and completed energy efficiency projects. In one, the simple payback from energy savings alone for 81 separate industrial energy efficiency projects was less than two years, indicating annual returns higher than 50 percent. When non-energy benefits were factored into the analysis, the simple payback fell to just under one year (Lung et al. 2005). In residential buildings, non-energy benefits have been estimated to represent between 10 to 50 percent of household energy savings (Amann 2006). If the additional benefits from energy efficiency measures were captured in conventional performance models, these non-energy benefits would make the investment case far more compelling.

As a strong complement to large-scale non-energy benefits in most climate policy assessments, there is also a significant body of evidence to indicate that technology development is neither static nor optimal today. Knight and Laitner (2009), for example, review a multitude of end-uses including transportation, appliances, and consumer electronics, identifying three dozen examples of recent technologies with significant declines in prices coupled to improved technology performance. The rapid technological change seen in semiconductor-enabled technologies, for example, has led to cheaper, higher performing, and more energy-efficient technologies (Laitner et al. 2009). The increasing penetration of information and communication technologies interacting with energy-related behaviors and products suggests that the energy efficiency resource may become progressively cheaper and more dynamic as the 21st century moves forward (Laitner and Ehrhardt-Martinez 2008). Given this and many other comparable studies, one could conclude with very strong likelihood that progress in the cost and performance of energy-efficient technologies will continue, and that new public policies will greatly increase the rate of improvement (McKinsey & Company 2009; Koomey 2008).

2. *Evolution of Consumer Behavior in a More Dynamic Market*

As the industrial revolution progressed into the present day, the use of energy gradually moved from chopping wood, to shoveling coal, and then to flipping a switch. Over this transition, "our visual appreciation of the volume of fuel consumption has been diminished to the point that energy consumption has become largely invisible and the only remaining, visible aspect of energy is "the monthly bill." And because this energy use is essentially invisible, effortless, and ubiquitous, emotions and habits hold sway over our best intentions and the "rational use" of energy resources (Ehrhardt-Martinez *forthcoming*). Nonetheless, human behaviors and choices can evolve as new information and new opportunities make it easier for households and businesses to adopt productive technologies or change their habits and production techniques — especially when motivated by a growing concern about climate change and energy security.

Customer feedback, time-of-use pricing, and public awareness campaigns are underway to inform energy consumers of the costs, in varying metrics, of their energy use. This helps consumers re-visualize their energy use and reconnect their behavior with the actual costs of using energy or contributing to climate change. The success of information programs has been shown to vary by the size of the effort, the timing of the effort, the type and quality of the presentation methods used, and the content of the message itself (Ehrhardt-Martinez *forthcoming*). Along with making energy use "visible" to the consumer, a greater awareness of more cost-effective efficiency opportunities — in effect, a greater awareness of the "efficiency gap" — can further inform consumers and businesses in ways that motivate a different set of actions (Wilson and Dowlatabadi 2007). Moreover, targeted efforts that address issues of trust, perception, ease of use, and perceived social status for the customer can further reduce energy consumption (Stern 2000; Abrahamse et al. 2005; Swim et al. 2009).

"What makes information effective is not so much its accuracy and completeness as the extent to which it captures the attention of the audience, gains their involvement, and overcomes possible skepticism about its credibility and usefulness for the recipient's situation" (Stern 20 00). As one example, psychologist Paul Stern described the response of utility customers to receiving three mailed letters that introduced an energy service company to its consumers. The first letter used only the letterhead of the new firm to introduce the company. The second letter mentioned that the county government was sponsoring a new program supported by the company while the third was from the chairman of the county board of commissioners who introduced the firm and its service on his own letterhead. The energy services company realized five times more contracts from the third letter than it did from the first. In other words, overcoming barriers of trust and credibility can greatly enhance efforts to reduce energy use within households and businesses (Stern 2000). "The most effective interventions, therefore, are those that are tailored to the target individual or household or that address all the significant barriers that matter in a target population by combining intervention strategies, such as information, personal communication, mass-media appeals, convenience, financial incentives and other strategies as the situation requires" (Swim et al. 2009).

While some policy models assume a fixed or rigid consumer response to energy prices and complementary programs, the more dynamic models are beginning to incorporate different behavioral responses within their analytical framework. As consumers shift their preferences in the way they use energy, they might be motivated to greatly increase their overall energy efficiency in ways that require only a small or modest price signal. Table 1 looks ahead to the modeling results detailed later in this report in order to illustrate how shifting awareness and changing preferences might lower the price signal needed to stimulate a large change in U.S. energy use.

Table 1: Illustrating the Impact of Programs and Consumer Behavior on CO_2 Price

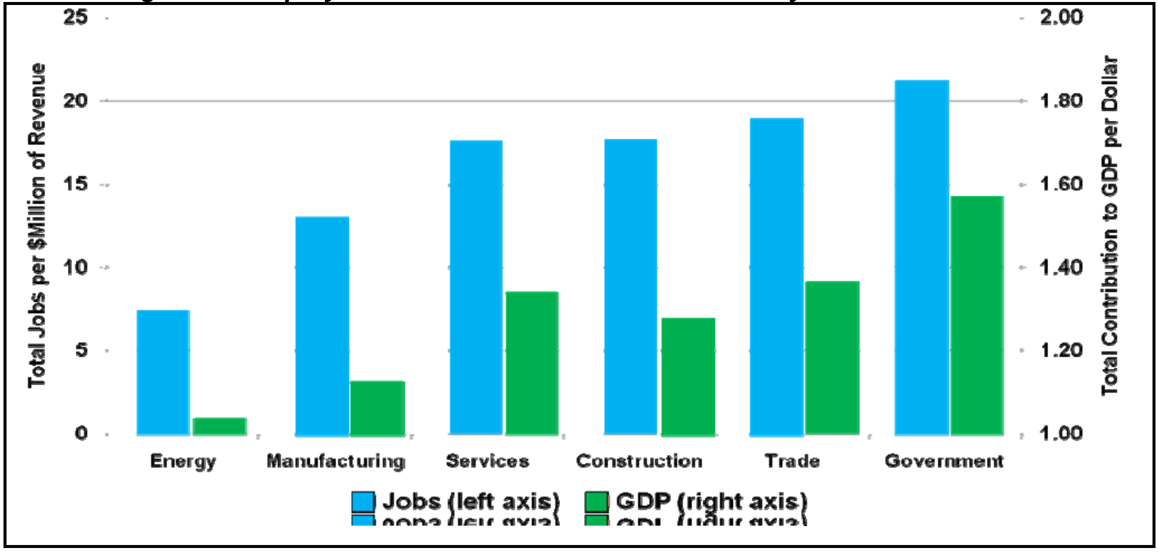
Assumed Policy Scenario	\$t/CO_2
Pricing policy with some complementary programs and limited change in behavior	\$753
Pricing policy with more complementary programs and evolving consumer behavior	\$239
Pricing policy with significant complementary programs and big shift in behavior	\$57

What is shown in Table 1 is a set of three different prices that might be associated with carbon dioxide emissions. These results are taken from three different scenarios, which are detailed in Table 3. The scenarios are described more fully in the next section of this report. Each of the imputed prices depends on the assumptions made about consumer preferences and the mix of complementary programs that might otherwise ease the impact of increased CO_2 prices. If a model assumes a small and rigid consumer response, as indicated in the first row of Table 1, then a very high carbon price would be required to drive down CO_2 emissions. As more programs are folded into the policy scenario, consumers are assumed to change their behaviors over time, and, as a result, much smaller prices are needed to achieve big reductions in emissions. By incorporating this kind of change in consumer values and behavior, the realistic economic models are likely to discover more positive outcomes than can be found with traditional modeling methods.

3. An Improved Economic Accounting of Investments

The good news, according to McKinsey & Company (2009) is that if we choose to address the “significant and persistent barriers” and deliver a “comprehensive and innovative approach” to unlock the energy efficiency resource, we are likely to open up an even more robust economic future at the same time that we dramatically reduce greenhouse gas emissions. This result is driven by investments in energy efficiency that are, in effect, an investment in larger economic productivity, and because such investments imply a change in the production mix of economically important activities in the country to one that encourages investment in those sectors that return greater rates of labor and value-added intensities. It is this latter focus to which the discussion now turns.

Figure 2. Employment and GDP Contributions for Key Economic Sectors



Source: IMPLAN (2009)

Figure 2, above, shows two sets of economic impacts based on economic accounts for the U.S. in 2007 (IMPLAN 2009). The first is the total number of jobs now directly and indirectly supported by spending within six major sectors of the U.S. economy.[9] For example, revenues received by firms in

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[9] While Figure 2 highlights only an aggregate of six sectors for the U.S. economy, the IMPLAN data set actually shows the full interaction among 440 sectors of the economy.

the energy sector support, on average, only 7.4 total jobs per million dollars of spending. All other sectors support a larger number of direct and indirect jobs for the same one million dollars of spending. The second impact is the rate of value-added contribution that is supported by spending in each of the major sectors. Here the data show that each dollar spent on energy contributes about $1.04 cents of GDP return while all other sectors show a larger value-added benefit. (See the appendix to this report for a more complete review of these sectoral differences and their implication for the national economy in the context of changes in overall spending).

The state of California has useful data that illustrates the potential benefits of moving away from capital intensive energy resources to spending in sectors that provide a greater benefit in terms of jobs and GDP. The state has had the most comprehensive and aggressive energy efficiency policies for decades. As a result, while per capita energy use has increased since 1970 in the rest of the country, it has fallen 18 percent below 1970 levels in California. Indeed, the state's per capita electricity consumption is about 40 percent less than the country as a whole (Next 10 2009). Despite relatively high electricity rates, California has the fifth lowest electricity bill in the country, measured as a fraction of Gross State Product. Roland-Holst has investigated the historical macroeconomic effects of these policies. He concludes that California's efficiency programs from 1972 onward have created about 1.5 million full-time jobs with a payroll of over $45 billion and saved households $56 billion in energy costs over that same period. One causal factor in this positive outcome is the same shift from energy-intensive economic activity to labor-intensive economic activity due to efficiency investments that is documented in this work (Roland-Holst 2008). This work is also consistent with assessments by Barrett et al. (2005) and the meta-review of four dozen state and regional impact assessments completed last year by ACEEE (Laitner and McKinney 2008).

The evidence highlighted in this discussion, together with other documented assumptions described in the remaining part of this report and its accompanying appendix, allow us to evaluate how changed investment and spending patterns might impact the U.S. economy as a whole. These results are summarized in the next section of the report.

III. EVIDENCE OF ECONOMY-WIDE BENEFITS

As in any of the studies of this type, the outcomes are very much dependent on the assumptions and the functional behavioral and economic relationships that underpin a given analytical framework. Much of the technical details of the DEEPER Model are provided in the appendix to this report. In this main section of the report we review the more critical technology and program assumptions that inform the suggested impacts that are likely to occur should some form of H.R. 2454 be adopted and signed into law.

A. Technology and Program Assumptions

Table 2 captures the dynamics of three different policy scenarios for the key years 2030 and 2050. All scenarios build from the reference case assumptions used in this report. They also reflect more aggressive policies that drive greater levels of energy efficiency and clean energy technology assumptions as they are reflected within the framework of H.R. 2454.

The first policy case is based on the various energy efficiency provisions included in H.R. 2454, such as improved equipment efficiency standards and building codes; modest energy savings targets for electric utilities; and some investment of emissions allowance income in state, utility, and municipal energy efficiency efforts (Gold et al. 2009). This amounts to an end-use savings of 6.4 quads by 2030 with net consumer savings (energy bill savings less investments and program spending) on the order of $62 billion also by 2030 (in constant 2007 dollars). If these programs were maintained and funded through 2050, the working estimate is an efficiency gain of 14.5 quads of end-use or delivered energy by 2050.

Table 2. Representative 2030 and 2050 Impacts of Climate Policy Scenarios

Financial and Economic Indicators	H.R. 2454 Basic EE		H.R. 2454 Enhanced EE		H.R. 2454 Optimal EE	
	2030	2050	2030	2050	2030	2050
Reference Case Emissions (MMTCO$_2$e)	7,954	8,879	7,954	8,879	7,954	8,879
Carbon Price ($/tCO$_2$e)	$47	$239	$41	$185	$35	$128
Policy Case Reductions (MMTCO$_2$e)						
Energy-Related	3,392	4,551	3,480	4,638	3,636	4,875
Other Domestic	399	1,122	366	1,028	323	795
International Offsets	253	1,112	253	1,112	253	1,112
U.S. Policy Case Emissions (MMTCO$_2$e)	3,911	2,095	3,855	2,102	3,742	2,098
Percent Reduction from Reference Case	51%	76%	52%	76%	53%	76%
Financial Impacts (Billion 2007 Dollars)						
Program Cost	12	17	16	20	23	31
Annual Payments on Investments	119	94	133	112	161	171
Energy Bill Savings	$485	$321	$548	$600	$637	$926
Net Savings	$354	$209	$399	$467	$452	$724
Macroeconomic Impacts						
Employment (Thousands of Jobs)	424	1,176	743	2,001	1,017	2,577
Percent from Reference Case	0.2%	0.4%	0.3%	0.7%	0.4%	0.9%
GDP (Billion 2007 Dollars)	2	-129	0	-93	4	-38
Percent from Reference Case	0.0%	-0.3%	0.0%	-0.2%	0.0%	-0.1%

Table 3. Highlighting the Impact of Key Scenario Assumptions in 2050

	Case #1	**Case #2**	**Case #3**	**Case #4**	**Case #5**	**Case #6**
	Big Tech–Big Price	**Big Tech–Little Policy**	**H.R. 2454 Basic EE**	**H.R. 2454 Enhanced EE**	**H.R. 2454 Optimal EE**	**H.R. 2454 Optimal EE Big Behavior**
Scenario Comparison — Year 2050						
Policy Levers	Price Only	Basic EE	Basic EE	Enhanced EE	Optimal EE	Behavior-Directed Optimal EE
Implicit Discount Rate Start	30%	30%	30%	30%	30%	30%
Implicit Discount Rate End	25%	25%	20%	20%	20%	15%
Year 2050 Results						
Emissions Price ($/tCO2e in 2007 $)	$1,839	$753	$239	$185	$128	$57
End-Use Energy Savings	29%	36%	43%	46%	52%	61%
Energy Price Increase	316%	144%	52%	38%	24%	10%
Energy Expenditure Increase	195%	56%	-13%	-26%	-41%	-57%
Reference Case Emissions (MMtCO$_2$e)	8,879	8,879	8,879	8,879	8,879	8,879
Policy Case Emissions (MMtCO$_2$e)	2,096	2,098	2,095	2,102	2,098	2,089
Emissions Reductions	76%	76%	76%	76%	76%	76%
Cumulative Efficiency Investments 2012 through 2050 (Billion $2007)	1,412	1,929	2,612	3,067	4,120	5,922
Average 2012 Energy Efficiency Payback (Years)	2.50	2.68	2.69	2.88	2.99	3.02
Average 2050 Energy Efficiency Payback (Years)	4.42	4.24	5.26	5.41	6.81	9.64

The second policy case adds several enhancements to H.R. 2454 package — stronger utility savings targets, a continuation of state and municipal energy efficiency programs beyond 2030, and a requirement that electric utilities invest one-third of their free emissions allowances to help their customers reduce their energy use (H.R. 2454 already includes such a requirement for gas utilities). As noted in Gold et al. (2009), the findings here suggest an end-use savings of 9.0 quads by 2030 with a net consumer savings that grows to $105 billion, again in 2030. For the analysis reported in Table 2, the assumption was that this enhanced set of programs would deliver a total efficiency gain of 19.8 quads by 2050.

The final policy case uses the assumptions in the National Academy of Sciences report *America's Energy Future* (AEF 2009) to extend the program savings of an "optimal H.R. 2454" up to a total savings of 13.5 end-use quads in 2030 and reaching 28.5 quads by 2050. In effect, the third scenario assumes many of the policies already described are further enhanced to approximately double efficiency savings relative to the first scenario.

With these different capacities of program effort mapped into DEEPER, presumably delivering a large chunk of emissions reductions through the resulting program stimulus, the model then tries to find the set of prices that will motivate the remaining emissions reductions needed to hit the 2050 target.[10] Table 2 highlights key financial and economic results for the years 2030 and 2050 for each of these three levels of program-delivered gains in energy efficiency improvements. As we scan the pattern of results shown in Table 2, there are perhaps three key insights that emerge from the modeling results shown here. They might be summarized as:

(1) A productive, investment-led perspective yields an entirely different outcome than the "cost containment strategy" that most models rely on;

(2) H.R. 2454 can provide at least one useful framework to implement a smart investment-led climate strategy, yet there remain productivity gains well beyond the current energy efficiency provisions of the bill — if we choose to develop them; and

(3) While there are large uncertainties in exactly how consumers and businesses will respond, and what innovation paths might actually unfold, stimulating further productive investment is the smart path forward.

Turning for a moment to results highlighted in Table 3, we might observe a different, but still related, set of insights. To provide a backdrop that might help readers more fully appreciate the key insights here, we first take a minute to explain several important metrics that will improve an understanding of the overall results. The first metric is the change in implicit discount rates while the second is the set of payback periods listed for the mix of technology investments shown in each of the six cases.

In an earlier discussion we noted that consumers may initially have an expectation of adopting more energy-efficient technology only if the energy bill savings pays for the investment in a short period of time. If the consumer sees a technology with a five-year payback (in effect, a 20 percent annual savings on the investment), but won't adopt the efficiency improvement unless the investment pays for itself in three years, we might then suggest the consumer wants at least a 33 percent return. In other words, they are acting as if they have a 33 percent discount rate. This suggests that prices will need to rise 67 percent for what is now a 5-year payback to drop to a 3-year payback. But if the consumer only needs some information or financial incentive, then significantly higher energy prices might not necessary to encourage adoption. In the DEEPER Model we adjust consumer expectations

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[10] One important note is that Gold et al. (2009) used an engineering-based analysis to determine the 2020 and 2030 energy savings and the costs for the full suite of energy efficiency provisions within H.R. 2454. Those assumptions were independent of changing energy prices and interactions within the larger economy — that, together with costs for all emissions reductions within a time horizon that extends out to 2050, generates different scenario estimates of costs and savings than for a standalone analysis of just the efficiency measures.

by modifying the implicit discount rate consistent with program evidence on how consumers might respond with better information, or being financially more able to respond to energy prices.

With that backdrop we might now observe in Table 3 two significant patterns starting with Case #1 — what is referred to as the "Big Tech–Big Price" scenario. In this example we show that if the model assumes consumers will continue to respond only to the highest of energy prices, and that there are no further efficiency programs beyond what is now authorized, then DEEPER would suggest that very high prices for CO_2 permits would be needed to bring overall greenhouse gas emissions down to the target levels. As a result, very little of the reductions occur from efficiency gains but, instead, are the result of very large and very expensive low- or no-carbon energy supply technologies (e.g., large nuclear plants or fossil fuel units with carbon capture systems). In fact, it is unlikely that this kind of scenario would actually occur since the very high prices would likely spur many new innovations and a changing pattern of consumer response. But this scenario also shows that, yes, any model can be designed to show highly negative impacts.

At the same time, as we move to Case #2 with some additional energy efficiency programs now being incorporated into the climate policy, the emissions prices come down steeply although they are still at a very high level. Moving into the H.R. 2454 energy efficiency programs, and showing a changed consumer response as concern about the climate problem becomes more widespread and as the programs make consumers and businesses more aware of cost-effective opportunities to save on their energy bills, the emissions prices continue to drop (Case #3, #4, and #5). Finally, in Case #6 we can see that an optimal set of efficiency programs — delivering about twice the benefits as the current H.R. 2454 legislation now support, coupled with a very big response from consumers as their implicit discount rate falls to 15 percent — the emissions prices declines to a low of $57 dollars per metric of CO_2 equivalent. In effect, there are two big drivers in creating a highly net positive outcome from legislation like H.R 2454.

First, it is the delivery of cost-effective energy efficiency programs, provided at a sufficient scale and over a sufficient period of time, that reduces the need for a large price signal to drive the same magnitude of change compared to our first case. Second, a pronounced shift in consumer behavior can deliver a much larger willingness to adopt smart technologies — also without as large of a price signal. Finally, while the technologies start out cost-effectively in the first years of each scenario, averaging a three-year payback, as more efficiency is "used up," the paybacks begin to lengthen. At the same time, but not shown in the Table 3 results, new research and development programs as well as market-based innovations begin to provide a new generation of cost-effective technologies over time. They slow the payback periods, generally holding in the 5–6 year range (reflecting a roughly 17–20 percent return on the resulting technology investments). The last case really pushes the adoption of technology very hard so that the payback increases over time to about 9.6 years. But even this implies a 10.4 percent return, which is better than most other investments in the economy.

One big observation might be worth noting here. There is a good bit of truth to the old adage that "it takes money to make money." As each scenario unfolds there is an increasing amount of capital investment. Case #1, saving only 29 percent of the 2050 delivered energy requirements, necessitates only a modest investment of $1.4 trillion. Since that investment is spread over a roughly 40-year time horizon, the annual outlay to promote greater energy productivity is only $36 billion. Recall, however, that the economy will require an annual total investment of about $4 trillion per year over that same 40-year time horizon. This means less than one percent of normal investment patterns are being devoted to efficiency improvements beyond normal reference case activities. And the results show up in a significantly higher cost of energy as the U.S. would be paying nearly double for energy compared to the reference case. But at least total GHG emissions are down substantially. In Case #3 — the basic H.R. 2454 policy framework — cumulative investment nearly doubles, but with the happy result that energy expenditures are now about 13 percent less than in the reference case — even as energy prices are shown to be higher. Moving over to Case #6, efficiency investments are now increased to a cumulative of $6 trillion through 2050. This saves about 60 percent of the energy that was previously required so that even as prices are up 10 percent in this scenario, total expenditures are down 57 percent.[11] With that backdrop, it becomes very clear that if climate policies can be designed to encourage greater investment in more productive technologies, then the economy as a whole can benefit. What's the bottom line from this part of the analysis? A smart approach to shaping future climate policy is one that encourages greater levels of productive energy efficiency investments while, at the same time, providing consumers and businesses with sufficient information and motivation to enable the integration of productive investments more seamlessly into their homes, schools, and workplaces.

B. Economy-Wide Impacts of a Climate Change Policy

With the appropriate technology and behavioral assumptions described previously, we now examine the economy-wide benefits of a smart climate policy over a more extended time horizon. Table 4 gives these details for Case #5, which reviews the optimal energy efficiency policies and measures that might be embedded within the H.R. 2454 framework. Again, this case would roughly double the efficiency investments compared to the version of the bill passed by the House of Representatives.

Table 4. Macroeconomic Impacts of Optimal Energy Efficiency in H.R. 2454 (Case #5)

	2012	2020	2030	2040	2050
Reference Case Emissions (MMTCO$_2$e)	7,349	7,633	7,954	8,357	8,879
Carbon Price (\$/tCO$_2$e)	\$11	\$18	\$35	\$66	\$128
Policy Case Reductions (MMTCO$_2$e)					
Energy-Related	1,088	2,251	3,636	4,233	4,875
Other Domestic	144	206	323	507	796
International Offsets	85	138	253	464	1,112
U.S. Policy Case Emissions (MMTCO$_2$e)	6,032	5,038	3,742	3,152	2,097
Percent Reduction from Reference Case	18%	34%	53%	62%	76%
Financial Impacts (Billion 2007 Dollars)					
Program Cost	11	29	23	22	31
Annual Payments on Investments	48	120	161	111	171
Energy Bill Savings	\$20	\$282	\$637	\$770	\$926
Net Savings	-\$38	\$133	\$452	\$637	\$724
Macroeconomic Impacts					
Employment (Thousands of Jobs)	179	575	1,017	2,068	2,577
Percent Change from Reference Case	0.1%	0.3%	0.4%	0.8%	0.9%
GDP (Billion 2007 Dollars)	7	13	4	37	-38
Percent Change from Reference Case	0.1%	0.1%	0.0%	0.2%	-0.1%

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[11] While the "productivity frontier" has not been explored fully in any policy assessments to this point (meaning that we don't have a really good handle on the maximum levels of efficiency improvements that we might ultimately expect), it is at about this point (i.e., a 60 percent savings) where issues like capital stock turnover and systems efficiencies might limit further energy productivity gains. This represents an important area of future research. At the same time, it is quite clear that over the next 20 to 30 years there is a huge opportunity for improvement — if we choose to encourage productive levels of investments.

In examining Table 4 above, two thoughts in particular are worth noting. First, energy-related reductions are an important cost-effective mechanism, contributing about 70 percent of total emissions reductions by 2050. Their net energy bill savings drives a strong positive result in terms of both job creation and offsetting or minimizing potential GDP losses.[12] And all of these benefits are driven by more productive investments in the nation's infrastructure and technologies. At the same time, other domestic emissions reductions and domestic offsets, as well as international offsets, are a vital part of total emissions reductions envisioned in H.R. 2454. Their combined 30 percent contribution goes a long way to hold down permit prices. If domestic resources alone had to drive down emissions, the working estimate within the DEEPER Model suggests that emissions prices would exceed $1,000 per metric ton after the year 2030. Second, a balanced portfolio — one that builds on productive investments in energy efficiency but that also includes both other domestic and international reductions — can drive a largely positive result for the U.S. economy. As shown in Table 4, the initial program and investment activity drives an early net gain in employment with an estimated 179,000 jobs in 2012, rising to just over one millions jobs by 2030, and moving past two million jobs by 2040.[13]

Throughout the time horizon reported in Table 4, the nation's GDP is largely unchanged as investments and a growing net energy bill savings offset losses elsewhere in the economy. This holds until the last few years in the time horizon when the purchase of international offsets begins to claim more of the revenue share. Looking at the emissions reduction profiles for 2012 as it compares to 2050, we note that energy-related reductions grow by a factor of four in that period. Other domestic emissions reductions follow a similar pattern, increasing by a factor of five in that time. International offsets, on the other hand, while still a relatively small part of the solution, increase by a factor of 13. As DEEPER evaluates this impact, the purchase or investment in international offsets is a factor payment that reduces GDP, especially as the total amount of offsets more than doubles in the last decade of this analysis. That is the reason for the small GDP losses (i.e., 0.1 percent) that are shown in 2050. At the same time, the ongoing investments and growing energy bill savings continues to power gains in jobs as the net employment benefits rise to more than 2.5 million jobs by 2050, just short of a one percent gain in jobs that are otherwise available in that year.

IV. CONCLUSION

Despite the enormous promise of existing technologies, and the even more productive ones yet to come, most of the economic assessments of climate change policies completed to date tend to overlook the role of productive investment in helping achieve the twin goals of a healthy economy and a healthy climate. As this study suggests, a productivity-enabled outcome would provide more job opportunities, not fewer. The unwritten assumption in most modeling exercises is that controlling greenhouse gas emissions is all about cost containment rather than a smart redirection of investments toward the more productive use of technologies and people. This analysis is markedly different in that respect. It draws from an investment-based perspective rather than a cost-constrained analysis, and it assumes imperfect markets and information flows that might be better informed through complementary policies that are embedded and expanded within the H.R. 2454 policy framework. It asks the question, how can we increase the robustness of the U.S. economy while positively impacting the global climate? The evidence suggests that smart technology investments can protect the climate and maintain a robust economy — if we choose to develop that opportunity.

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[12] As the DEEPER model now reports information, it appears that a combination of renewable energy and decentralized energy technologies now account for about 70 percent of the total energy-related emissions reductions. But this understates the critical importance of this family of technologies, especially as post-2050 efficiency gains will be much harder to achieve and the economy will increasingly rely on low- or non-carbon energy supplies. Perhaps just as important, to the extent that early investments more quickly reduce the cost of these clean energy technologies, they are more likely to become an earlier part of the energy contribution to overall reductions in greenhouse gas emissions.

[13] Although too late to integrate the findings into this analysis, a new modeling assessment by Roland-Holst et al. (2009) shows highly comparable results to the outcomes reported here. Those similarities are less surprising perhaps when one realizes that both the DEEPER Model and the EAGLE Model developed by Roland-Holst and his colleagues embrace an economic development framework rather than a cost-constraint perspective.

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APPENDIX: KEY ECONOMIC AND FINANCIAL ASSUMPTIONS

As implied in the main part of this report, the impact assessment described here is really an examination of how changed behaviors and investment flows might reasonably characterize an alternative and perhaps a more productive energy and economic future. As business leaders and policymakers first think about the policy implications of suggested climate change legislation, they may conclude that the implied transition to a less carbon-intensive economy will end up costing more. On the other hand, when all system costs are properly included and balanced, it can be shown — on a net basis — that the alternative future or the enacted policy scenarios may actually cost less.

In a format consistent with a number of other past studies that inform this debate (see, for example, McKinsey & Company 2009; CCS 2008; Laitner and McKinney 2008; Barrett et al. 2005; Laitner et al. 2006; Lovins et al. 2004; Interlaboratory Working Group 2000), this appendix highlights the major analytical assumptions that underpin the assessment described in the main part of the report.

The assumptions generally fall into four major categories: prices, quantities, investment flows, and input-output modeling. Each of these categories is subscripted by sector and by end-use energy or fuels. The analytical tool used to evaluate the energy and climate policy impacts is the DEEPER Model, which is described next. This is then followed by the major price, cost, income, and demand assumptions that underpin the results summarized in the main body of the report.

The DEEPER Modeling System

The **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine — the DEEPER Modeling System — is a 15-sector quasi-dynamic input-output model of the U.S. economy.[14] Although an updated model with a new name, the model has a 15-year history of use and development. See Laitner, Bernow, and DeCicco (1998) for an example of an earlier set of modeling results.[15] Laitner and McKinney (2008) also reviews past modeling efforts using this modeling framework. The model is used to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at both the state and national level. The timeframe of the model for evaluating policies at the national level is 2010 through 2050, or in the case of evaluating H.R. 2454, the period 2012 through 2050. In its current implementation, the model solves for the set of energy prices that achieves a desired, exogenously determined level of greenhouse gas emissions (i.e., below some previously defined reference case).

The model includes a representation of both energy-related CO_2 emissions and all other greenhouse gas emissions as well as emissions reduction opportunities. The DEEPER Model focuses, in particular, on the use of energy in all sectors of the economy, electricity production, and energy-related CO_2 emissions as well as on the prices, policies, and programs necessary to achieve the desired emissions reductions. The DEEPER Model is an Excel-based analytical tool with three linked modules combining approximately two dozen interdependent worksheets. The primary analytic modules are: (i) the Energy and Emissions Module, (ii) the Electricity Production Module, and (iii) the Macroeconomic Module. The block diagram of the DEEPER Modeling System on the following page lays out the analytical framework of the model.

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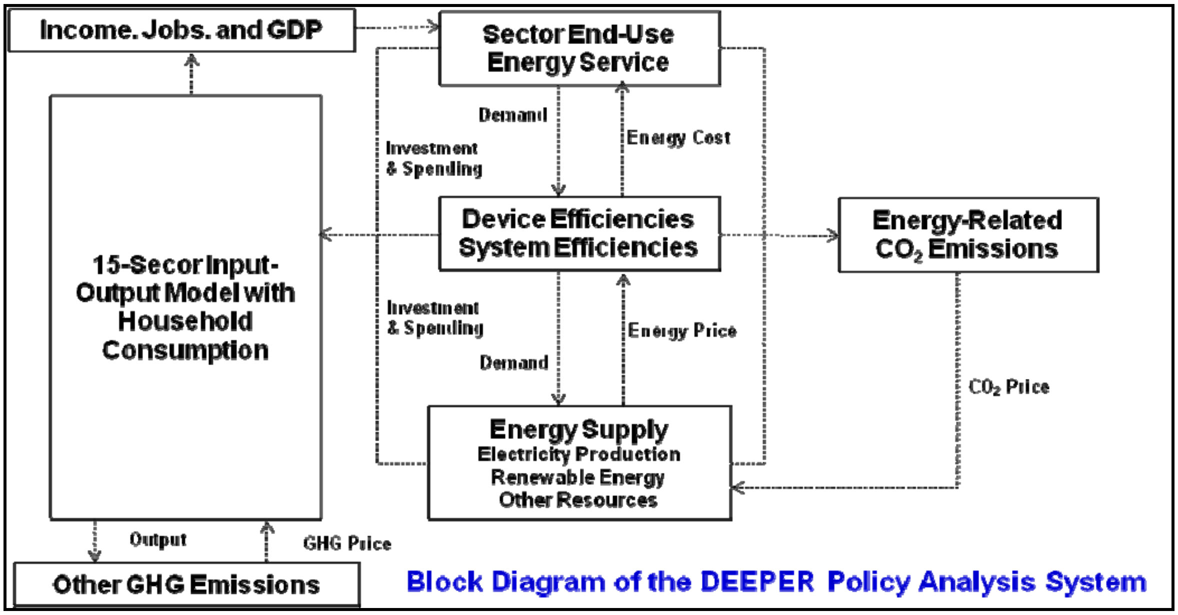
[14] There are two points that might be worth noting here. First, the model solves recursively. That is, the current year set of prices and quantities is dependent on the previous years' results. As the model moves through time, there are both secular and price-quantity adjustments to key elasticities and coefficients within the model. Second, there is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. If the analyst chooses to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be easily accomplished. Expanding the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

[15] When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.



Block Diagram of the DEEPER Policy Analysis System

The model outcomes are driven primarily by the demands for energy services and alternative investment patterns as they are shaped by changes in policies and prices. A key feature of the model is one that also allows consumer behaviors to also adjust to changing preferences. This follows the logic outlined in Laitner, DeCanio, and Peters (2000), and fits within the framework outlined by Ehrhardt-Martinez (2008). The changes are implemented in what we call a price-preference ratio following Laitner (2009a) and Laitner and Hanson (2006). The functional form of the price-preference ratio is computed as an index of price divided by the consumer's implicit discount rate. This is a rate that reflects a desired return on investment. For example, if a consumer chooses not to adopt a technology, for whatever reason, unless it pays for itself over a 2-year period, that suggests a 50 percent discount rate; or said differently, a desire to earn at least a 50 percent return on his or her investment in an energy-efficient technology. All else being equal, either a doubling of prices or a 50 percent reduction in the implicit discount rate (or some equivalent combination of the two) will have the same impact on the various elasticities within the model.[16]

Although the DEEPER Model is not a general equilibrium model, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors. As shown in the block diagram above, the demand for energy-related services is the starting point for policy-induced changes. Both price and non-price policies — including standards, technical assistance, financial incentives, research and development (R&D), or general information and labeling programs (e.g., the EPA and DOE ENERGY STAR programs) — can shift consumer preferences and the availability of technologies. Implementation of these policies stimulates an array of changes in prices, investments, and expenditures. These changes include program costs and incentives that might be needed to shift behaviors and investments so that the energy and emissions targets are satisfied. As changing demands confront a changing mix of energy resources, GHG prices (in constant dollars per metric ton of avoided CO_2-equivalent emissions) and energy prices (in constant dollars per million Btus of energy) are likely to change in response. The combination of new policies and induced changes in prices stimulates changes in investments and other consumer behaviors. These changes in investments and consumer behaviors drive the final results that emerge from application of the DEEPER Model.[17] With this preliminary characterization of the model, the sections that follow describe the three major modules within DEEPER.

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[16] One nice feature of this functional form is that it is less important to determine the "right" starting implicit discount rate as it is to show what a shift in the size of that rate might matter.

[17] As noted in Hanson and Laitner (2004), a combination of price and non-price policies can generally produce a much more

Energy and Emissions Module: The DEEPER Model is benchmarked to the most current version of the *Annual Energy Outlook* (EIA 2009a), which now extends out through 2030. Based on data available from other sources like Economy.com (2009), which now goes out to 2039, we must make a reasoned estimate of how the economy might grow through the year 2050 in a "Business-as-Usual" or Reference Case scenario, and how that will, in turn, affect energy use, fuel and electricity prices, and greenhouse gas emissions.

Key Reference Case Scenario Data for DEEPER Policy Run (Key Benchmark Years)					
	2012	**2020**	**2030**	**2050**	**Annual Growth Rate 2012-2050**
Gross Domestic Product (Billions of 2007 Dollars)	14,947	18,472	23,460	38,332	2.5%
Energy-Use or Delivered Energy (quads)	73.0	74.4	79.0	93.3	0.7%
Electricity Consumption (Billion kWh)	3,847	4,127	4,527	5,415	0.9%
Energy-Related CO_2 Emissions ($MMTCO_2e$)	6,172	6,309	6,639	7,411	0.5%
Non-Energy GHG Emissions ($MMTCO_2e$)	1,177	1,324	1,315	1,468	0.6%
Total GHG Emissions ($MMTCO_2e$)	7,349	7,633	7,954	8,879	0.5%
Household Electricity Price (2007 $/kWh)	0.103	0.111	0.118	0.144	0.9%
Household Natural Gas Price (2007 $/MBtu)	11.40	12.56	13.96	21.23	1.6%
Total Household Energy Bill (Billion 2007 $)	55.85	62.72	69.54	105.73	1.7%
Total Economy-Wide Energy Bill (Billion 2007 $)	1,168.2	1,502.9	1,704.1	2,256.0	1.7%
Ecomomy-Wide Energy Price (2007 $/MBtu)	16.01	20.19	21.58	24.17	1.1%

The main reference case assumptions are shown in the table above for key benchmark years 2012 through 2050. In general the economy is expected to grow at a rate of about 2.5 percent annually; total end-use energy consumption will grow 0.7 percent per year while electricity use is expected to grow at about 0.9 percent per year. Rising energy prices (with all values in 2007 dollars) will increase total household energy expenditures at a rate of about 1.7 percent annually. Because of the expected growth in petroleum fuel (not shown here) and natural gas prices, the nation's total energy bill (across all sectors and all fuels) will grow about 1.7 percent per year — escalating from an estimated $1.2 trillion dollars in 2012 to nearly $2.3 trillion by 2050.

Some of the important inputs derived from this module that feed into the macroeconomic model described below include:

- The policies and measures that are phased in over time;
- The stringency of the emissions reduction target;
- The rates of growth in energy-related prices;
- The pattern of consumer and investor decisions concerning the adoption of new technologies; and
- The resulting innovations that lead to new technologies and/or changes in demands for services.

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cost-effective policy resolution than either type of policies would induce by itself. The resulting deployment of new technologies depends on the assumed effectiveness of programs that might be implemented and the incentives being offered. Implementation of these policies — along with the resulting deployment of new technologies — strengthens the ability of the market to respond to the price signal. In this context, prices act as a signal for necessary changes, rather than as a punishment for consumers and producers.

Output, Employment, Wages, and Value Added Data, 2007				
	Output*	**Jobs**	**Wages***	**Value Added***
Agriculture	371,484	3,771,606	41,790	159,152
Oil and Gas Extraction	410,704	662,110	47,008	226,025
Coal Mining	28,358	81,277	6,745	15,719
Other Mining	52,745	164,553	11,165	30,838
Electric Utilities	359,446	537,905	60,619	258,661
Natural Gas Utilities	126,746	108,900	12,427	43,816
Transportation, Water, Sewer	695,045	4,182,656	194,295	311,975
Construction	1,617,010	11,320,144	440,861	688,847
Manufacturing	5,187,399	13,799,875	936,431	1,482,617
Petroleum Refineries	557,555	70,410	13,059	85,483
Wholesale Retail Trade	2,444,344	25,248,416	906,865	1,646,136
Services	9,822,773	83,879,288	3,006,503	6,012,169
Financial Services	2,030,984	8,203,043	617,879	1,087,844
Government	1,898,597	24,878,120	1,517,927	1,758,319
Totals	25,603,191	176,908,303	7,813,573	13,807,600
*Millions of 2007 Dollars				

Macroeconomic Module: This set of spreadsheets contains the “production recipe” for the U.S. economy for a given “base year.” For this study, the base year used was 2007. This is the latest year for which a complete set of economic accounts is available for the U.S. economy. The input-output or I-O data, currently purchased from the Minnesota IMPLAN Group (IMPLAN 2009), is essentially a set of economic accounts that specifies how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other. Further details on this set of linkages can be found in Hanson and Laitner (2009). For this study, the model was run to evaluate impacts of the selected policies upon 15 different sectors, including: Agriculture, Oil and Gas Extraction, Coal Mining, Other Mining, Electric Utilities, Natural Gas Distribution, Construction, Manufacturing, Wholesale Trade, Transportation and Other Public Utilities (including water and sewage), Retail Trade, Services, Finance, Government, and Households.[18] To provide the reader with a sense of scale for these major sectors, the table above provides sector output, jobs, compensation, and the value-added contributions to the nation’s gross domestic product (in millions of 2007 dollars). As described below, examining the job and value-added intensities of the different sectors in this table provides early insights of likely scenario outcomes.

The principal energy-related sectors of the U.S. economy are not especially job-intensive. For example, taking total employment for the natural gas and electric utilities and dividing it by the total number of revenues received by those two sectors, it turns out that the nation’s utilities support only 1.3 direct jobs for every one million dollars of revenue received in the form of annual utility bill payments. The rest of the economy, on the other hand, supports about 7 direct jobs per million dollars of receipts. Thus, any productive investment in energy efficiency that pays for itself over a short period of time will generate a net energy bill savings that can be spent for the purchase of goods and services other than energy. The impact of a one million dollar energy bill savings suggests there may be a net gain of about 5.7 jobs (that is, 7 jobs supported by a more typical set of consumer purchase compared to the 1.3 jobs supported by the electric and natural gas utilities). Depending on the sectoral interactions, however, this difference may widen or close as the changed pattern of spending works its way through the model, and as changes in labor productivity changes the number of jobs needed in each sector over a period of time.[19]

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[18] While there are only 14 sectors shown in the table above, household spending is allocated to each of the sectors using the personal consumption expenditure data provided with the IMPLAN data set.

[19] As we will see later in this appendix, DEEPER does capture sector trends in labor productivity. That means the number of

Based on the scenarios mapped into the Energy and Emissions module, the set of worksheets in the Macroeconomic Module translates the selected energy policies into an annual array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. Using appropriate technology cost and performance characterization as it fits into the investment stream algorithm discussed below, DEEPER estimates the needed investment path for an alternative mix of energy efficiency and other technologies (including efficiency gains on both the end-use and the supply side). It also evaluates the impacts of avoided or reduced investments and expenditures otherwise required by the electric generation sector. These quantities and expenditures feed directly into the final demand worksheet of the module. The final demand worksheet provides the detailed accounting that is needed to generate the implied net changes in sector spending. Once the mix of positive and negative changes in spending and investments have been established and adjusted to reflect changes in prices within the other modules of DEEPER, the net spending changes in each year of the model are converted into sector-specific changes in final demand. This then drives the input-output model according to the following predictive model:

$$X = (I-A)^{-1} * Y$$

where:

X = total industry output by sector
I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)
A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)
Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$$\Delta X = (I-A)^{-1} * \Delta Y$$

which reads, a change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[20] Employment quantities are adjusted annually according to exogenous assumptions about labor productivity in each of the sectors within the DEEPER Modeling System (based on Bureau of Labor Statistics forecasts; see BLS 2007). From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the U.S. economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

For each year of the analytical time horizon (i.e., 2012 to 2050 for the climate policy assessment in this report), the model copies each set of results into this module in a way that can also be exported to a separate report. For purposes of this separate report, and absent any anomalous outcomes in the intervening years, we highlight the decadal results in order to focus attention on the differences in results emerging from various alternative policy scenarios. For a review of how an I-O framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an equilibrium model, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Laitner and Hanson (2009). Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.

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jobs needed per million dollars of revenue will decline over time.

[20] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

Energy Prices

The sector prices for electricity and fuels are shaped by the change in the cost of CO_2 emissions as a function of their carbon intensities. For example, if the permit price goes up to 50$ per metric ton, all energy prices would adjust according to the carbon content of each fuel as referenced in the EPA Greenhouse Gas Emissions Inventory (EPA 2009a). In the case of natural gas, for example, the CO_2 content is listed at 0.05306 tonnes per million Btu. If the reference case price of natural gas for industrial customers is $8.69/MBtu in 2030, the new price would be 0.05306 * $50 + 8.69, or $11.34/MBtu, a roughly 30 percent increase in the price to industry.

Technology Investment Streams

As previously noted, the investment costs are estimated for three different categories of emissions reductions: energy efficiency investments, low-carbon energy supply technologies, and non-CO_2 emissions reductions. The key set of assumptions for each of the major sources of investment flows is summarized below.

Energy Efficiency

One critical piece of information needed to evaluate the impact of these scenarios is the cost of investment in energy efficiency technologies. To derive this information, we adapt the structure of the Long-Term Industrial Energy Forecast or LIEF model (Cleetus et al. 2003). The key relationship in this model is the current gap between average and best energy efficiency technology or the best efficiency practice.

The assumption in the LIEF model is that as a sector moves closer and closer to best practice or best technology (sometimes referred to as the production frontier), the cost of efficiency investment per unit of energy saved will increase. The rate of that potential cost increase depends on the energy prices, the elasticity of the efficiency supply curve, and the discount rate. It also depends on how innovations and R&D policies might shift the best technology or best practice frontier. As used in this exercise, the investment cost is shown as:

$$\text{Investment per Unit Energy Savings} = \left[\frac{1-G_0}{1-S}\right]^{(1/A)} * \left[\frac{P}{C}\right]$$

where:

P = price of energy in the base year
C = capital recovery factor (CRF) or sector implicit discount rate for the given year
A = an elasticity that reflects the magnitude of the investment response to changes in price levels or the capital recovery factor
S = percent of sector energy savings in current year compared to base year consumption
G_0 = the energy intensity gap, or the difference between best and average practice

In many ways this can be thought of as the energy savings that should be economically viable in the base year, but have not been realized.

By way of example, the data might suggest that today there is a current energy intensity gap of 25 percent based on the potential for long-term efficiency gains through the year 2050, a long run efficiency substitution elasticity of 0.6, and an implicit discount rate of 20 percent. [21] With energy

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[21] This adaptation of the LIEF equation ignores the autonomous time trend component. In other words, as used here, the assumption of an efficiency gap remains static and there is only movement toward best practice or best technology rather than improvement in the base year representation of best practice or best technology. As the historical record suggests, the gap may actually grow to 50 percent — if the U.S. chooses to invest in greater innovation and energy productivity improvements. Hence, the use of a fixed 25 percent gap for purposes of estimating investment costs will tend to overstate the cost of the new efficiency gains.

prices of about \$12.19 per million Btu in 2010, these assumptions suggest an average payback of about 3.7 years for a 10 percent efficiency gain based on prices in 2010. This rises to a 10-year payback for a 50 percent efficiency gain by 2050. Based on the much higher reference case prices in 2050, these paybacks would decline over time to 1.4 and 3.7 years. These results are broadly consistent with results summarized in Laitner et al. (2006) and Hanson and Laitner (2004).[22]

At the same time, the DEEPER Model uses a modified accounting function for each of the end-use sectors and fuels as they are impacted by the H.R. 2454 provisions, out to 2030. Using estimates from McKinsey & Company (2009), AEF (2009), Gold et al. (2009), and Eldridge et al. (2009), among others, each of the cost curve functions was adjusted by sector to reflect both the current and anticipated technology costs and performance reflected in those various studies. In the modeling characterized in this report, the payback periods typically begin at about 2.5 to 3 years in 2012, and depending on policy assumptions, R&D, changes in implicit discount rates, and how quickly efficiency is "used up," the payback periods in 2050 might range from 5 to 9 years. The last two rows of Table 3 in the main report highlight outcomes of the technology costs as shown in each of the cases simulated within the DEEPER Model.

Emissions Reductions

Drawing from the IGEM model data used in the EPA (2009b) assessment, this analysis complements the detailed efficiency improvement costs with a simplified set of marginal abatement cost curves for standard for domestic non-CO_2. This curve is represented by the following formula:

Domestic Offsets = 28.03 * Price $^{0.69}$

Where:

Price = the CO_2e price needed in a given year to reach the necessary reduction target (beyond any energy efficiency and renewable energy reductions made possible through complementary policies and programs).

There is a huge uncertainty with the eventual cost of international offsets. As an important conservatism in this analysis, the assumption now embedded in DEEPER is that all international emissions reductions will be made at the average weighted CO_2e price. The result of this set of assumptions, especially with limits imposed on international offsets, undoubtedly overstates the required permit price. Still it is an insufficient effect to reduce the domestic benefits driven by the significantly larger energy productivity gains. As Hanson (2007) suggests, however, even if the current generation of models captured the full potential of today's technology and market flexibilities, the long-term carbon price could be considerably lower than we estimate based on today's knowledge. We know that there will be some breakthroughs on the technological, political, and international scenes, and a shift in consumer preferences and behaviors. All of these imply the strong likelihood that we will find solutions that are not too much more expensive than today. In fact, there is also evidence that some could be even cheaper (see also Knight and Laitner 2009).

Policy and Program Costs

One of the working assumptions in this review is that that policies and programs are needed to drive the requisite investments. In generating an estimate of what these incremental costs might look like, we borrow from a study by Amy Wolfe and Marilyn Brown, *Estimates of Administrative Costs for*

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[22] Although this is not emphasized in either the report or appendix, DEEPER also can explore changes in costs needed to drive a final result. For example, as it is now configured, if investments cost 20 percent less than now projected for the year 2050, the net jobs shown in Table 4 in the main report increase by about 3.5 percent. On the other hand, if the investments run about 50 percent more than now suggested, the net increase in jobs decline by about 9 percent as shown in Table 4. But this would continue to be a highly positive net gain of more than 2.3 million jobs in 2050. The significance of this finding is that the H.R. 2454 framework — especially if it includes a greater emphasis on energy productivity benefits — is likely to generate a robust outcome for the American economy for all the reasons described earlier in the report.

Energy Efficiency Policies and Programs (Interlaboratory Working Group 2000, Appendix E-1). In that study the average administrative cost is assumed to be $0.60 per million Btu of efficiency gains. In Eldridge et al. (2009) and McKinsey & Company (2009), these program costs were generally assumed to run about 15-20 percent of the annual investments in efficiency gains. In Table 4 of this main report, comparing the program cost totals with the annual payments for investments, the range is shown to be approximately 24 percent in the early years as program activity and R&D investments scale up early in the scenario. Under the current assumptions this declines to about 18 percent by 2050.